LARGE FILING SEPARATOR SHEET

CASE NUMBER 13-1129-EL-EEC

FILE DATE MAY 15 2013

SECTION: 2

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DESCRIPTION OF DOCUMENT:

APP - STATUS REPORT

VOL 1 - CONT.

Field Survey Points

Post – installation

The following data was collected for all equipment logged:

- Lighting survey
    - Fixture Type
    - Fixture Count
    - Fixture wattage
    - Current lighting on/off scheduling

- Pre retrofit survey was conducted before the customer performed the lighting retrofit.
- The lighting load connected to the circuit was spot measured by measuring the kW load and current of the circuit during both the pre-retrofit and post retrofit survey.
- Lighting control settings were noted and recorded
- Verified that all existing fixture specifications and quantities are consistent with the application.
- Verified that all pre (existing) fixtures were removed
- Verified that all post (new) fixture specifications and quantities are consistent with the application
- Determined what holidays the building observes over the year

One-time measurements for all equipment logged (to establish ratio of kW/amp and simultaneous logger amp readings) were taken

Field Data Logging

- **ECM-1**

3. Deployed dataloggers during pre survey to measure operating hours
    a. Installed one lighting logger at each lighting control zone.
4. Loggers were set up for 5 minute instantaneous readings and allowed to operate for a period of three weeks.

Logger Table

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

Store	Hobo U-12	20 amp CT's
a	1	2
b	1	3
c	1	1
d	1	1
e	1	1
f	1	2
g	1	2
h	1	3
i	1	3
j	1	3
Total	**10**	**21**

Note: CT count based on 20 amp, 120v circuits. Field survey will need to be conducted to determine actual number and type of loggers/CT's needed.

DATA ANALYSIS

- **ECM-1**

5. The Pre annual kWh was calculated using the following equation:

$$\frac{kWh}{year_{pre}} = Watts_{fixture} * No._{fixtures} * HoursOn_{day} * \frac{365days}{year}$$

6. The Post annual kWh was calculated using the following equation:

$$\frac{kWh}{year_{post}} = Watts_{fixture} * No._{fixtures} * HoursOn_{day} * \frac{365days}{year}$$

Annual Total:

$$\frac{kWh}{year} = \sum \left[\frac{kWh}{year_{weekday}} + \frac{kWh}{year_{weekend}} \right]$$

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

$$\frac{hWh_{saved}}{year} = \frac{kWh_{pre}}{year} - \frac{kWh_{post}}{year}$$

RECORDING AND DATA EXCHANGE FORMAT

16. Survey Forms
17. *Excel spreadsheets*

RESULTS SUMMARY

The following results account for benefits of the lighting replacement. These results are based on the following assumptions:

- The "Pre" and "Post" lighting hours run from sunrise to sunset, according to published sunrise-sunset times for Cincinnati, OH. Published hours were adjusted to account for differences in run hours as noted from the collected time-series data.
- The pre-retrofit lamp watts for each fixture is as noted:
  - Wall Packs – 250 watts
  - Canopy Lights – 400 watts
  - Parking Lot Pole Lights – 1000 watts
- The post-retrofit electrical demand for each fixture was taken from actual field measurements. Averages are as follows:
  - Wall Packs – 45 watts
  - Canopy Lights – 54 watts
  - Parking Lot Pole Lights – 112 watts
- It should be noted that only the lights listed in the application were included in this analysis. During the survey, it was discovered that more lights had been replaced than were listed in the application.

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

TABLE 1. ESTIMATED ANNUAL ENERGY SAVINGS

[redacted] kWh Savings					
Store #	Pre	Post	Savings	App. Realization Rate	Duke Realizaton Rate
a	53082.7	5190.3	47892.4	71.9%	-
b	48048.9	5036.8	43012.0	57.5%	-
c	33782.5	3378.2	30404.2	70.3%	-
d	28394.0	3265.3	25128.7	79.3%	-
e	26741.3	4211.8	22529.5	65.1%	-
f	13127.1	2714.6	10412.6	42.3%	-
g	23232.2	3642.8	19589.4	52.9%	-
h	57204.6	6893.8	50310.8	57.8%	-
i	34963.6	3716.4	31247.2	59.9%	-
j	55855.8	7023.8	48832.0	53.2%	-
Total	374432.6	45073.8	329358.7	60.6%	60.6%

<u>ON AVERAGE, THE SAVINGS FOR ALL 10</u> [redacted] <u>STORES WAS 60.6%. THE CALCULATIONS INCLUDED WITH THE APPLICATION APPEAR TO HAVE MADE WITH THE ASSUMPTION THAT THE LIGHTING WAS ON 24 HOURS/DAY, 7 DAYS/WEEK. THE LIGHTING IS ACTUALLY CONTROLLED BY LIGHT LEVEL SENSORS, WHICH TURN THE LIGHTS ON AT SUNSET AND OFF AT SUNRISE.</u>

<u>A SUMMARY OF THE ESTIMATED ANNUAL PEAK KW SAVINGS IS SHOWN IN TABLE 2</u>

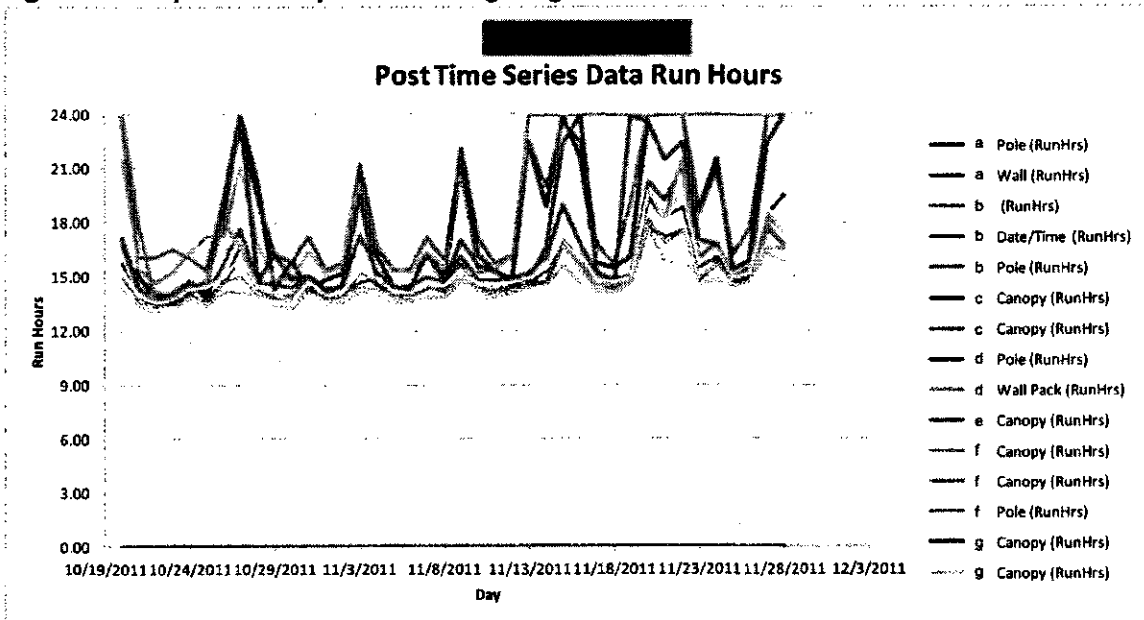
TABLE 2. ESTIMATED PEAK DEMAND SAVINGS

[redacted] Peak kW Savings					
Store #	Pre	Post	Savings	App. Realization Rate	Duke Realizaton Rate
a	9.0	0.9	8.1	116.0%	-
b	10.2	1.1	9.1	101.0%	-
c	6.0	0.6	5.4	108.0%	-
d	4.4	0.5	3.9	97.4%	-
e	4.8	0.8	4.0	101.1%	-
f	2.7	0.5	2.1	70.1%	-
g	5.0	0.8	4.2	84.3%	-
h	11.8	1.4	10.3	93.9%	-
i	7.2	0.8	6.4	106.5%	-
j	12.4	1.6	10.8	98.2%	-
Total	73.25	8.9	64.4	99.1%	103.8%

Note, since the lighting system is controlled off at 2pm on weekdays, the coincident peak kW savings are zero.

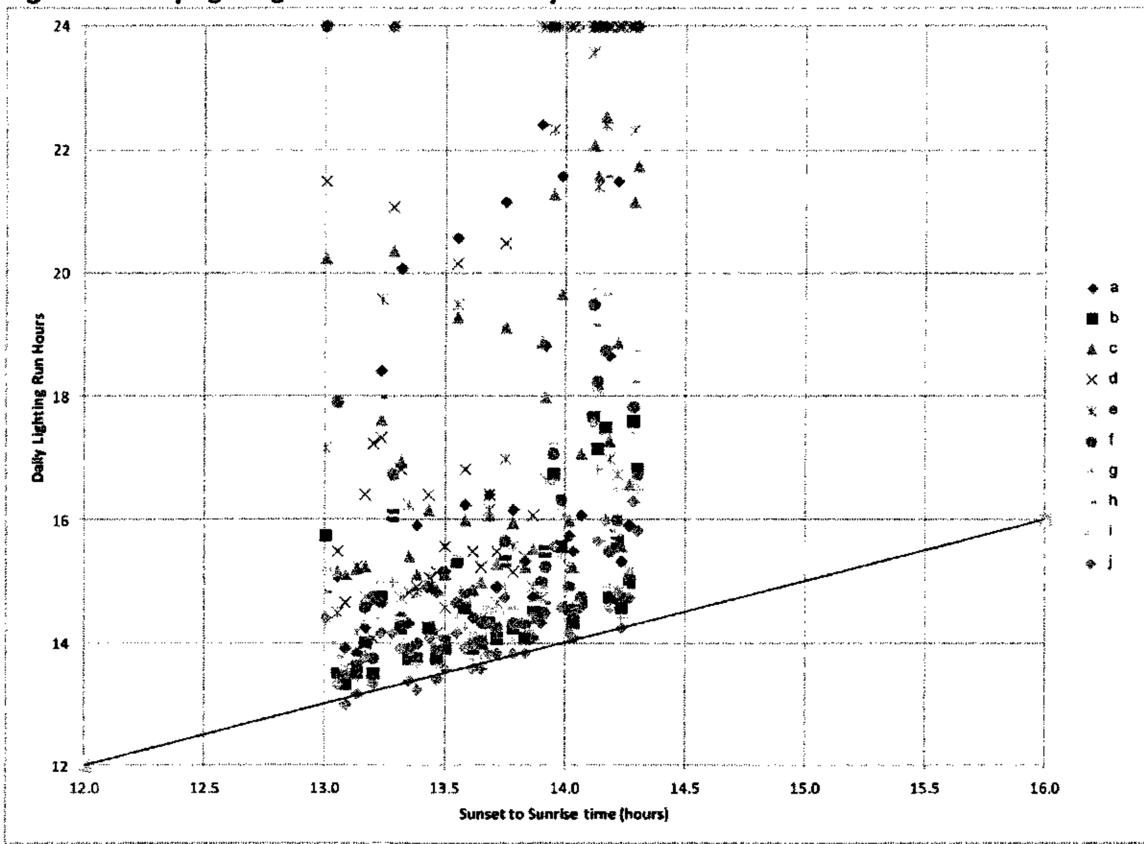
Figure 1 shows the daily run hours from the time-series data taken during the logging period. Discrepancies in daily run hours can be accounted for by the fact that there are two different types of light level sensors installed at these locations. One sensor is less accurate that the other and needs to be set when ambient light levels are appropriate for turning the lights on/off. The other sensor can be programmed digitally, and can be more accurate. Lighting override switches are also at all locations. If these switches are activated, the lights will stay on no matter the ambient light level. This accounts for the spikes in Figure 1 which show the lights on 24 hours/day.

Figure 1. Daily run hours per outdoor lighting circuit



Another representation of the lighting run hours is shown below, in Figure 2. This shows the average lighting hours per day for each store versus the time between sunset and sunrise. If the lights turned on exactly and sunset and turned off at sunrise, all of the data would follow the diagonal line. Data above the line indicate run hours longer than necessary. As was mentioned earlier, there are several days when the lights were on 24 hours a day.

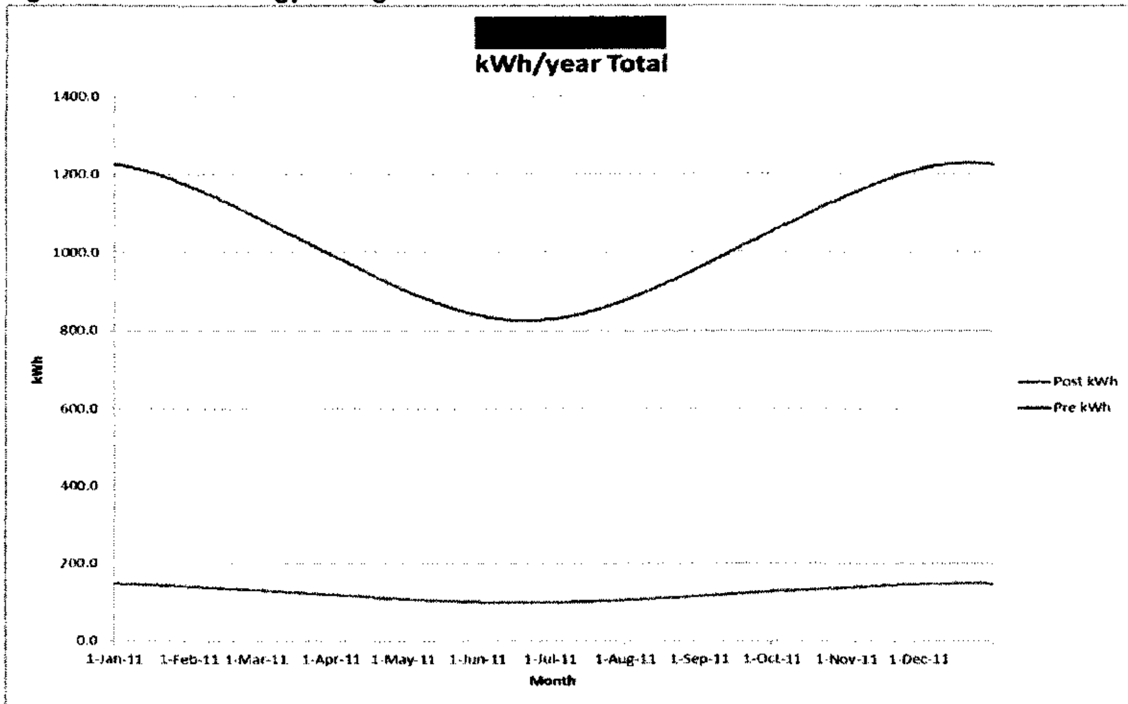
Figure 2. Daily lighting run hours versus daily hours of darkness



Run hours/day for each store were calculated and compared to actual sunset-sunrise times for the Cincinnati area during the logging period. Differences between these two values were calculated for each day of the year, and then averaged. The average difference for each location was added to the actual sunset-sunrise time for each day to adjust for the differences in run hours noted above.

Figure 3 shows the difference in kWh for the year as a result of the lighting change.

Figure 3. Annual energy savings



Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
329,359	528,652	0.62	64	60	1.07	0	61	0.00

Site 11

[redacted]

High Bay Lighting Retrofit

Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
September 2011

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

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

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

INTRODUCTION

This report summarizes M&V activities for [redacted] custom program application. The application covers a lighting retrofit at one 70,000 ft^2 warehouse in the Cincinnati area. The measure includes:

ECM-1 – High bay light fixture retrofit

- 70 existing metal halide light fixtures were replaced with 59 LVD high bay 200 TX200W/277 light fixtures and 13 T5/T8 high bay fluorescent fixtures. This resulted in a per-fixture energy reduction from 430W to 235W in the case of LVD replacements, and 430W to 192W in the case of high bay fluorescent replacements.

GOALS AND OBJECTIVES

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

- Annual gross energy (kWh) savings
- Summer peak demand (kW) savings
- Coincident peak demand (kW) savings
- kWh & kW Realization Rates

PROJECT CONTACTS

Duke Energy M&V Admin.	Frankie Diersing	[redacted]	
Duke Energy BRM	Cory Gordon	[redacted]	
Customer Contact	[redacted]	[redacted]	

SITE LOCATIONS/ECM'S

Site	Address	Sq. Footage	ECM's Implemented
[redacted] Warehouse	[redacted]	70,000	# 1

DATA PRODUCTS AND PROJECT OUTPUT

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

M&V Option

IPMVP Option A

Data Accuracy

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

Field Data Points

Pre-Installation

Survey data

- Fixture count and Wattage
  - Pre-retrofit, (70) 430-Watt metal halide light fixtures were in use.
- Determine how lighting is controlled and record controller settings
  - The pre-retrofit schedule was taken to be the same as the post-retrofit schedule. This was NOT 10.5 hours per weekday with no weekend and holiday operation, as listed in the application, but rather an average of 13.15 equivalent full-load hours per weekday and 4.63 equivalent full-load hours per weekend day and holiday.
- During the pre-retrofit survey, verify that all existing fixture specifications and quantities are consistent with the application
  - Pre-retrofit fixtures and quantities were consistent with the application.
- During the post survey, verify that all pre (existing) fixtures were removed.
  - All pre-retrofit fixtures were removed.
- During the post survey, verify that all post (new) fixture specifications and quantities are consistent with the application.
  - Post-retrofit fixture types and counts are NOT consistent with the application. The application claimed (70) 235-Watt induction fixtures, but the survey found (59) 235-Watt induction fixtures and (13) 192-Watt T8 high bay fluorescents.
- Determine what holidays the building observes over the year. Determine if the lighting zones are disabled during the holidays.
  - There are (8) holidays observed throughout the year, although it appears that lighting zones are NOT disabled, but rather approximate weekend operation.

One-time and time-series measurements

- Lighting circuit power when lights are on.
  - 14 individual lighting circuits were monitored during the three-week study period. Each of these circuits was also spot-checked for Volts, Amps, Watts, and Power Factor.

FIELD DATA LOGGING

- Current measurement CT loggers were deployed to measure current at the panelboard
- Original CT Instructions: Prepare to deploy current measurement CT loggers to measure current at the panelboard. If the panelboard is dedicated to the lighting being logged, log the panel board. If the panelboard is not dedicated to lights in question, but the circuit is, log the individual circuits. If both the panelboard and circuit layouts are unknown or involve additional loads such as other lighting or plug loads, install lighting loggers OR On/OFF CT loggers to measure light status at the fixture.
- Set up loggers for 5 minute instantaneous readings and allow loggers to operate for a minimum period of three weeks.
- Original spot measurement instructions: Spot measure the lighting load connected to the circuit by measuring the kW load and current draw of the circuit during both the pre-retrofit and post-retrofit survey. The lighting load circuit must have only one fixture type on the circuit. If the circuit has more than one type, spot measure the lighting load at the fixture ballast for the fixture in question. It is likely that the current will be so low that it will require amplification for accurate measurement. Use a 'donut' approach and record the number of windings.

LOGGER TABLE

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

ECM	Hobo U-12	20A CT	Hobo Lighting Loggers (If circuits are not dedicated)
1	14	14	14
Total	**14**	**14**	**14**

VERIFICATION AND QUALITY CONTROL

22. Time series data was visually inspected for gaps.
23. Readings were compared to nameplate. Consequently, samples J and L were identified as out of range, and not included in the calculations. Sample J showed 0A readings at all times, while Sample L showed 20A readings at all times. These clearly did not match up with the total lighting wattage numbers of 1132W on each of these samples.
24. The data was examined for physically impossible combinations.
25. Pre-retrofit schedules were corrected to correspond to the actual schedules observed in the post-retrofit data. This measure was not a schedule modification measure.

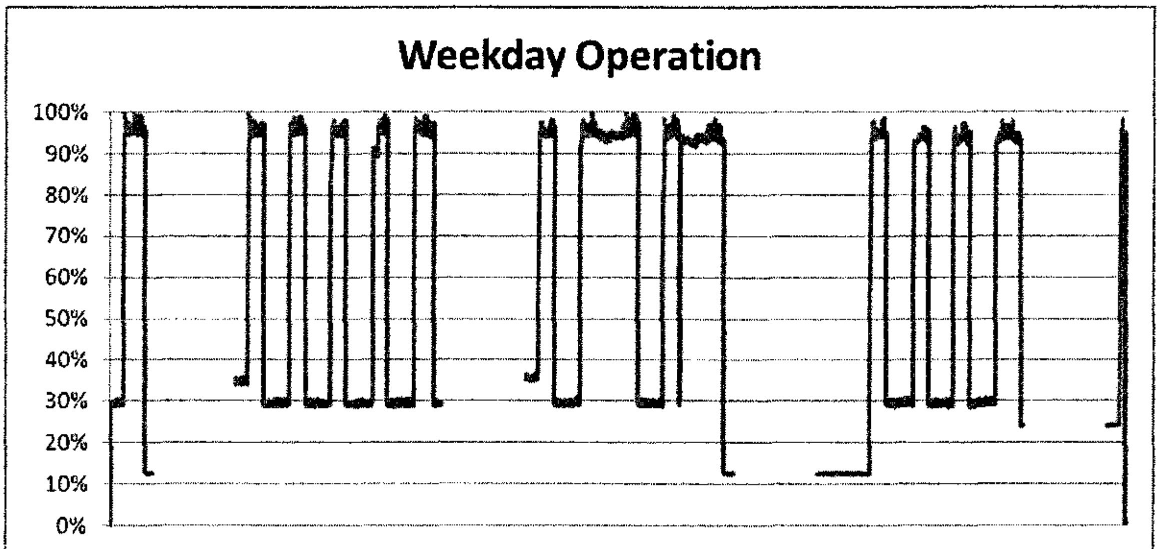
RECORDING AND DATA EXCHANGE FORMAT

18. Pre-installation Lighting Survey Form and Notes.

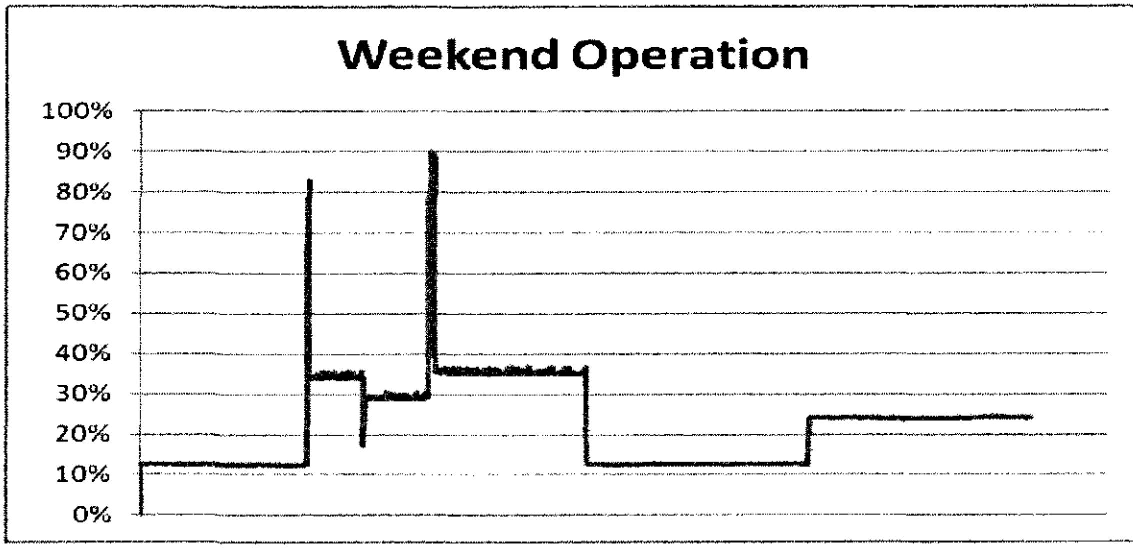
19. Post-installation Lighting Survey Form and Notes.
20. Hobo/Elite Pro logger binary files
21. Excel spreadsheets

DATA ANALYSIS

Analysis of the combined data reveals that the light systems run for an average of 13.15 equivalent full load hours during each weekday. This compares to the 10.5 hours per weekday listed in the application. Data for all of the logged circuits was combined to provide a Watt-weighted overall lighting profile. The three week profile of all monitored lighting circuits can be seen below.



A similar analysis of weekend operation revealed that although the application listed zero lighting operation on weekends, the lights are in fact on for 4.63 equivalent full-load hours per weekend day and holiday. (Note: all weekend days are combined into a single data stream for this graph, and there are no gaps in the data, where weekdays would normally occur.)



These schedules, including the 13.15 hours per day on weekdays and 4.63 hours per day on weekend days and holidays, were used as the average schedules for both the pre-retrofit and post-retrofit cases. In addition, given the 8 holidays per year, the annual schedule amounts to 252 weekdays and 112 weekend days/holidays.

The overall lighting wattage in the pre-retrofit case was 30.1 kW (70 fixtures X 430 Watts). In the post-retrofit case, that figure decreased to 16.4 kW (59 fixtures X 235 Watts + 13 fixtures X 192 Watts).
Combining the annual equivalent full-load operating hours with the pre- and post-retrofit lighting wattage allows us to calculate annual energy (kWh) and demand (kW) savings. The following table illustrates all calculation details.

Energy and Demand Savings Summary			
	Pre-	**Post-**	
Operating Hours Per Weekday	13.15	13.15	
Operating Hours Per Weekend Day	4.63	4.63	
Annual Operating Hours (Full Load)	3832	3832	
Lighting kW / Demand	30.10	16.361	
Annual Energy Consumption [kWh]	115,354	62,701	
	Expected	**Evaluated**	***Realization* Rate**
Annual Energy Savings [kWh]	42,070	52,653	125%
Building Peak Demand Savings [kW]	15.0	13.7	92%
Coincident Peak Demand Savings [kW]	15.0	13.7	92%

Because lighting loads coincide with air conditioning loads (typically the most important driver of building and utility peak kW usage), the coincidence factor of the lighting demand reduction, and the utility coincident peak demand reduction, will both be 1.0. Therefore, the full amount of demand reduced by the lighting retrofit measure is counted toward both of these demand reduction metrics.

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
52,653	40,915	1.29	14	15	0.89	14	15	0.89

Site 12

[redacted]

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011
Revision 1.1

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

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

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

INTRODUCTION

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

The measures include:

ECM-1 – Replace existing 750 Ton Chiller with new 400 Ton Chiller

- Replace 23 year old CFC refrigerant based chiller with new 400 ton chiller. New chiller will have factory mounted VFD

ECM-2 – Add VFD to 1100 Ton Chiller

- Chiller #6

Note: ECM's have already been implemented. Only post measurements will be taken.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are:

ECM	Application Proposed Annual savings (kWh)	Application Proposed Peak Savings (kW)	Duke Projected savings (kWh)	Duke Projected Peak savings (kW)
1	502,345	172	-	-
2	130,181	191	-	-
Total	**632,526**	**363**	**679,536**	

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

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

PROJECT CONTACTS

Approval has not yet been granted from the Duke Energy contacts listed below to plan and schedule the site visit with the Customer.

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Mike Heath	[redacted]
Customer Contact	[redacted]	[redacted]

Site Locations/ECM's

Site	Address	Sq. Footage	Age	ECM's Implemented
[redacted]	[redacted]			1,2

Data Products and Project Output

- Average pre/post load shapes by daytype for controlled equipment
- Model predicting pre/post kWh as a function of outdoor temperature
- Summer peak demand savings
- Coincident peak demand savings
- Annual Energy Savings

M&V Option

IPMVP Option A

M&V Implementation Schedule

- ECM's dictate that this plan should be implemented during the summer months (peak cooling season).
- Post data will need to be collected for a thorough evaluation.
- Monitoring period should include both normal workday and weekend/holiday periods

Field Survey Points

For ECM-1, survey/log the 400 ton chiller. For ECM-2, survey/log the 1100 ton chiller.

Survey data (for all equipment logged)

- 400 and 1100 ton Chiller make/model/serial number
- 400 and 1100 ton Chiller VFD make/model
- 400 ton chiller flow rate
- 1100 ton chiller flow rate

One-time measurements for all equipment logged (to check and validate Elite Pro data)

- 400 and 1100 ton Chiller volts, amps, kW and power factor
- OA Temperature

Data Accuracy

Measurement	Sensor	Accuracy	Notes
Temperature	Hobo thermistor	±0.5°	
Current	Magnelab CT	±1%	> 10% of rating

Field Data Logging

- **ECM-1&2**
  5. Install loggers to measure and record chiller kW in 5 minute intervals
  6. For ECM-1, log the 400 ton replacement chiller.
  7. For ECM-2, log the 1100 ton chiller.
  8. Log Chilled water supply and return temperatures for both chillers in 5 minute intervals.
  9. Log condenser water supply and return temperatures in 5 minute intervals.
  10. Log for 4 weeks post-measure installation.

  Note: Chiller kW and chiller/condenser water temperatures must be logged at the same time.

- **Outdoor Air**

  1. Install a weather logging station to record outside air temperature and relative humidity in 5 minute intervals. If BAS is capable of logging OA temperature and RH, set up trends in place of weather station installation. Log for 4 weeks pre-measure installation and 4 weeks post-measure installation. **Outdoor air readings must coincide with chiller kW readings for the post logging interval.**

Logger Table

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

ECM	Elite-Pro	Hobo U-12 (4 CH)	Temperature Probe	CT's	Weather Stations
1	1	1	2	(3) 450 amp	1
2	1	1	2	(3) 1200 amp	-
Total	**2**	**2**	**4**	**6**	**1**

Note: CT sizes are based on worst case scenario. Hobo logger count is based on four (4) channel loggers. Field survey will need to be conducted to verify actual breaker sizes.

DATA ANALYSIS

10. Convert time series data on logged equipment into pre/post average load shapes by day-type.
11. Develop pre/post regression model of total daily kWh as a function of average outdoor drybulb and wetbulb temperature,
12. Estimate peak demand savings by subtracting pre/post time series data during peak ambient temperatures. Find time series sequences that have equivalent temperatures. Calculate coincident peak savings by subtracting pre/post peak kW values at equivalent hot days at 4 pm local time.

- **ECM-1&2**

1. Calculate Post chiller tons by using the following equation:

$$tons = 500 \times GPM \times \Delta T$$

where

Tons	=	Chiller load
GPM	=	Chilled water flow rate
ΔT	=	Chilled water supply/return temperature differential

2. Use DOE-2 chiller curves to estimate Pre chiller operating conditions. Chiller load from equation above remains the same. Modify chiller curves for actual chilled water/condenser water temperatures realized during logging period.
3. Determine kWh for both Pre and Post operating conditions.
4. Convert time series data on logged equipment into pre/post average load shapes by daytype. Compare pre/post peak kW for evidence of peak demand limiting. Calculate peak demand savings
5. Regress data into a temperature dependent load model. Form of the regression equation is:

$$kWh / day = a + b \times T_{avg}$$

where

kWh/day	= daily energy consumption
T_{avg}	= Daily average drybulb or wetbulb temperature

6. Apply equation above to TMY3 data processed into average drybulb and wetbulb temperature for each day of the year. Use correlation that gives the best fit.

Verification and Quality Control

26. Visually inspect time series data for gaps
27. Compare readings to nameplate and spot-watt values; identify out of range data

Recording and Data Exchange Format

22. Elite Pro logger and weather station binary files
23. Excel spreadsheets

Results Summary

The following results account for benefits of the VFD retrofit/chiller replacement.

A summary of the estimated annual savings is shown in Table 1, broken out by each chiller's individual savings.

Table 1

kWh Summary				
	750 to 400 ton		1100 ton; add VFD	
	Pre	Post	Pre	Post
	854,839	616,152	1,860,574	1,649,965
Total Savings (kWh)	**238688**		**210609**	
Application Realization Rate	**48%**		**162%**	
Total Savings (kWh) for both chillers	**449,297**			
Duke Realization Rate	**66%**			

Realization rates varied between 48% for the 400 ton chiller replacement, to 162% for the 1100 ton chiller VFD implementation, with 66% for the Duke estimated kWh savings.

Evidence of peak demand reduction is shown in Table 2.

Table 2

Peak kW Summary				
	750 to 400 ton		1100 ton; add VFD	
	Pre	Post	Pre	Post
	261	253	490	476
Total Savings (Peak kW)	**8**		**13**	
Application Realization Rate	**5%**		**7%**	
Total kW Savings (both	**21**			

chillers)	
Duke Realization Rate	N/A

Figures 1 and 2 depict graphs of energy consumption and savings for the metered equipment (750/1100 ton chillers pre and 400/1100 ton chillers post) during the monitoring period.

Figure 1

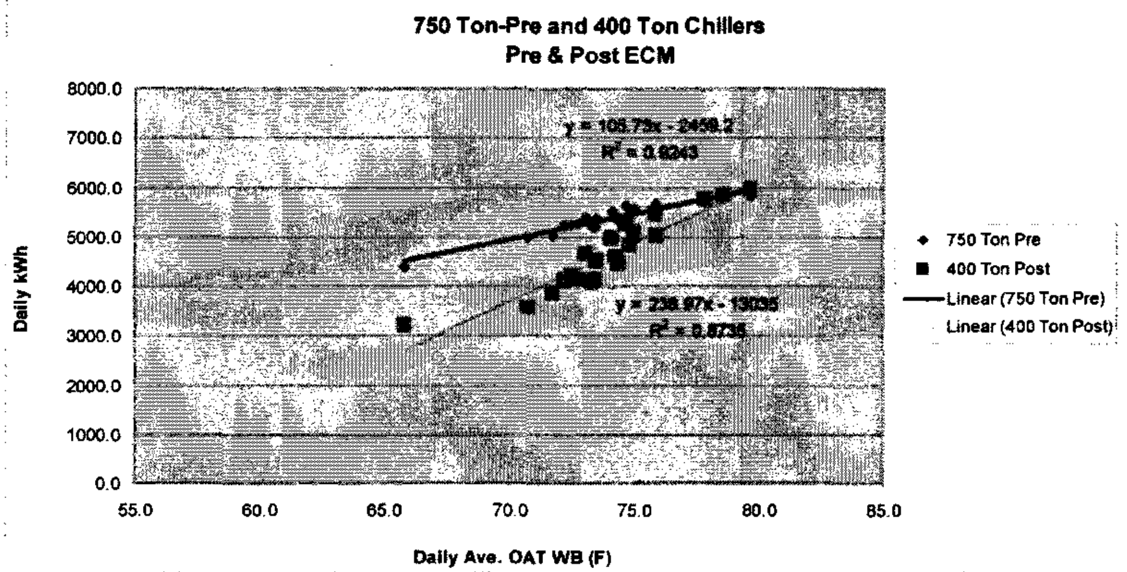
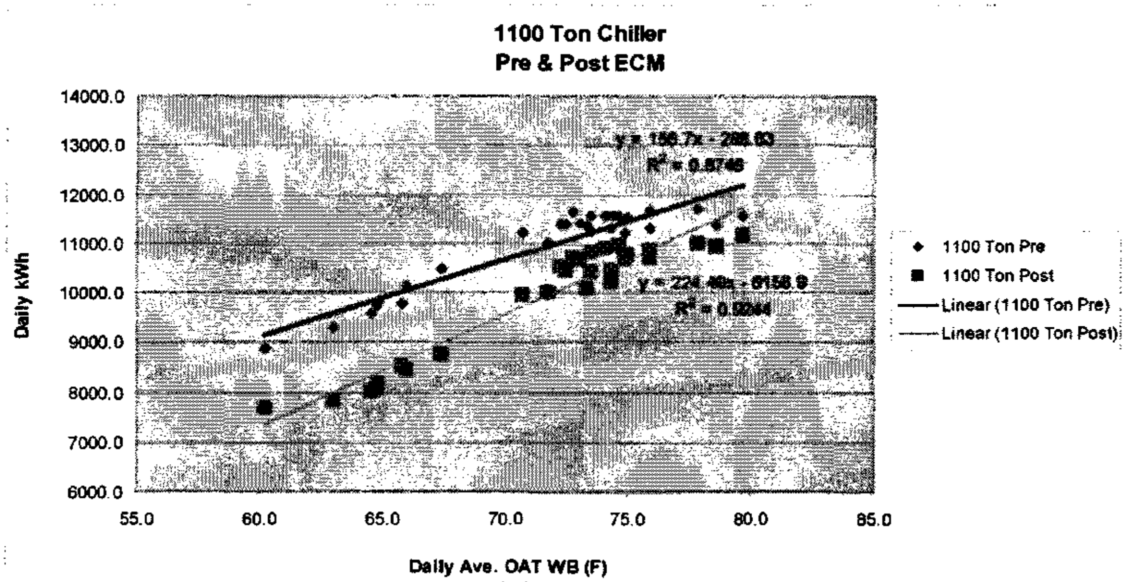


Figure 2



Figures 3 and 4 depict graphs of energy consumption and savings for the metered equipment extrapolated over the course of one year. kWh/day were extrapolated for the year by substituting TMY3 outside air temperatures (wet bulb) into the linear regression equations above for both pre and post ECM install. The chillers were assumed to run 100% under 34 OAT (DB). The chillers were assumed to be off between 34 and 64 OAT (DB), where the flat plate heat exchanger would be able to offer free cooling. Above 64 degrees, the chillers were assumed to follow the linear regressions noted above.

Figure 3

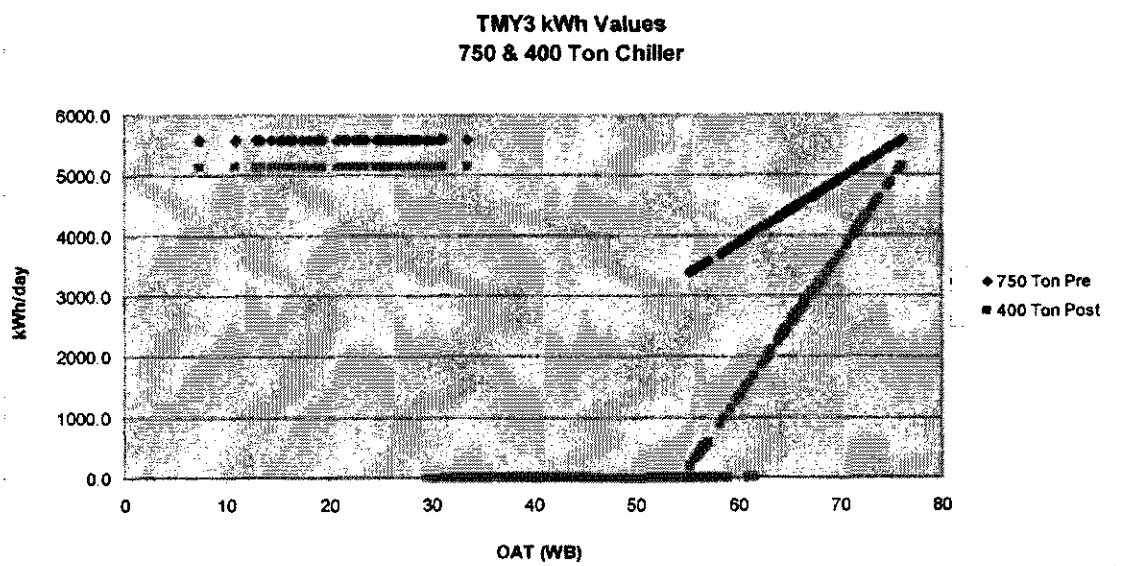
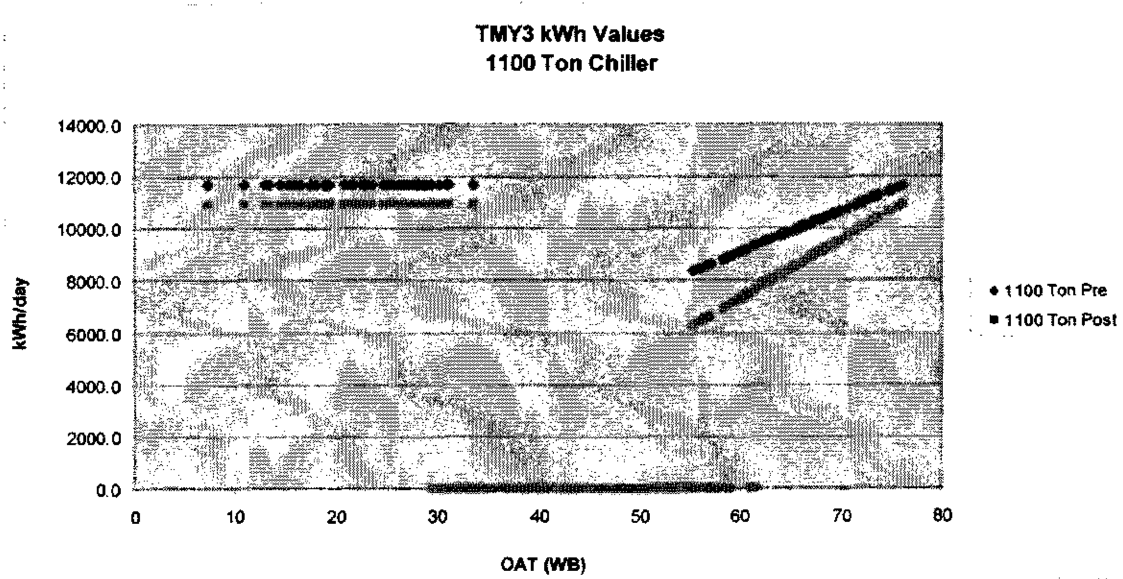


Figure 4



Although overall kWh savings were realized for this application, they were, overall, slightly lower than originally expected for the 400 ton chiller. Part of this may be due to the loading of the chillers post-retrofit. The 400 and 750-ton chillers were allocated similar loads, and so the 400-ton chiller was loaded at a higher part load ratio. The demand curves show that the demand of the two chillers at high wet bulb temperatures, and consequently high loads, is very similar, leading to having somewhat similar energy consumption at high ambient temperatures. The modeling of the two chillers resulted in somewhat similar annual energy reductions, about 210MWh to 240MWh each.

Figures 5 and 6 depict peak kW values for both Pre and Post ECM. The 400 ton Post as well as both Pre and Post 1100 ton regressions were noted to be change-point models. The 750 ton Pre regression was assumed to be linear. Similar to the kWh/day extrapolation, Peak kW/day were then extrapolated for the year by substituting TMY3 outside air temperatures (wb) into the linear regression equations which resulted in the highest kW value.

Figure 5. 750 and 400 ton chiller demand

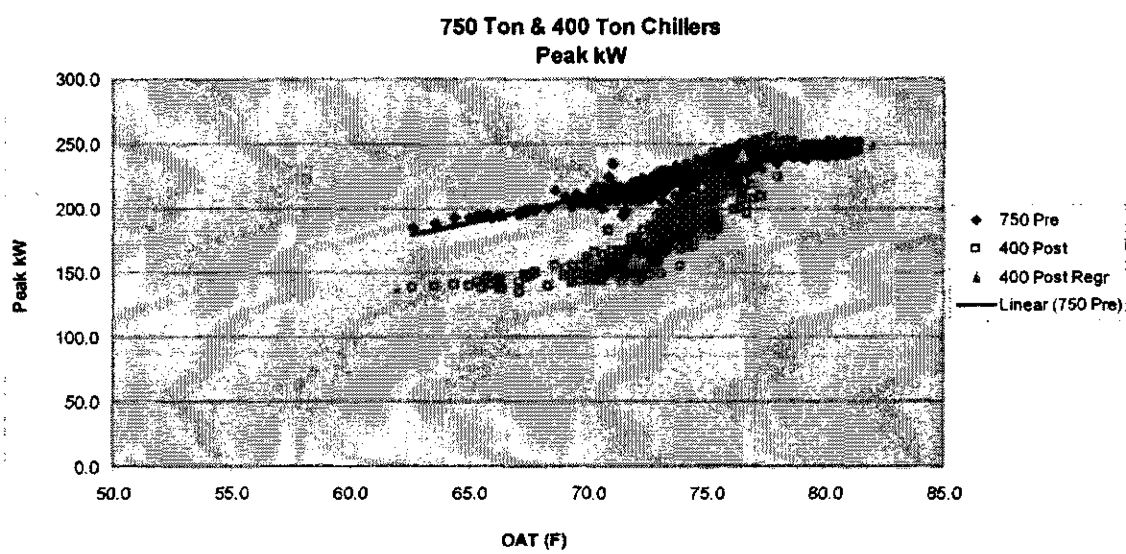
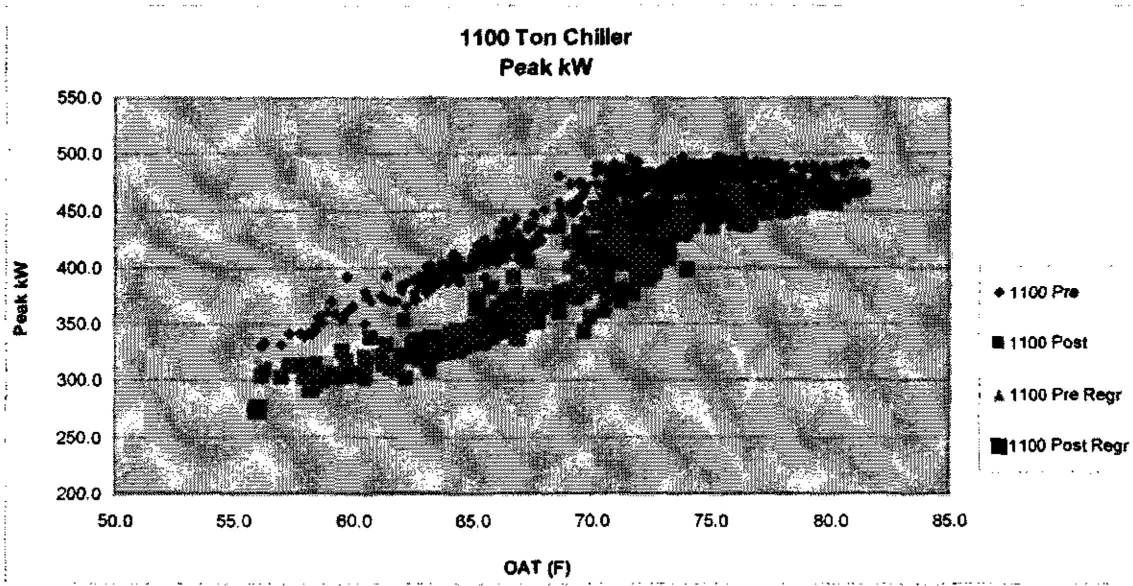


Figure 6. 1100 ton chiller pre and post retrofit demand



Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
449,297	632,527	0.71	21	86	0.24	21	106	0.20

Site 13

[redacted] School District

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
January 2012

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

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

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

INTRODUCTION

This report addresses M&V activities for the [redacted] School District custom program application. Ten schools in [redacted] NC are included in this application. The measures included several types of interior and exterior lighting fixture replacement at each school, as well as window replacements and HVAC measures at some schools. Only the lighting upgrades and window replacements earned incentive payments from Duke Energy.

ECM installation is complete. Surveys were completed to verify the new lighting fixtures.

The measures included:

NORTH ELEMENTARY

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Install photocell on exterior fixtures.
- ECM-4 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-5 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.
- ECM-8 – Replace windows with new double pane, coated low-e glass with aluminum frames (3,797 sqft total).

SOUTH ELEMENTARY

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Install photocell on exterior fixtures.
- ECM-4 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-5 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.

WEST ELEMENTARY

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Install photocell on exterior fixtures.
- ECM-4 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 with high efficiency electronic ballast.

- ECM-5 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.
- ECM-8 – Replace windows with new double pane, coated low-e glass w/ aluminum frames (4,247 sqft total).

CENTRAL ELEMENTARY

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Install photocell on exterior fixtures.
- ECM-4 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 with high efficiency electronic ballast.
- ECM-6 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.

EAST ELEMENTARY

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-4 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.

INTERMEDIATE SCHOOL

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Install photocell on exterior fixtures.
- ECM-4 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-5 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.

MIDDLE SCHOOL

- ECM-1 – Replace exterior 250w and 400w fixtures with 80w induction fixtures.
- ECM-2 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-3 – Replace the 1000w and 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-4 – Install photocell on exterior fixtures.

- ECM-5 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-6 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.
- ECM-8 – Replace windows with new double pane, coated low-e glass w/ aluminum frames (9,214 sqft total).

FRESHMAN SCHOOL

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Install photocell on exterior fixtures.
- ECM-4 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-5 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.

SENIOR HIGH SCHOOL

- ECM-1 – Replace exterior 175w wallpak lighting fixtures with 20w LED wallpaks.
- ECM-2 – Replace the 400w parking lot fixtures with 200w pulse start fixtures.
- ECM-3 – Replace gym 400w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-4 – Replace gym 1000w HID fixtures with high efficiency 2 lamp T-8 fixtures.
- ECM-5 – Retrofit select existing troffer lighting to high efficiency 2 lamp T-8 fixtures with high efficiency electronic ballasts.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are:

Facility	Application Proposed Annual savings (kWh)	Application Proposed Peak Impact (kW)	Duke Projected savings (kWh)	Duke Projected Peak Impact (kW)
[redacted] Kindergarten Center	55,995	19	-	-
[redacted] Elementary School	166,509	57	-	-
[redacted] Elementary School	157,965	54	-	-

[redacted] Elementary School	171,256	59	-	-
[redacted] Elementary School	160,263	55	-	-
[redacted] Intermediate School	333,610	115	-	-
[redacted] Middle School	331,673	114	-	-
[redacted] Elementary /Freshman High School	166,920	58	-	-
[redacted] High School	661,360	228	-	-
Total	**2,205,551**	**759**	**1,910,023**	**529**

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

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

PROJECT CONTACTS

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Michelle Kolb	[redacted]
Customer Contact	[redacted]	[redacted]

SITE LOCATIONS

Site	Address	Building Area (sqft)
[redacted] Kindergarten Center	[redacted]	36,912
[redacted] Elementary School	[redacted]	77,482
[redacted] Elementary School	[redacted]	76,960
[redacted] Elementary School	[redacted]	77,363
[redacted] Elementary School	[redacted]	82,250
[redacted] Elementary School	[redacted]	68,886

[redacted] Intermediate School	[redacted]	160,850
[redacted] Middle School	[redacted]	147,427
[redacted] Freshman High School	[redacted]	95,978
[redacted] Senior High School	[redacted]	317,000

Data Products and Project Output

- Average pre/post load shapes by day-type for lighting systems included in project
- Summer building peak demand savings
- Annual Energy Savings
- kWh & kW Realization Rates

M&V Option

IPMVP Option A

M&V Implementation Schedule

- ECMs dictated that verification should be implemented while school is in session.
- Post installation survey/time series data were collected for a thorough evaluation.
- Monitoring period included both normal school day and weekend/holiday periods.

Field Survey Points

For All Schools

Typical Survey Procedure for Lighting ECMs

- Conducted the Post retrofit survey after the customer performed the lighting retrofit.
    - Verified new fixture types and counts with application and supporting documentation

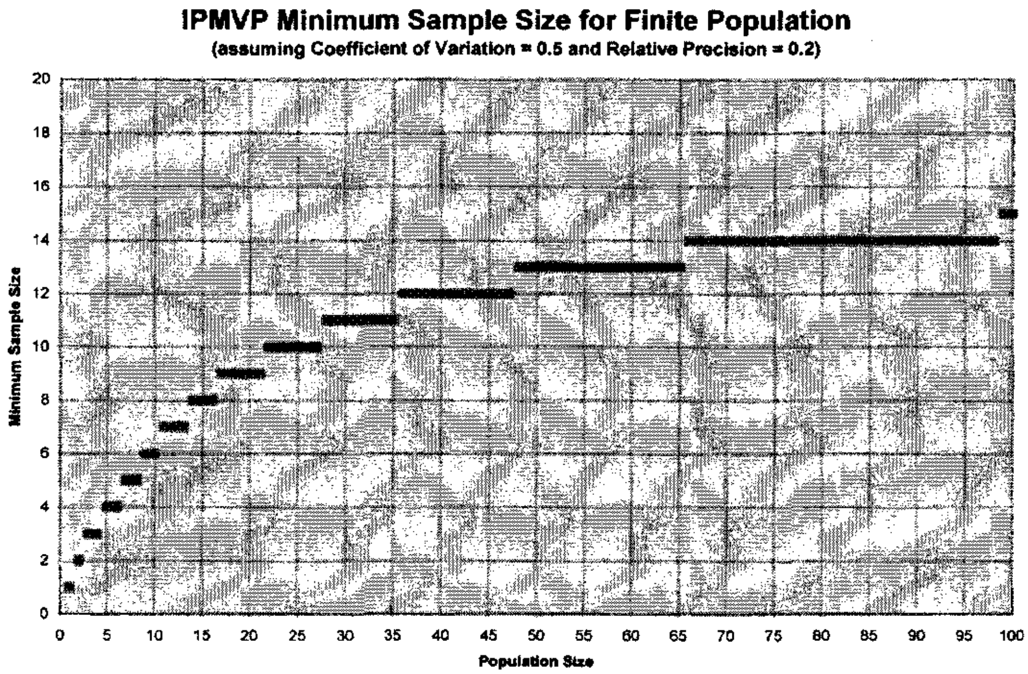
  - Interviewed site personnel to identify typical summer use of spaces affected by the project.
- Pre-retrofit operating hours were estimated from the measured post-retrofit operating hours and pre-retrofit fixture information was taken from the application. The field survey attempted to verify that the pre-retrofit fixture specifications and quantities that were removed from the project match the application.
- Determined how lighting is controlled and record controller settings
- Interviewed site personnel to estimate the light use before the controllers were installed.
- During the post survey, verified that all post (new) fixture specifications and quantities are consistent with the application
- Determined what holidays the building observes over the year
- Determined if the lighting zones are disabled during the holidays, including Christmas and spring break.

DATA ACCURACY

Measurement	Sensor	Accuracy	Notes
Spot Watt	Fluke meter w/ current transducer	Reference Fluke literature	
Current	Magnelab CT	±1%	> 10% of rating

FIELD DATA LOGGING

The following graph was used to determine the control zone sample size for survey/logging.



FOR ALL SCHOOLS

TYPICAL FIELD LOGGING PROCEDURE FOR LIGHTING ECMs

- Deployed dataloggers during post survey to measure operating hours
    - Installed lighting loggers to measure light status at the fixture.
    - Installed one lighting logger at each lighting control zone; using the IPMVP Minimum Sample Size for Finite Population chart above to determine the zone sample size. In the largest control zone installed a second logger for redundancy. A control zone is any group of fixtures that is switched in unison with a manual switch or automatically switched via a device, relay, contactor, or breaker. Control zones may also be groups of switched zones which are controlled simultaneously.
    - Set up loggers for 5 minute instantaneous readings and allowed loggers to operate for a minimum period of three weeks.

DATA ANALYSIS

LIGHTING

8. "Synthesized" Pre-retrofit time series data by using the following equations. Determine "Hours On" from Post-retrofit time series data:

Weekdays:

$$\frac{kWh}{year_{pre}} = Watts_{fixture} * No._{fixtures} * HoursOn_{day} * \frac{180days}{year}$$

Weekends:

$$\frac{kWh}{year_{pre}} = Watts_{fixture} * No._{fixtures} * HoursOn_{day} * \frac{72days}{year}$$

9. Converted time series data on logged equipment into pre/post average load shapes by day type.

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

Weekdays:

$$\frac{kWh}{year_{post}} = \sum\left[\frac{kW_{spot}}{Ampacity_{spot}} * Ampacity_{time-measured} * \frac{5\min._{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{180days}{year} \div \frac{weekdays}{monitoringperiod}\right]$$

Weekends:

$$\frac{kWh}{year_{post}} = \sum\left[\frac{kW_{spot}}{Ampacity_{spot}} * Ampacity_{time-measured} * \frac{5\min._{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{72days}{year} \div \frac{WEdays}{monitoringperiod}\right]$$

Annual Total:

$$\frac{kWh}{year} = \sum\left[\frac{kWh}{year_{weekday}} + \frac{kWh}{year_{weekend}}\right]$$

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

$$\frac{hWh_{saved}}{year} = \frac{kWh_{pre}}{year} - \frac{kWh_{post}}{year}$$

Verification and Quality Control

28. Visually inspected time series data for gaps
29. Compared readings to rated values to identify out of range data

Recording and Data Exchange Format

24. Hobo logger binary files
25. ElitePro logger files
26. Excel spreadsheets

Results

In the application supporting documents, lighting operating hours at all schools were estimated as 12 hr/day, 5.5 days/week, or 66 hours/week. This estimate is usually too high for interior lights and too low for exterior lights. The data shows that interior lights typically operate 35-45 hr/week, and exterior lights typically operate 12 hr/day, seven days/week, or approximately 84 hr/week. Thus, results for individual ECMs varied greatly, but tended to even out for each school and as a group.

Various HVAC measures were undertaken at six of the schools. These measures include BAS upgrades / software replacement, HVAC systems recommissioning, new RTUs, new furnaces, and programmable set-back thermostats. No details about the estimated energy savings other than an annual dollar amount (which may include gas cost savings) were provided in the application documents, nor were any incentives paid by Duke, for the HVAC measures. In addition, windows were replaced at three schools.

The lighting savings are estimated in the application documents in great detail, but in dollars only. Using the application's blended electric energy rate of $0.087 / kWh, the energy values (in kWh) were derived. These savings estimates from the application documents were used to calculate the realization rate for the lighting measures on a school-by-school basis.

By subtracting the lighting electric energy savings from the total electric savings estimated in the application for each school, the electric savings for the HVAC and window measures combined can be determined. By further separating the three schools with window replacements from the total of six schools with HVAC measures, the approximate contributions of window and HVAC measures to the total electric energy savings was estimated to determine the baselines for the window and HVAC measures at the schools that have them.

In order to determine realization rates with respect to the Application's savings estimate, the lighting energy usage was measured and verified in detail. Window energy savings were estimated by using a building energy simulation program with a "generic" school building in the Cincinnati climate with old versus new windows to determine the savings per square foot of window in each compass direction. These per-square-foot savings were then multiplied by the window area installed for each exposure to determine the verified energy savings for new windows at the three schools with this measure.

Since no incentives were paid for the HVAC[1] measures, these contributions were estimated as realized at 100% for purposes of comparing the evaluated results to the original application. Note, the final realization rate is based on lighting and window measure savings only, consistent with the final filed savings claim for this site.

Details of these calculations are shown on the All-Schools Summary on the next two pages. Results for individual schools then follow.

[1] HVAC measures refer to BAS upgrades / software replacement, HVAC systems recommissioning, new RTUs, new furnaces, and programmable set-back thermostats mentioned above. Window replacements, while affecting the HVAC end-use, were tracked separately.

All-Schools Summary

Applic'n Project #	School	Lighting	Occ Sensors	Windows	HVAC	Lighting Application (Note 1)	Lighting Verified	Lighting Realization Rate	Windows Application	Windows Allowed	Windows Realization Rate	HVAC Application	HVAC Allowed	HVAC Realization Rate	TOTAL Application	TOTAL Verified	TOTAL Realization Rate	Notes
#1	Senior High	✓	✓		✓	449,708	492,717	109.6%				211,652	211,652	100.0%	661,360	704,370	106.5%	
2a	Central Elementary	✓				118,893	84,276	70.9%							118,893	84,276	70.9%	
2b	Freshman High	✓				121,381	91,657	75.5%							121,381	91,657	75.5%	
#2	Combined Central / Freshman	✓													166,920	175,933	105.4%	2
#3	Middle School	✓	✓	✓	✓	195,297	202,566	103.7%	76,800	101,651	132.4%	59,577	59,577	100.0%	331,673	363,793	109.7%	
#4	Intermediate School	✓				349,148	290,659	83.2%							333,610	290,659	87.1%	3
#5	North Elementary	✓	✓	✓	✓	150,450	171,496	114.0%	11,173	40,708	364.4%	4,886	4,886	100.0%	166,509	217,090	130.4%	
#6	South Elementary	✓				180,251	134,118	74.4%							171,256	134,118	78.3%	4
#7	East Elementary	✓			✓	123,449	96,216	77.9%				36,814	36,814	100.0%	160,263	133,030	83.0%	
#8	West Elementary	✓	✓	✓	✓	125,685	135,652	107.9%	24,175	45,639	188.8%	8,105	8,105	100.0%	157,965	189,396	119.9%	
#9	Kindergarten	✓			✓	7,899	10,765	136.3%				48,096	48,096	100.0%	55,995	58,861	105.1%	
	TOTAL					1,822,161	1,710,123	93.9%	112,147	187,998	167.6%	369,130	369,130	100.0%	**2,205,551**	**2,267,251**	**102.8%**	

Annual Energy Savings (kWh)

Notes

Derived from "Energy Audit Findings and Recommendations" document, "Energy Savings & Payback Calculations" table.

Energy savings listed in the Application are 31% less than the sum of the individual Central and Freshman savings derived from the EAF&R document. Demand savings are 23% less.

Energy savings listed in the Application are 4.5% less than the savings derived from the EAF&R document. Demand savings are 8.5% higher.

Energy savings listed in the Application are 5% less than the savings derived from the EAF&R document. Demand savings are 5% higher.

All-Schools Summary

Peak Demand Savings (kW)

Applic'n Project #	School	Lighting	Occ Sensors	Windows	HVAC	Lighting: Application (Note 1)	Lighting: Verified	Lighting: Realization Rate	Windows: Application	Windows: Allowed	Windows: Realization Rate	HVAC: Application	HVAC: Allowed	HVAC: Realization Rate	TOTAL: Application	TOTAL: Verified	TOTAL: Realization Rate	Notes
#1	Senior High	✓	✓		✓	65.4	83.1	127.1%				162.3	162.3	100.0%	227.7	245.5	107.8%	
2a	Central Elementary	✓				18.8	22.2	118.1%							18.8	22.2	118.1%	
2b	Freshman High	✓				18.6	22.3	120.0%							18.6	22.3	120.0%	
#2	Combined Central / Freshman														57.5	44.6	77.5%	2
#3	Middle School	✓	✓	✓	✓	27.4	32.9	120.0%	48.9	38.9	79.6%	37.9	37.9	100.0%	114.2	109.7	96.1%	
#4	Intermediate School	✓				53.0	65.9	124.5%							114.9	65.9	57.4%	3
#5	North Elementary	✓	✓	✓	✓	23.3	28.1	120.8%	23.7	15.9	67.1%	10.4	10.4	100.0%	57.3	54.4	94.9%	
#6	South Elementary	✓				28.1	34.8	123.9%							59.0	34.8	59.0%	4
#7	East Elementary	✓			✓	18	21	120.0%				38	38	100.0%	55.2	58.7	106.4%	
#8	West Elementary	✓	✓	✓	✓	19.43	23.508	121.0%	26.1895424	17.58617	67.1%	8.78045755	8.78045755	100.0%	54.4	49.9	91.7%	
#9	Kindergarten	✓			✓	0	0	N/A				19.28	19.28	100.0%	19.3	19.3	100.0%	
	TOTAL					272	334	123.0%	99	72	73.3%				759	683	89.9%	

Notes
Derived from "Energy Audit Findings and Recommendations" document, "Energy Savings & Payback Calculations" table.
Energy savings listed in the Application are 31% less than the sum of the individual Central and Freshman savings derived from the EAF&R document. Demand savings are 23% less.
Energy savings listed in the Application are 4.5% less than the savings derived from the EAF&R document. Demand savings are 8.5% higher.
Energy savings listed in the Application are 5% less than the savings derived from the EAF&R document. Demand savings are 5% higher.

Project #1:
[redacted] High School

From Logged Data or Field Notes | Peak Demand for Ext Lights = 0

Planned

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures (Baseline) # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures (Proposed) # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings kWh	PEAK kW
400w MH Gym (106)	221w 6L-T-8 (106)	106	465	49.29	66	3253	49.29	106	221	23.43	66	1546	23.43	1707	25.9
1000w MH Gym (16)	471w 8L-T-5 (16)	16	1080	17.28	66	1140	17.28	16	471	7.54	66	497	7.54	643	9.7
148w T8 Troffer (1400)	80w 2L-T-8 (1400)	1400	148	207.20	66	13675	207.20	1400	80	112.00	66	7392	112.00	6283	95.2
400w MH Pole (67)	200w P-5 (67)	67	465	31.16	66	2056	0	67	235	15.75	66	1039	0	1017	0.0
400w MH Wall (18)	80w Induction (18)	18	465	8.37	66	552	0	18	85	1.53	66	101	0	451	0.0
175w MH Wall (10)	RAB 20W LED (10)	10	200	2.00	66	132	0	10	20	0.20	66	13	0	119	0.0
Totals						20809	273.8					10589	143.0		130.8
Weeks / Year						44						44			50%*
kWh / Year		Lighting Only				915,617						465,909		449,708	65.4
Annual Utility Cost				At $ 0.087 / kWh		$79,659						$40,534		$39,125	

Verified

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures (Updated Baseline) # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures (Verified) # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings kWh	PEAK kW
400w MH Gym (106)	148w 4L-T-8 (106)	106	465	49.29	75.7	3733	49.29	106	148	15.69	75.7	1188	15.69	2545	33.6
1000w MH Gym (16)	471w 8L-T-5 (16)	16	1080	17.28	73.9	1277	17.28	16	471	7.54	73.9	557	7.54	720	9.7
148w T8 Troffer (1400)	80w 2L-T-8 (1400)	1400	148	207.20	46.4	9618	207.20	1400	80	112.00	37.8	4237	112.00	5381	95.2
400w MH Pole (67)	200w P-S (67)	67	465	31.16	50.6	1576	0	67	235	15.75	50.6	797	0	780	0.0
400w MH Wall (18)	RAB 20W LED (22)	18	465	8.37	84.0	703	0	22	26	0.57	84.0	48	0	655	0.0
175w MH Wall (10)	RAB 20W LED (10)	10	200	2.00	84.0	168	0	10	26	0.26	84.0	22	0	146	0.0
Totals						17075	273.8					6849	135.2		138.5
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					751,313						301,343		449,970	69.3
Realization Rates	*Lighting Only*													100.1%	105.9%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	42,747	13.9
Total Savings														492,717	83.1
Total Realization Rates														109.6%	127.1%

Notes

The *Energy Audit Findings and Recommendations* document also recommends installing a 200 kVAR capacitor to correct the power factor at this facility, and estimates additional utility cost savings of $25,000 / year.

Classroom lights are now controlled by occupancy sensors.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary: [redacted] High School

			Energy kWh	Demand kW
From Application	Electric Energy and Demand	Baseline	4,857,187	1672.59
		Proposed	4,195,827	1444.85
		Savings	**661,360**	**227.74**
Lighting Only	(from table above)		449,708	65.4
Balance of Project #1:	(BAS upgrade, recommissioning & PF correction)		211,652	162.3
Realization Rates	Lighting only, from table above		109.6%	127.1%
	For balance of project, estimated		100.0%	100.0%
Estimated Total Realized Savings	Lighting		492,717	83.1
	Balance of Project		211,652	162.3
	Totals		**704,370**	**245.5**
Overall Realization Rate:	**Project #1: [redacted] High School**		**106.5%**	**107.8%**

Project #2:

[redacted] Elementary School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
175w MH Wall (10)	RAB 20W LED (10)	10	200	2.00	66	132	0	10	20	0.20	66	13	0	119	0.0
400w MH Wall (6)	200w P-S (6)	6	465	2.79	66	184	0	6	235	1.41	66	93	0	91	0.0
250w MH Gym (8)	148w 4L-T-8 (10)	8	295	2.36	66	156	2.36	10	148	1.48	66	98	1.48	58	0.9
400w MH Gym (14)	221w 6L-T-8 (12)	14	465	6.51	66	430	6.51	12	221	2.65	66	175	2.65	255	3.9
50w MH (3)	RAB 20w LED (3)	3	57	0.17	66	11	0	3	20	0.06	66	4	0	7	0.0
148w T8 Troffer (484)	80w 2L-T-8 (484)	484	148	71.63	66	4728	71.63	484	80	38.72	66	2556	38.72	2172	32.9
Totals						5641	80.5					2938	42.9		37.7
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					248,185						129,292		118,893	18.8
Annual Utility Cost				At $ 0.087 / kWh		$21,592						$11,248		$10,344	

Verified

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
175w MH Wall (10)	RAB 20W LED (10)	10	200	2.00	82.8	166	0	10	20	0.20	82.8	17	0	149	0.0
400w MH Wall (6)	200w P-S (6)	6	465	2.79	82.8	231	0	2	235	0.47	82.8	39	0	192	0.0
250w MH Gym (8)	148w 4L-T-8 (10)	8	295	2.36	48.5	114	2.36	8	148	1.18	48.5	57	1.18	57	1.2
400w MH Gym (14)	221w 6L-T-8 (12)	14	465	6.51	45.4	295	6.51	16	221	3.54	45.4	160	3.54	135	3.0
50w MH (3)	RAB 20w LED (3)	3	57	0.17	82.8	14	0	4	26	0.10	82.8	9	0	6	0.0
148w T8 Troffer (484)	80w 2L-T-8 (484)	484	148	71.63	36.8	2635	71.63	484	80	38.72	36.8	1424	38.72	1211	32.9
Totals						3455	80.5					1706	43.4		37.1
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					152,034						75,070		76,964	18.5
Realization Rates	*Lighting Only*													64.7%	98.4%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	7,312	3.7
Total Savings														84,276	22.2
Total Realization Rates														70.9%	118.1%

Notes

Due to an error in the Application, the actual realization rates of the combined schools is better than shown here. See Central - Freshman combined page.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project #2:
Freshman High School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
250w HP Sodium (1)	80w Induction (1)	1	295	0.30	66	19	0	1	85	0.09	66	6	0	14	0.0
400w MH Wall (6)	80w Induction (6)	6	465	2.79	66	184	0	6	85	0.51	66	34	0	150	0.0
400w MH Pole (8)	200w P-S (8)	8	465	3.72	66	246	0	8	235	1.88	66	124	0	121	0.0
400w MH Gym (16)	221w 6L-T-8 (16)	16	465	7.44	66	491	7.44	16	221	3.54	66	233	3.54	258	3.9
70w MH Wall (4)	RAB 20w LED (4)	4	81	0.32	66	21	0	4	20	0.08	66	5	0	16	0.0
148w T8 Troffer (490)	80w 2L-T-8 (490)	490	148	72.52	66	4786	72.52	490	80	39.20	66	2587	39.20	2199	33.3
Totals						5748	80.0					2989	42.7		37.2
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					252,906						131,525		121,381	18.6
Annual Utility Cost				At $ 0.087 / kWh		$22,003						$11,443		$10,560	

Verified

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
250w HP Sodium (1)	RAB 26w LED (1)	1	295	0.30	84.0	25	0	1	26	0.03	84.0	2	0	23	0.0
400w MH Wall (6)	RAB 26w LED (6)	6	465	2.79	84.0	234	0	6	26	0.16	84.0	13	0	221	0.0
400w MH Pole (8)	200w P-S (8)	8	465	3.72	105.0	391	0	8	235	1.88	105.0	197	0	193	0.0
400w MH Gym (16)	221w 6L-T-8 (16)	16	465	7.44	52.2	388	7.44	16	221	3.54	52.2	185	3.54	204	3.9
70w MH Wall (4)	RAB 26w LED (10)	4	81	0.32	84.0	27	0	10	26	0.26	84.0	22	0	5	0.0
148w T8 Troffer (490)	80w 2L-T-8 (490)	490	148	72.52	37.7	2734	72.52	490	80	39.20	37.7	1478	39.20	1256	33.3
Totals						3799	80.0					1897	42.7		37.2
Weeks / Year						44						44			50%
kWh / Year	*Lighting Only*					167,172						83,467		83,705	18.6
Realization Rates	*Lighting Only*													69.0%	100.0%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	7,952	3.7
Total Savings														91,657	22.3
Total Realization Rates														75.6%	120.0%

Notes

During the monitoring period, two of the eight parking lot pole lights were on continuously because of bad photocells. The above operating hours (105 / week) includes this less-than-optimal performance. The other exterior lights function properly. The operating hours (84 / week) reflects this.

Due to an error in the Application, the actual realization rates of the combined schools is better than shown here. See Central - Freshman combined page.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Combined Central Elementary School + Freshman High School

Planned		Existing Fixtures kWh / Year	Existing Fixtures Peak kW	New Fixtures kWh / Year	New Fixtures Peak kW	Savings kWh / Year	Savings Peak kW
Central		248,185	80.5	129,292	42.9	118,893	37.7
Freshman		252,906	80.0	131,525	42.7	121,381	37.2
Combined		501,091	160.5	260,817	85.6	240,274	74.9
	With peak demand coincidence factor of 50% applied						37.4
From Application	*For Central Elem. + Freshman High Schools combined*	900,520	310.1	733,600	252.6	166,920	57.48
						<See Note>	

Verified		Existing Fixtures kWh / Year	Existing Fixtures Peak kW	New Fixtures kWh / Year	New Fixtures Peak kW	Savings kWh / Year	Savings Peak kW
Central		152,034	80.5	75,070	43.4	76,964	37.1
Freshman		167,172	80.0	83,467	42.7	83,705	37.2
Combined		319,206	160.5	158,537	86.2	160,669	74.3
	With peak demand coincidence factor of 50% applied						37.1
Realization Rates	*For Central Elem. + Freshman High Schools combined*					**96.3%**	**64.6%**
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*			0.095	0.20	**15,264**	**7.4**
Total Savings						**175,933**	**44.6**
Total Realization Rates						**105.4%**	**77.5%**

Project Summary: **Central Elementary School & Freshman High School**

			Energy kWh	Demand kW
From Application	Electric Energy and Demand	Baseline	900,520	310.10
		Proposed	733,600	252.62
		Savings	**166,920**	**57.48**
Lighting Savings Only	(Baseline, from table above)		240,274	37.4
Balance of Project #2:	*(N/A, no other measures)*		N/A	N/A
Realization Rates	Lighting only, from table above		105.4%	77.5%
	For balance of project, estimated		N/A	N/A
Estimated Total Realized Savings	Lighting		175,933	44.6
	Balance of Project		N/A	N/A
	Totals		**175,933**	**44.6**
Overall Realization Rate:	**Project #2:**		**105.4%**	**77.5%**

Note:
Energy savings listed in the Application are 31% less than those derived from the backup document.

Project #3:
Middle School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
400w MH Ext (5)	80w Induction (5)	5	465	2.33	66	153	0	5	85	0.43	66	28	0	125	0.0
250w MH HPS (2)	80w Induction (2)	2	295	0.59	66	39	0	2	85	0.17	66	11	0	28	0.0
175w MH Wall (18)	RAB 20w LED (18)	18	200	3.60	66	238	0	18	20	0.36	66	24	0	214	0.0
175w MH Barn (5)	RAB 20w LED (5)	5	200	1.00	66	66	0	5	20	0.10	66	7	0	59	0.0
70w MH Wall (7)	RAB 20w LED (7)	7	81	0.57	66	37	0	7	20	0.14	66	9	0	28	0.0
1000w MH HPS (6)	400w P-S (6)	6	1080	6.48	66	428	0	6	460	2.76	66	182	0	246	0.0
400w Cobra (8)	200w P-S (8)	8	465	3.72	66	246	0	8	235	1.88	66	124	0	121	0.0
148w T8 Troffer (450)	80w 2L-T-8 (450)	450	148	66.60	66	4396	66.60	450	80	36.00	66	2376	36.00	2020	30.6
400w MH Gym (30)	221w 6L-T-8 (30)	30	465	13.95	66	921	13.95	30	221	6.63	66	438	6.63	483	7.3
250w MH Gym (37)	221w 6L-T-8 (15)	30	295	8.85	66	584	8.85	15	221	3.32	66	219	3.32	365	5.5
	148w 4L-T-8 (7)	7	295	2.07	66	136	2.07	7	148	1.04	66	68	1.04	68	1.0
295w T12 (48)	80w 2L-T-8 (48)	48	295	14.16	66	935	14.16	48	80	3.84	66	253	3.84	681	10.3
Totals						8178	105.6					3739	50.8		54.8
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					359,826						164,529		195,297	27.4
Annual Utility Cost			At $ 0.087 / kWh			$31,305						$14,314		$16,991	

Verified

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
400w MH Ext (5)	80w Induction (5)	5	465	2.33	80.1	186	0	5	85	0.43	80.1	34	0	152	0.0
250w MH HPS (2)	80w Induction (2)	2	295	0.59	80.1	47	0	2	85	0.17	80.1	14	0	34	0.0
175w MH Wall (18)	RAB 20w LED (18)	18	200	3.60	83.0	299	0	18	26	0.47	83.0	39	0	260	0.0
175w MH Barn (5)	RAB 20w LED (5)	5	200	1.00	83.0	83	0	5	26	0.13	83.0	11	0	72	0.0
70w MH Wall (7)	RAB 20w LED (7)	7	81	0.57	83.0	47	0	7	26	0.18	83.0	15	0	32	0.0
1000w MH HPS (6)	400w P-S (6)	6	1080	6.48	80.1	519	0	6	1080	6.48	80.1	519	0	0	0.0
400w Cobra (8)	200w P-S (8)	8	465	3.72	80.1	298	0	8	235	1.88	80.1	151	0	147	0.0
148w T8 Troffer (450)	80w 2L-T-8 (450)	450	148	66.60	50.5	3366	66.60	450	80	36.00	36.0	1297	36.00	2069	30.6
400w MH Gym (30)	221w 6L-T-8 (30)	30	465	13.95	62.0	865	13.95	30	221	6.63	62.0	411	6.63	454	7.3
250w MH Gym (37)	221w 6L-T-8 (15)	30	295	8.85	62.0	549	8.85	15	221	3.32	62.0	206	3.32	343	5.5
	148w 4L-T-8 (7)	7	295	2.07	62.0	128	2.07	7	148	1.04	62.0	64	1.04	64	1.0
295w T12 (48)	80w 2L-T-8 (48)	48	295	14.16	50.5	716	14.16	48	80	3.84	36.0	138	3.84	577	10.3
Totals						7103	105.6					2898	50.8		54.8
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					312,518						127,527		184,992	27.4
Realization Rates	*Lighting Only*													94.7%	100.0%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	17,574	5.5
Total Savings														202,566	32.9
Total Realization Rates														103.7%	120.0%

Notes

The 1000w MH HPS lamps were not replaced.

Classroom lights are now controlled by occupancy sensors.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary:	Middle School			Energy kWh	Demand kW
From Application	Electric Energy and Demand		Baseline	1,607,867	553.67
			Proposed	1,276,194	439.46
			Savings	**331,673**	**114.21**
Lighting Only	(from table above)			195,297	27.4
Balance of Project #3:	(New windows, RTUs, furnaces, set-back thermostats)			136,376	86.8
	Est'd proportion for Windows	56%		76,800	48.9
	Est'd proportion for HVAC	44%		59,577	37.9
Savings	Lighting			202,566	32.9
	Windows			101,651	38.9
	HVAC			59,577	37.9
Realization Rates	Lighting			103.7%	120.0%
	Windows			132.4%	79.6%
	HVAC			100.0%	100.0%
Estimated Total Realized Savings	**Totals**			**363,793**	**110**
Overall Realization Rate:	**Project #3: Middle School**			**109.7%**	**96.1%**

Project #4:

Intermediate School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings kWh	PEAK kW
1000w MH Pole (16)	400w P-S (16)	16	1080	17.28	66	1140	0	16	460	7.36	66	486	0	655	0.0
400w MH Pole (12)	200w P-S (12)	12	465	5.58	66	368	0	12	235	2.82	66	186	0	182	0.0
250w MH HPS (4)	80w induction (4)	4	295	1.18	66	78	0	4	85	0.34	66	22	0	55	0.0
175w MH Wall (3)	RAB 20w LED (3)	3	200	0.60	66	40	0	3	20	0.06	66	4	0	36	0.0
70w MH Wall (4)	RAB 20w LED (4)	4	81	0.32	66	21	0	4	20	0.08	66	5	0	16	0.0
400w MH Gym (54)	221w 6L-T-8 (54)	54	465	25.11	66	1657	25.11	54	221	11.93	66	788	11.93	870	13.2
150w T8 Troffer (1325)	80w 2L-T-8 (1325)	1325	150	198.75	66	13118	198.75	1325	80	106.00	66	6996	106.00	6122	92.8
Totals						16422	223.9					8487	117.9		105.9
Weeks / Year						44						44			50%*
kWh / Year		Lighting Only				722,585						373,437		349,148	53.0
Annual Utility Cost			At	$ 0.087	/ kWh	$62,865						$32,489		$30,376	

Verified

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings kWh	PEAK kW
1000w MH Pole (16)	400w P-S (16)	16	1080	17.28	86.0	1486	0	16	460	7.36	86.0	633	0	853	0.0
400w MH Pole (12)	200w P-S (12)	12	465	5.58	86.0	480	0	11	235	2.59	86.0	222	0	258	0.0
250w MH HPS (4)	RAB 20w LED (4)	4	295	1.18	87.2	103	0	4	26	0.10	87.2	9	0	94	0.0
175w MH Wall (3)	RAB 20w LED (3)	3	200	0.60	87.2	52	0	3	26	0.08	87.2	7	0	46	0.0
70w MH Wall (4)	RAB 20w LED (4)	4	81	0.32	87.2	28	0	4	26	0.10	87.2	9	0	19	0.0
400w MH Gym (36)	221w 6L-T-8 (24)	36	465	16.74	53.2	891	16.74	24	221	5.30	53.2	282	5.30	608	11.4
" " " (18)	148w 4L-T-8 (18)	18	465	8.37	45.9	384	8.37	18	148	2.66	45.9	122	2.66	262	5.7
150w T8 Troffer (1325)	80w 2L-T-8 (1325)	1325	150	198.75	42.0	8343	198.75	1325	80	106.00	42.0	4450	106.00	3893	92.8
Totals						11767	223.9					5734	114.0		109.9
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					517,745						252,302		265,442	54.9
Realization Rates	*Lighting Only*													76.0%	103.7%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	25,217	11.0
Total Savings														290,659	66.9
Total Realization Rates														83.2%	124.6%

Notes

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary:	Intermediate School		Energy kWh	Demand kW
From Application	Electric Energy and Demand	Baseline	2,574,116	886.40
		Proposed	2,240,506	771.52
		Savings	**333,610**	**114.88**
Lighting Only	(from table above)		349,148	53.0
Balance of Project #4:	*(N/A, no other measures)*		N/A	N/A
Realization Rates	Lighting only, from table above		83.2%	124.5%
	For balance of project, estimated		N/A	N/A
Estimated Total Realized Savings	Lighting		290,659	65.9
	Balance of Project		N/A	N/A
	Totals		**290,659**	**65.9**
Overall Realization Rate:	**Project #4: Intermediate School**		**87.1%**	**57.4%**

Project #5:
[redacted] Elementary School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
175w MH (24)	RAB 20w LED (24)	24	200	4.80	66	317	0	24	20	0.48	66	32	0	285	0.0
400w MH (4)	200w P-S (4)	4	465	1.86	66	123	0	4	235	0.94	66	62	0	61	0.0
220w T-12 (14)	80w 2L-T-8 (14)	14	260	3.64	66	240	3.64	14	80	1.12	66	74	1.12	166	2.5
400w MH Gym (20)	221w 6L-T-8 (20)	20	465	9.30	66	614	9.30	20	221	4.42	66	292	4.42	322	4.9
148w T8 Troffer (576)	80w 2L-T-8 (576)	576	148	85.25	66	5626	85.25	576	80	46.08	66	3041	46.08	2585	39.2
Totals						6920	98.2					3501	51.6		46.6
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					304,479						154,028		150,450	23.3
Annual Utility Cost				At $ 0.087 / kWh		$26,490						$13,400		$13,089	

Verified

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
175w MH (24)	RAB 20w LED (24)	24	200	4.80	80.9	388	0	24	26	0.62	80.9	50	0	338	0.0
400w MH (4)	200w P-S (4)	4	465	1.86	66	123	0	Not Done		1.86	66	123	0	0	0.0
220w T-12 (14)	80w 2L-T-8 (14)	14	260	3.64	55.8	203	3.64	10	80	0.80	55.8	45	0.80	158	2.8
400w MH Gym (20)	221w 6L-T-8 (20)	20	465	9.30	59.9	557	9.30	20	221	4.42	59.9	265	4.42	292	4.9
148w T8 Troffer (576)	80w 2L-T-8 (576)	576	148	85.25	54.23	4623	85.25	576	80	46.08	40.20	1852	46.08	2771	39.2
Totals						5895	98.2					2335	51.3		46.9
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					259,363						102,746		156,617	23.4
Realization Rates	*Lighting Only*													104.1%	100.7%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	14,879	4.7
Total Savings														171,496	28.1
Total Realization Rates														114.0%	120.8%

Notes

Classroom lights are now controlled by occupancy sensors.

* *For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.*

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary: [redacted] **Elementary School**

			Energy kWh	Demand kW
From Application	Electric Energy and Demand	Baseline	577,810	198.97
		Proposed	411,301	141.63
		Savings	**166,509**	**57.34**
Lighting Only	(from table above)		150,450	23.3
Balance of Project #5:	(New windows, RTUs, setback thermostats)		16,059	34.1
	Est'd proportion for Windows	70%	11,173	23.7
	Est'd proportion for HVAC	30%	4,886	10.4
Savings	Lighting		171,496	28.1
	Windows		40,708	15.9
	HVAC		4,886	10.4
Realization Rates	Lighting		114.0%	120.8%
	Windows		364.4%	67.1%
	HVAC		100.0%	100.0%
Estimated Total Realized Savings	**Totals**		**217,090**	**54**
Overall Realization Rate:	**Project #5** [redacted] **Elementary School**		**130.4%**	**94.9%**

Project #6:

[redacted] Elementary School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
175w MH (24)	RAB 20w LED (24)	24	200	4.80	66	317	0	24	20	0.48	66	32	0	285	0.0
400w MH Park Lot (7)	200w P-S (7)	7	465	3.26	66	215	0	7	235	1.65	66	109	0	106	0.0
400w MH Gym (35)	221w 6L T-8 (35)	35	465	16.28	66	1074	16.28	35	221	7.74	66	511	7.74	564	8.5
148w T8 Troffer (700)	80w 2L-T-8 (700)	700	148	103.60	66	6838	103.60	700	80	56.00	66	3696	56.00	3142	47.6
Totals						8443	119.9					4347	63.7		56.1
Weeks / Year						44						44			50%*
kWh / Year		Lighting Only				371,509						191,257		180,251	28.1
Annual Utility Cost				At $ 0.087 / kWh		$32,321						$16,639		$15,682	

Verified

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
175w MH (24)	RAB 20w LED (24)	24	200	4.80	84.77	407	0	22	26	0.57	84.77	48	0	358	0.0
400w MH Park Lot (7)	200w P-S (7)	7	465	3.26	84.77	276	0	7	235	3.26	84.77	276	0	0	0.0
400w MH Gym (35)	221w 6L T-8 (35)	10	465	4.65	46.07	214	4.65	10	221	2.21	46.07	102	2.21	112	2.4
400w MH Gym (35)	148w 4L T-8 (25)	25	465	11.63	46.07	536	11.63	25	148	3.70	46.07	170	3.70	365	7.9
148w T8 Troffer (700)	80w 2L-T-8 (700)	700	148	103.60	40.92	4239	103.60	700	80	56.00	40.92	2291	56.00	1948	47.6
Totals						5672	119.9					2888	61.9		58.0
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					249,562						127,080		122,482	29.0
Realization Rates	*Lighting Only*													68.0%	103.3%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	11,636	5.8
Total Savings														134,118	34.8
Total Realization Rates														74.4%	123.9%

Notes

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary: [redacted] Elementary School

			Energy kWh	Demand kW
From Application	Electric Energy and Demand	Baseline	977,191	336.50
		Proposed	805,935	277.53
		Savings	**171,256**	**58.97**
Lighting Only	(from table above)		180,251	28.1
Balance of Project #6:	*(N/A, no other measures)*		N/A	N/A
Realization Rates	Lighting only, from table above		74.4%	123.9%
	For balance of project, estimated		N/A	N/A
Estimated Total Realized Savings	Lighting		134,118	34.8
	Balance of Project		N/A	N/A
	Totals		**134,118**	**34.8**
Overall Realization Rate:	**Project #6: [redacted] Elementary School**		**78.3%**	**59.0%**

Note:
Energy savings listed in the Application are 5% less than those derived from the backup document.

Project #7:

[redacted] Elementary School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
400w MH Pole Lts (15)	200w P-S (15)	15	465	6.98	66	460	0	15	235	3.53	66	233	0	228	0.0
175w MH Wall (16)	RAB 20w LED (16)	16	200	3.20	66	211	0	16	20	0.32	66	21	0	190	0.0
175w MH Pole (6)	RAB 20w LED (6)	6	200	1.20	66	79	0	6	20	0.12	66	8	0	71	0.0
400w MH Gym (12)	221w 6L T-8 (12)	12	465	5.58	66	368	5.58	12	221	2.65	66	175	2.65	193	2.9
400w MH Gym (18)	221w 6L T-8 (18)	18	465	8.37	66	552	8.37	18	221	3.98	66	263	3.98	290	4.4
110w T8 Troffer (178)	80w 2L-T-8 (178)	178	110	19.58	66	1292	19.58	178	80	14.24	66	940	14.24	352	5.3
148w T8 Troffer (330)	80w 2L-T-8 (330)	330	148	48.84	66	3223	48.84	330	80	26.40	66	1742	26.40	1481	22.4
Totals						6187	82.4					3382	47.3		35.1
Weeks / Year						44						44			50%*
kWh / Year	Lighting Only					272,235						148,786		123,449	17.6
Annual Utility Cost				At $ 0.087	/ kWh	$23,684						$12,944		$10,740	

Verified

		Existing Fixtures						New Fixtures						Savings	
Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	# of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	kWh	PEAK kW
400w MH Pole Lts (15)	200w P-S (15)	15	465	6.98	85.0	593	0	15	235	3.53	85.0	300	0	293	0.0
175w MH Wall (16)	RAB 20w LED (16)	16	200	3.20	85.0	272	0	16	26	0.42	85.0	35	0	237	0.0
175w MH Pole (6)	100w P-S (6)	6	200	1.20	85.0	102	0	6	114	0.69	85.0	58	0	44	0.0
400w MH Gym (12)	221w 6L T-8 (12)	12	465	5.58	55.6	310	5.58	12	221	2.65	55.6	147	2.65	163	2.9
400w MH Gym (18)	221w 6L T-8 (18)	18	465	8.37	55.6	465	8.37	18	221	3.98	55.6	221	3.98	244	4.4
110w T8 Troffer (178)	80w 2L-T-8 (178)	178	110	19.58	36.6	717	19.58	178	80	14.24	36.6	521	14.24	195	5.3
148w T8 Troffer (330)	80w 2L-T-8 (330)	330	148	48.84	36.6	1787	48.84	330	80	26.40	36.6	966	26.40	821	22.4
Totals						4246	82.4					2249	47.3		35.1
Weeks / Year						44						44			50%*
kWh / Year	Lighting Only					186,823						98,954		87,868	17.6
Realization Rates	Lighting Only													71.2%	100.0%
HVAC Interaction –	Additional HVAC Savings: Lighting-HVAC Interaction Factors											0.095	0.20	8,348	3.5
Total Savings														96,216	21.1
Total Realization Rates														77.9%	120.0%

Notes

The replacement of 175w MH wall lights with LED lighting had not been finished as of the date of the verification. Based on the intent to complete this work, Op Hours / week are set the same as the other pole lights.

Six 175w pole lights are to be replaced with 100w P-S fixtures instead of LEDS. This work had also not been finished as of the date of the verification.

The *Energy Audit Findings and Recommendations* document also shows the installation of a 150 kVAR capacitor to correct the power factor at this facility, and projects utility cost savings of $8,000 / year.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The *Lighting-HVAC Interaction Factors* for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary:	[redacted] Elementary School		Energy kWh	Demand kW
From Application	Electric Energy and Demand	Baseline	1,077,084	370.90
		Proposed	916,821	315.71
		Savings	**160,263**	**55.19**
Lighting Only	(from table above)		123,449	17.6
Balance of Project #7:	(BAS upgrade, recommissioning, PF correction)		36,814	37.6
Realization Rates	Lighting only, from table above		77.9%	120.0%
	For balance of project, estimated		100.0%	100.0%
Estimated Total Realized Savings	Lighting		96,216	21.1
	Balance of Project		36,814	37.6
	Totals		**133,030**	**58.7**
Overall Realization Rate:	**Project #7: [redacted] Elementary School**		**83.0%**	**106.4%**

Project #8:
[redacted] Elementary School

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
175w MH (22)	RAB 20w LED (22)	22	200	4.40	66	290	0	22	20	0.44	66	29	0	261	0.0
400w MH Park Lot (2)	200w P-S (2)	2	465	0.93	66	61	0	2	235	0.47	66	31	0	30	0.0
400w MH Gym (20)	221w 6L T-8 (20)	20	465	9.30	66	614	9.30	20	221	4.42	66	292	4.42	322	4.9
220w T-12 8' (14)	80w 2L-T-8 (14)	14	260	3.64	66	240	3.64	14	80	1.12	66	74	1.12	166	2.5
220w T-12 4' (1)	80w 2L-T-8 (1)	1	260	0.26	66	17	0.26	1	80	0.08	66	5	0.08	12	0.2
148w T8 Troffer (460)	80w 2L-T-8 (460)	460	148	68.08	66	4493	68.08	460	80	36.80	66	2429	36.80	2064	31.3
Totals						5716	81.3					2860	42.4		38.9
Weeks / Year						44						44			50%*
kWh / Year		Lighting Only				251,515						125,830		125,685	19.4
Annual Utility Cost				At $ 0.087 / kWh		$21,882						$10,947		$10,935	

Verified

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
175w MH (22)	RAB 20w LED (22)	22	200	4.40	74.20	326	0	16	26	0.42	74.20	31	0	296	0.0
400w MH Park Lot (2)	200w P-S (2)	2	465	0.93	74.20	69	0	2	235	0.47	74.20	35	0	34	0.0
400w MH Gym (20)	221w 6L T-8 (20)	20	465	9.30	52.84	491	9.30	20	221	4.42	52.84	234	4.42	258	4.9
220w T-12 8' (14)	80w 2L-T-8 (14)	14	260	3.64	66.53	242	3.64	10	80	0.80	66.53	53	0.80	189	2.8
220w T-12 4' (1)	80w 2L-T-8 (1)	1	260	0.26	66.53	17	0.26	1	80	0.08	66.53	5	0.08	12	0.2
148w T8 Troffer (460)	80w 2L-T-8 (460)	460	148	68.08	50.00	3404	68.08	460	80	36.80	37.42	1377	36.80	2027	31.3
Totals						4550	81.3					1735	42.1		39.2
Weeks / Year						44						44			50%*
kWh / Year		*Lighting Only*				200,216						76,333		123,883	19.6
Realization Rates		*Lighting Only*												98.6%	100.8%
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	11,769	3.9
Total Savings														135,652	23.5
Total Realization Rates														107.9%	121.0%

Notes

Classroom lights are now controlled by occupancy sensors.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary: [redacted] Elementary School

				Energy kWh	Demand kW
From Application	Electric Energy and Demand		Baseline	561,778	193.45
			Proposed	403,813	139.05
			Savings	**157,965**	**54.4**
Lighting Only	(from table above)			125,685	19.4
Balance of Project #8:	(New windows, RTUs, set-back thermostats)			32,280	35.0
	Est'd proportion for Windows	75%		24,175	26.2
	Est'd proportion for HVAC	25%		8,105	8.8
Savings	Lighting			135,652	23.5
	Windows			45,639	17.6
	HVAC			8,105	8.8
Realization Rates	Lighting			107.9%	121.0%
	Windows			188.8%	67.1%
	HVAC			100.0%	100.0%
Estimated Total Realized Savings	**Totals**			**189,396**	**49.9**
Overall Realization Rate:	**Project #8: [redacted] Elementary School**			**119.9%**	**91.7%**

Project #9:
Kindergarten

From Logged Data or Field Notes | Peak Demand for Ext. Lights = 0

Planned

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
400w MH Pole (4)	200w P-S (67)	4	465	1.86	66	123	0	4	235	0.94	66	62	0	61	0.0
175w MH Wall (10)	RAB 20W LED (10)	10	200	2.00	66	132	0	10	20	0.20	66	13	0	119	0.0
Totals						255	0.0					75	0.0		0.0
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					11,209						3,311		7,899	0.0
Annual Utility Cost			At $ 0.087 / kWh			$975						$288		$687	

Verified *NOT PERFORMED*

Existing Fixture Type (# of Fixtures)	New Fixture Type (# of Fixtures)	Existing Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	New Fixtures: # of Fixtures	W per Fixt	Total kW	Op Hr / Week	kWh / Week	PEAK demand (kW)	Savings: kWh	PEAK kW
400w MH Pole (4)	200w P-S (67)	4	465	1.86	84.0	156	0	4	235	0.94	84.0	79	0	77	0.0
175w MH Wall (10)	RAB 20W LED (10)	10	200	2.00	84.0	168	0	10	26	0.26	84.0	22	0	146	0.0
Totals						324	0.0					101	0.0		0.0
Weeks / Year						44						44			50%*
kWh / Year	*Lighting Only*					14,267						4,435		9,831	0.0
Realization Rates	*Lighting Only*													124.5%	<N/A>
HVAC Interaction --	*Additional HVAC Savings: Lighting-HVAC Interaction Factors*											0.095	0.20	934	0.0
Total Savings														10,765	0.0
Total Realization Rates														136.3%	<N/A>

Notes

Although datalogging was not performed at this site, the operating hours per week was changed to a more typical value for outside lights.

* For schools, a summer peak demand coincidence factor of 50% is applied to demand savings.

Additional HVAC Savings: The Lighting-HVAC Interaction Factors for energy and demand represents the reduced electric space cooling requirements resulting from the reduction in waste heat rejected by the efficient lighting.

Project Summary:	**Kindergarten**		**Energy kWh**	**Demand kW**
From Application	Electric Energy and Demand	Baseline	426,548	146.88
		Proposed	370,553	127.6
		Savings	**55,995**	**19.28**
Lighting Only	(from table above)		7,899	0.0
Balance of Project #9:	(Set-back thermostats and other controls)		48,096	19.3
Realization Rates	Lighting only, from table above		136.3%	<N/A>
	For balance of project, estimated		100.0%	100.0%
Estimated Total Realized Savings	Lighting		10,765	<N/A>
	Balance of Project		48,096	19.3
	Totals		**58,861**	**19.3**
Overall Realization Rate:	**Project #9: Kindergarten**		**105.1%**	**100.0%**

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. Note, the final DSMore runs claimed savings for lighting and windows only; Central Elementary School was not included. The evaluated savings consistent with the DSMore runs are shown below:

Evaluated Savings Consistent with DSMore

	Evaluated Annual Energy Savings (kWh)			Evaluated NCP Demand Savings (kW)			Evaluated CP Demand Savings (kW)		
School	Lighting	Win	Total	Lighting	Win	Total	Lighting	Win	Total
Senior High	492,717		492,717	166.3		166.3	83.1		83.1
Freshman High	91,657		91,657	44.7		44.7	22.3		22.3
Middle School	202,566	101,651	304,216	65.8	77.9	143.6	32.9	38.9	71.8
Intermediate School	290,659		290,659	131.9		131.9	65.9		65.9
[redacted] Elementary	171,496	40,708	212,204	56.3	31.8	88.1	28.1	15.9	44.0
[redacted] Elementary	134,118		134,118	69.6		69.6	34.8		34.8
[redacted] Elementary	96,216		96,216	42.1		42.1	21.1		21.1
[redacted] Elementary	135,652	45,639	181,291	47.0	35.2	82.2	23.5	17.6	41.1
Kindergarten	10,765		10,765	0.0		0.0	0.0		0.0
TOTAL	1,625,847	187,998	1,813,844	623.5	144.8	768.3	311.8	72.4	384.2

The comparison with the DSMore run is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
1,813,844	1,910,023	0.95	768	611	1.26	384	528	0.73

Site 14

[redacted]

Energy Savings Compressed Air Project

M&V Plan

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011

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

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

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

Introduction

This report addresses M&V activities for the [redacted] custom program application. The application covers an air compressor VFD retrofit at one location in [redacted], Ohio. The measure includes:

ECM-1 – Air Compressor with VFD

- *Inefficient compressed-air equipment, including one 100hp, one 75hp, and one 50hp compressor has been replaced with a new, modern variable frequency drive compressor. In addition, zero-loss condensate drains and air main charging valves were installed. The previous condensate drains involved 2 auto drains that vented for 60 seconds every 15 minutes, and one drain that vented for 60 seconds every hour. The system pressure was 110psi, and the drain orifice sizes were 1/4". This M&V plan is for post-retrofit only.*

Goals and Objectives

The projected savings goals identified in the application are:

Facility	Duke Projected Annual kWh savings	Duke Projected kW savings
[redacted]	106,587	17
Total	**106,587**	**17**

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

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

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Bob Bandenburg	
Customer Contact	[redacted]	[redacted]

Site Locations/ECM's

Site	Address
[redacted]	[redacted]

Data Products and Project Output

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

M&V Option

IPMVP Option A

M&V Implementation Schedule

- Conducted the post-retrofit survey after the customer performed the compressed air system retrofit.
    - Collected data during normal operating hours.
    - Obtained and verified the post-retrofit operating schedule for the compressed air system.
    - Deployed post-retrofit loggers to record kW on the new VFD compressor to determine post-retrofit load shapes and energy consumption.
- Evaluated the energy savings of the retrofit measure.

Data Accuracy

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

Field Data Points

Pre – installation

Reviewed the detailed calculations of pre-retrofit energy consumption.

Post – installation

Obtained the following survey data:

- Compressor nameplate data for the new VFD compressor
- Operating hours for the compressed air system.

Collected time series data on compressor. Logger was configured for 5 minute instantaneous readings and deployed for 3 weeks.

FIELD DATA LOGGING

- **ECM-1**

  One logger was installed to monitor compressor kW on the new VFD compressor. Each leg of the power cable was monitored with separate current transducers. Logger was configured for 3 weeks post-measure data collection.

LOGGER TABLE

The following table summarizes all logging equipment used:

ECM	Elite Pro loggers	Current Transducers (200A)
Post-retrofit	1	3
Total	**1**	**3**

DATA ANALYSIS

1. Converted time series data on logged equipment into pre/post average load shapes by day type.
2. The annual kWh (both PRE-with reported schedules, and POST-with collected logger data) was calculated using the following equations:

Weekdays: $$\frac{kWh}{year} = \sum\left[kW_{time-measured} * \frac{5\min\cdot_{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{260days}{year} \div \frac{weekdays}{monitoringperiod}\right]$$

Weekends: $$\frac{kWh}{year} = \sum\left[kW_{time-measured} * \frac{5\min\cdot_{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{104days}{year} \div \frac{WEdays}{monitoringperiod}\right]$$

Annual Total:

$$\frac{kWh}{year} = \sum\left[\frac{kWh}{year}_{weekday} + \frac{kWh}{year}_{weekend}\right]$$

3. In the PRE-retrofit case, the original calculation methodology considered including additional compressor load based upon the drain venting schedule, system pressure, and orifice sizes. Since the analysis performed by Compressed Air Technologies accounted

for this load already, the venting loss did not have to be added. This additional load did not apply to the POST case, as zero-loss drains have been installed.

4. The annual kWh ***saved*** was calculated by comparing the data extrapolated from pre-retrofit schedules, and post-retrofit schedule data monitored by data loggers, using the following equation:

$$\frac{hWh_{saved}}{year} = \frac{kWh_{pre}}{year} - \frac{kWh_{post}}{year}$$

Verification and Quality Control

30. Logger data was visually inspected for consistent operation. No inconsistencies were noted.
31. Verified that pre-retrofit and post retrofit equipment specifications and quantities were consistent with the application. No inconsistencies were noted.
32. Electrical voltage of equipment circuits was verified.

Recording and Data Exchange Format

27. Elite Pro logger binary files
28. Excel spreadsheets

Post Data Results

The post data results were based on a single logger deployed as shown in the logger table above.

The existing Sullair LS16-100 100hp compressor was replaced with a Kaeser SFC75S-100hp w/VFD. The other two existing compressors; Sullair LS20-50 50hp and Kaeser CS 91 75hp compressor will remain in place as backup. The pre-install estimated savings for the compressor replacement is 106,587 kWh per year.

The following tables summarize the energy and demand savings resulting from the installation of the new compressor. The projected annual savings based on the post install trend data is 161,433 kWh. The pre-install annual kWh was not adjusted to account for the compressor power required overcome the condensate drain valve air loss since the power was accounted for in the Compressed Air Technologies analysis. The total additional compressor energy required for the condensate drain valve loss is estimated to be 28,130 kWh per year.

Day Type	Days/Yr	Holidays	Daily kWh	kWh/Yr
Weekdays	260	8	1161.34	292,657
Saturday, Holidays	52	8	767.58	46,055
Sunday	52	0	775.24	40,312
TOTAL				**379,025**

	Demand (kW)	Annual Consumption (kWh)
Pre Retrofit: Comp#1,2,3	95.3	540,135
Post-Data Operation Projections		
Weekdays	90.2	292,657
Weekend, Holidays	36.8	86,367
Total Consumption		379,025
Savings	5.1	161,110

The realization rate for the compressor replacement is shown in the following table.

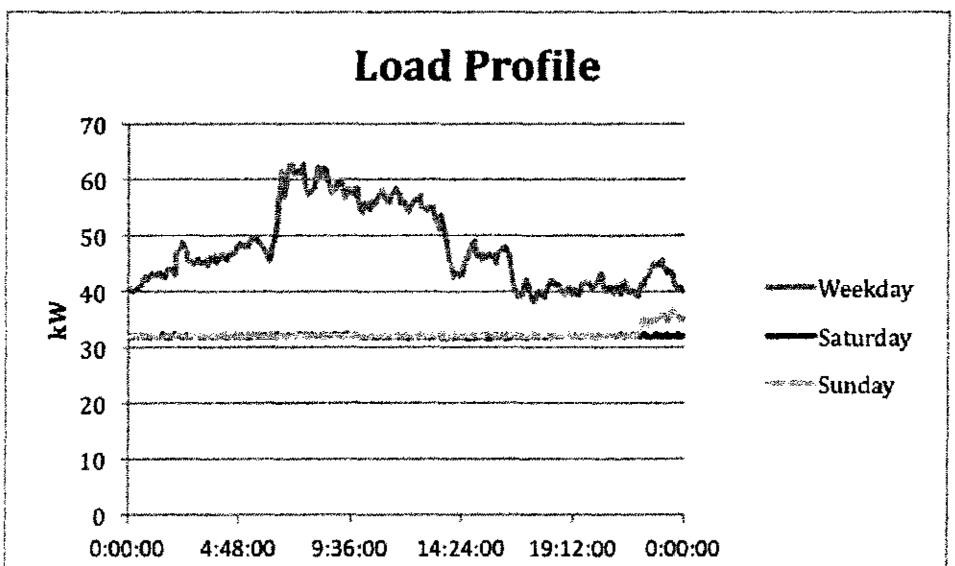
	Energy (kWh)	Demand (kW)
Realization Rate	151%	30%

The coincident peak demand was determined by selecting the highest peak at 2 p.m.

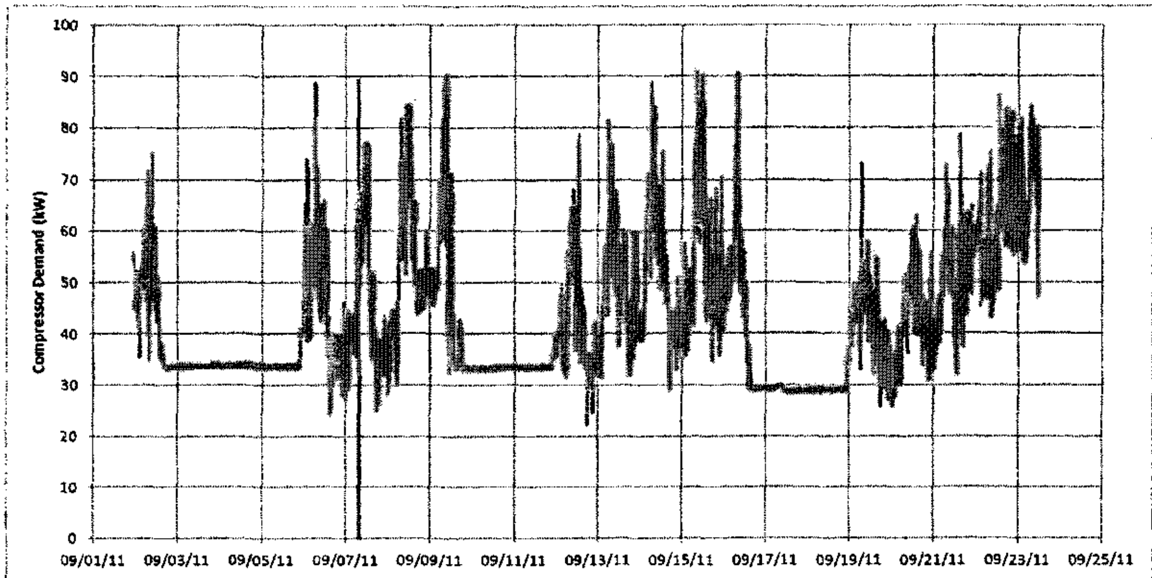
Coincident peak demand: 67.6 kW

Coincident peak demand savings: 27.7 kW

The graphs below show the average daily load shape for the monitored compressor. These plots average the entire monitoring period into two day type load shapes, weekday and weekend. Holidays are assumed to be the same as weekend. The load profile shows the compressor idling during the weekend, drawing a constant 32 kW.



The graph below shows a summary of the post-data trend. The compressor operated 24/7 with the exception of 20min on 9/7. The weekends and Labor Day, the only holiday during the monitoring period, show the compressor idling.



Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
161,110	106,952	1.51	5	12	0.42	28	17	1.66

Site 15

[redacted]

- Air Compressor Retrofit -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011

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

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

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

Introduction

This report addresses M&V activities for the [redacted] custom program application. The application covers an air compressor VFD retrofit at one location in the Cincinnati area. The measure included:

ECM-1 – Air Compressor with VFD

- *Three constant speed air compressors previously operated without variable speed drives, which used excess energy. One 75hp variable speed air compressor was installed to replace the operation of the three previous compressors (sized 40hp, 40hp, and 50hp). The compressors operate approximately 144 hours per week. The M&V plan was used post-retrofit only.*

Goals and Objectives

The projected savings goals identified in the application are:

Facility	Proposed Annual kWh savings	Duke Projected kWh savings
[redacted]	237,640	**31.7**
Total	**237,640**	**31.7**

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

- Annual gross energy (kWh) savings
- Summer building peak demand (kW) savings
- Coincident peak demand (kW) savings
- kWh & kW Realization Rates

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Cory Gordon	
Customer Contact	[redacted]	[redacted]

Site Locations/ECM's

Site	Address	Sq. Footage/Age
[redacted]	[redacted]	35,000/24

Data Products and Project Output

- Average pre/post load shapes by daytype for controlled equipment
- Facility peak demand savings
- Summer utility coincident peak demand savings
- Annual Energy Savings
- kWh & kW Realization Rates

M&V Option

IPMVP Option A

M&V Implementation Schedule

- Conducted the post-retrofit survey after the customer performed the compressed air system retrofit.
  - Collected data during normal operating hours (logged 8/19 to 9/9, including the Labor Day holiday).
  - Obtained and verified the post-retrofit sequence of operations and operating schedule for the compressed air system. Confirmed that the compressor operates for a 5 ½ day work week, with 8 holidays throughout the year. Determined variability in the compressed air demand by certain days of the week.
  - Deployed post-retrofit loggers to record kW on the new VFD compressor to determine post-retrofit load shapes and energy consumption.
- Evaluated the energy savings of the retrofit measure.

Data Accuracy

Measurement	Sensor	Accuracy	Notes
Current	Magnelab CT	±1%	> 10% of rating
True electric power	ElitePro	±1%	

Field Data Points

Survey data:

- Compressor nameplate data:
  - Siemens Motor, ILA5207-1AA93-2T02
    - 480V, 55kW
  - Altas Copco, Model GA55VSD, 75hp motor
- Compressor discharge air pressure setpoint: 108-109 psi, constant

Time series data on controlled equipment:

- Compressor kW

Loggers were setup for 5 minute instantaneous readings and deployed for 3 weeks, beginning 8/19 and ending 9/9.

Field Data Logging

- **ECM-1**

  Post-retrofit, installed one logger to monitor compressor kW. Used current transducers on each leg of the power cable. Logged for 3 weeks post-measure installation.

Logger Table

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

ECM	Elite Pro loggers	Current Transducers (75A)
Post-retrofit	1	3
Total	**1**	**3**

Verification and Quality Control

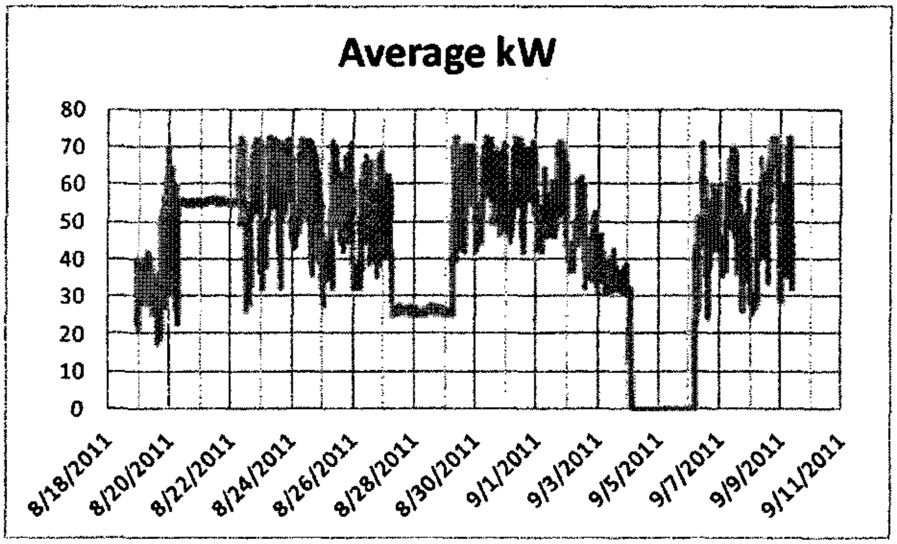
33. Inspected logger data for consistent operation. No data was removed.
34. Verified that pre-retrofit and post retrofit equipment specifications and quantities were consistent with the application.
35. Verified electrical voltage of equipment circuits.

Recording and Data Exchange Format

29. Elite Pro logger binary files
30. Excel spreadsheets

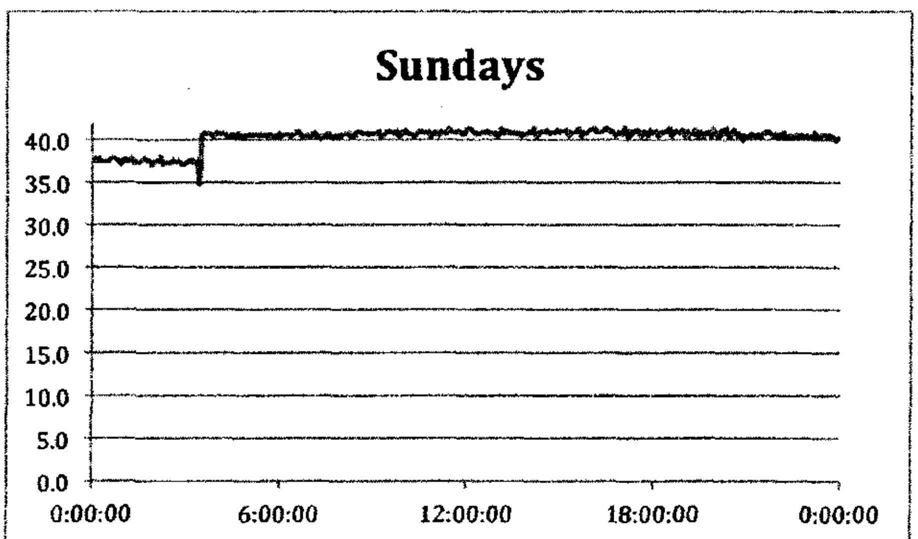
Data Analysis

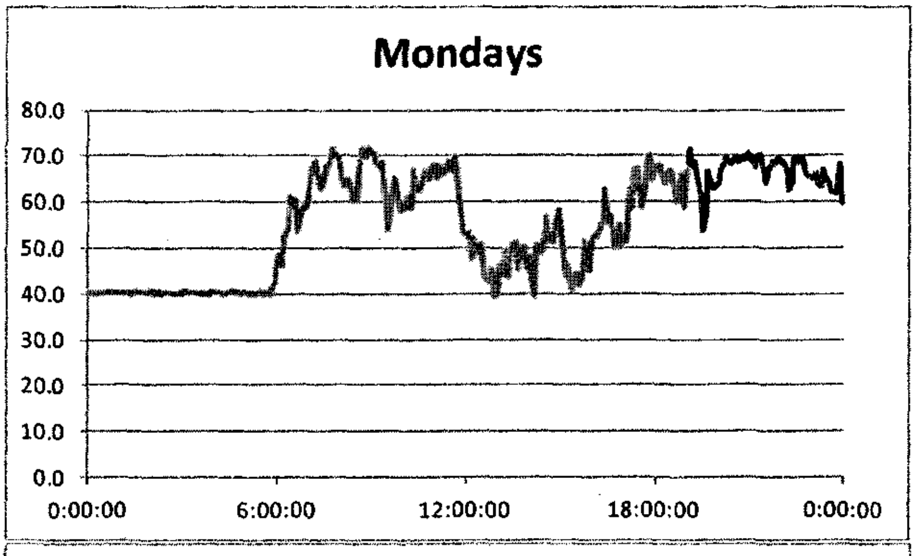
Average kW was measured on the new VFD compressor in 5 minutes intervals from 8/19/2011 to 9/9/2011. The entire data stream can be seen below.

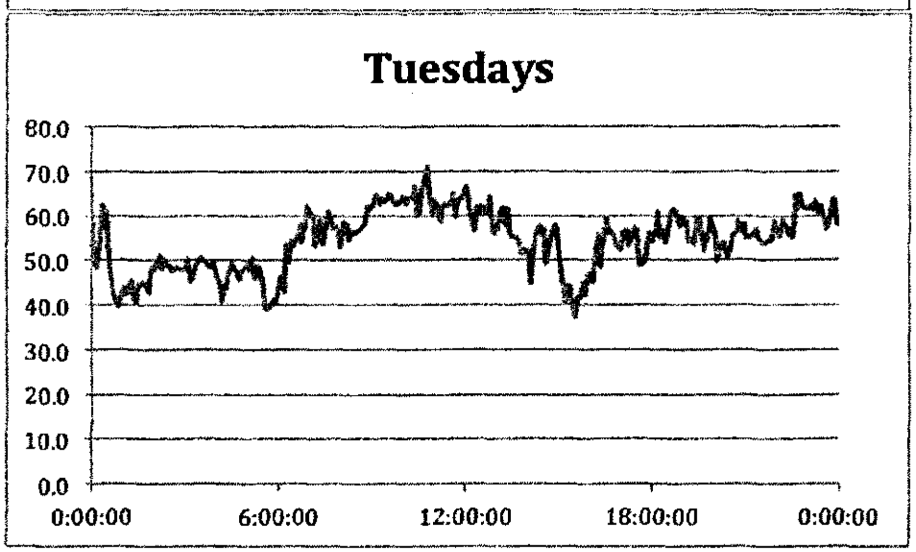


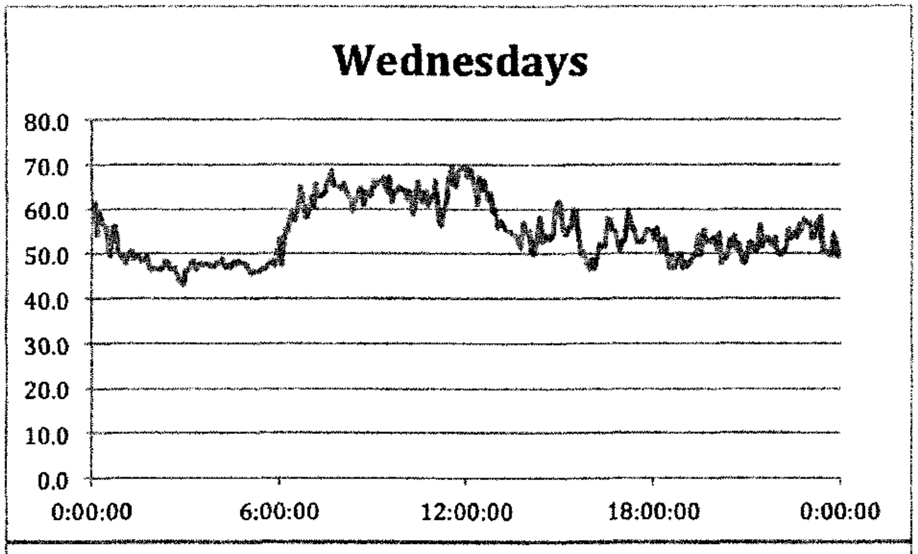
Holidays: Note that the shutdown for the Labor Day holiday on 9/5 appears to last 2 full days (½ day before 9/5 and ½ day after). If the shutdown for each isolated holiday typically lasts 1 full day longer than the official day off, this is effectively 14 shutdown per year, as opposed to 8 (Christmas and New Year's both have 2 adjacent holidays).

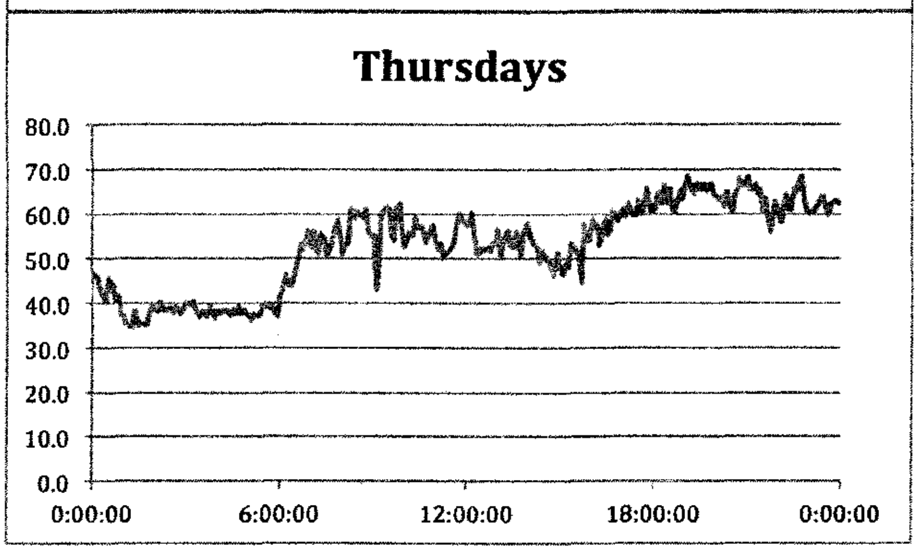
The following graphs show the average daily kW profile, by day of the week.

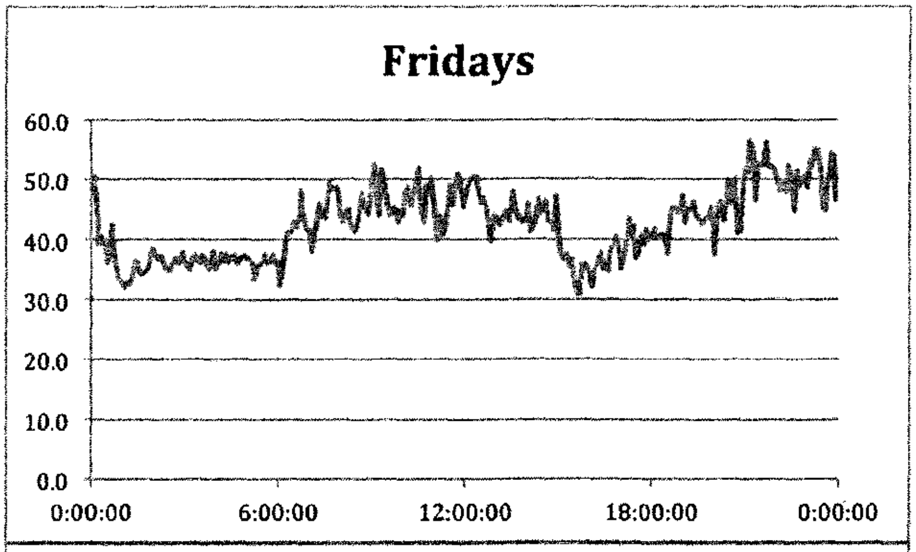


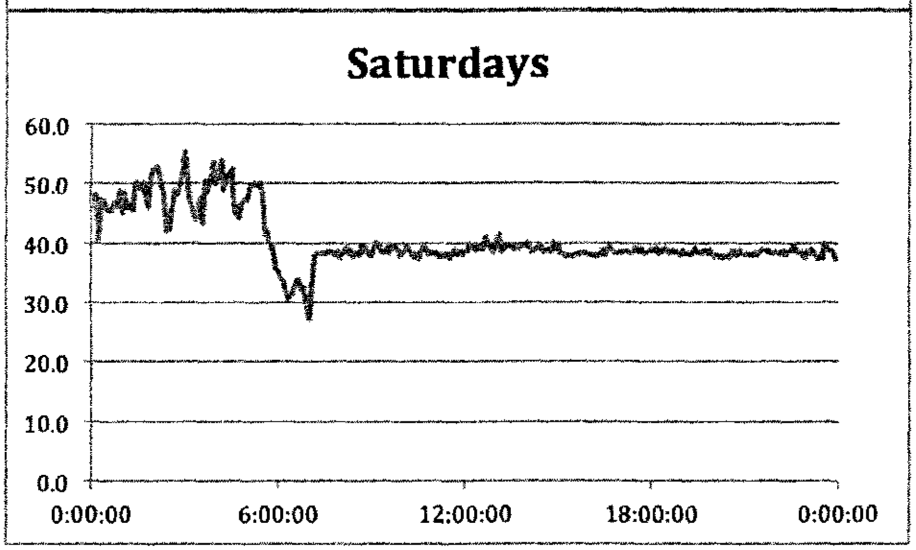

Mondays
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0:00:00
6:00:00
12:00:00
18:00:00
0:00:00

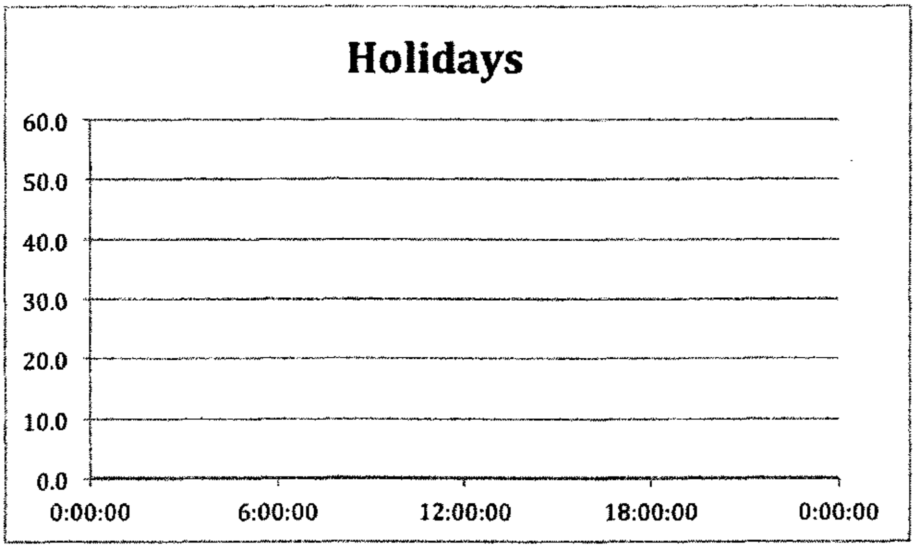

Tuesdays
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0:00:00
6:00:00
12:00:00
18:00:00
0:00:00


Wednesdays
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0:00:00
6:00:00
12:00:00
18:00:00
0:00:00


Thursdays
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0:00:00
6:00:00
12:00:00
18:00:00
0:00:00


Fridays
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0:00:00
6:00:00
12:00:00
18:00:00
0:00:00


Saturdays
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0:00:00
6:00:00
12:00:00
18:00:00
0:00:00



According to the data set, the average weekly energy consumption is 8,181 kWh, and the peak observed kW was 72.6kW. If applied to the entire year (with 14 shutdown days), this amounts to an annual consumption of 410,216 kWh per year.

This compares to the pre-retrofit calculations, which provided the following estimates.

Table 13: Pre-retrofit savings estimates

	Existing installation	Recommended installation
Annual power consumption (kWh)	757744	520104
[illegible]	[illegible]	[illegible]

In total, the actual energy savings as a result of the retrofit was 347,394kWh, for a realization rate of 146%. The actual demand savings was 28.6 kW, for a realization rate of 90%. Detailed results can be seen in the following table.

Table 14: Final Savings Results

	Pre-Retrofit	Post-Retrofit	Realization Rate
Annual kWh	757,744	410,350	-
kW	101.19	72.59	-
Est kWh Savings		347,394	146%
Est kW Savings		28.6	90%

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
347,394	252,206	1.38	29	39	0.74	29	11	2.57

Site 16

[redacted]

M&V Results Summary

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011

INTRODUCTION

Architectural Energy Corporation was hired to evaluate the Duke Energy custom incentive program for several Energy Conservation Measures (ECMs) being implemented as a part of a large building addition to the [redacted] Intermediate School in [redacted], Ohio. The measures include:

ECM-1 – Night Setback on Thermostats

- The building management system will control all aspects of the building's HVAC system, including allowing for nighttime setback of the temperatures. Thermostats will set the temperature back at night to allow for a reduced load during the nighttime. This does not change the amount of kW demand, however, because peak demand typically occurs during the day, and this measure takes effect at night.

ECM-2 – Demand-Controlled Ventilation

- Demand controlled ventilation (DCV) in the gymnasium allows the ventilation load to be reduced. The reduction of the volume of supplied outside air for the gymnasium air handling unit is from 4,200 CFM to 2,000 CFM. This results in a savings of both sensible and latent heat load, which is typically served by the chiller. This measure would result in energy savings as well as demand reduction.

ECM-3 – Heat Recovery Wheels

- Heat recovery wheels will be installed in three air handling units. The amount of energy recovery is based on the Basis of Design selections from the manufacturer. The total airflow on these systems is 29,600 CFM, and the heat recovery wheels are able to recover approximately 64.7 tons of cooling. This measure reduces energy consumption, as well as demand.

ECM-4 – Economizers

- All air handling units will be provided with a full economizer mode. Due to the economizer running on cooler/dryer days, this will not affect the kW demand, only energy. By utilizing the economizer, roughly 5,380 kWh per year will be saved by not operating the chiller.

The M&V portion of the project involved conducting post-installation site visits to complete the AEC Survey-IT data form and establishing trend data for accurate measure analysis.

GOALS AND OBJECTIVES

A pre-retrofit survey and post-retrofit energy model of all of the controlled equipment's energy usage was conducted to determine the power reduction from the control system upgrade.

The projected savings goals identified in the application are:

Facility	Proposed Annual kWh Savings	Proposed Summer Peak kW Savings
[redacted] Intermediate School	145,814	77

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

- Annual gross kWh savings
- kWh Realization Rate

PROJECT LOCATION

- [redacted]

DATA PRODUCTS AND PROJECT OUTPUT

- AEC Survey-IT dataform
- Energy consumption pre- and post-retrofit for controlled equipment
- Annual Energy Savings
- Building kW savings
- Coincident Peak kW savings

M&V OPTION

IPMVP Option D: Calibrated Simulation[2]

VERIFICATION AND QUALITY CONTROL

36. Visually inspect trend data for consistent operation. Sort by day type and remove invalid data. Look for data out of range and data combinations that are physically impossible.
37. Verify post retrofit equipment specifications and quantities are consistent with the application. If they are not consistent, record discrepancies.

RECORDING AND DATA EXCHANGE FORMAT

31. Post-installation Survey Form and Notes.
32. Excel spreadsheets.
33. DOE-2 energy model data files.

[2] This school is an addition to an existing high school. The billing data and the new construction area do not match. The model inputs will be developed from monitored data, but billing data calibration is not possible.

Results Summary

Data Analysis

8. Verify Proposed Measures Were Implemented:

The building addition was constructed per scope with the necessary equipment to achieve the intended ECM functionality. A Survey Form was also filled out for the addition during a site walk following completion. The information requested by the Form helps attain a complete picture of the facility operation and equipment necessary to determine annual energy use. All other information in the AEC Survey-IT data form was filled out as available or applicable. This Form requests detailed information about all building systems and general attributes, including:

- Sequence of operations for all controlled-equipment, including economizer and temperature reset characterizations.
- Thermostat setback
  - BAS interface to verify:
    - Zone temperature setpoints
    - Zone setpoint schedules
- Building wall, window and floor area
- Space types and uses
- HVAC zoning
- Occupancy schedules and operations (daily, weekly, annually, holidays)
- Lighting loads and schedules
- Equipment loads and schedules
- Temperature setpoints, Energy Management Systems
- HVAC system controls
- Fan and pump operation
- Shading and blinds
- Chillers, cooling towers, boilers, central air handlers, and water heating
- Building envelope, including windows, walls, areas, and construction types

9. Set Up Field Data Logging:

Post-Installation Survey data was collected and Trend Logs were established at 5 minute intervals to collect instantaneous readings in the Building Automation System (BAS). These trends were then retrieved after a minimum period of three weeks and included the following data:

Time series data on controlled equipment

- Outdoor air temperature
- Demand Controlled Ventilation
  - Setup trend logs for each of the 4 units

- Establish trend logs to monitor:
  - Gymnasium fan flow or fan speed
  - Outdoor air damper position
  - Indoor CO_2 levels
  - Outside air fraction (if available) OR <u>all three</u> of:
    - Outside air temperature
    - Mixed air temperature
    - Return temperature
- Heat recovery wheels
  - Setup trend logs for each of the 3 units
  - Establish trend logs to monitor:
    - Incoming air temperature and humidity on one stream of the heat wheel
    - Outgoing air temperature and humidity <u>on the same</u> stream of the heat wheel
    - Entering air temperature and humidity <u>on the opposite stream</u> of the heat wheel
- Economizers
  - Setup trend logs for each of the 4 units
  - Establish trend logs to monitor ALL of the same <u>temperature</u> setpoints as in the Demand Controlled Ventilation measures. <u>If a single unit is employing both DCV and economizers, one set of measurements can be used for the calculation of both measures.</u>

10. <u>Calculation Methodology:</u>

<u>*ECM-1: Night Thermostat Setback*</u>

Return air temperature is assumed to be accurately representative of the associated internal spaces, if the unit's fan is operating. At other times when the air is stagnant there is a limited relationship since hot air could rise to the level of the temperature sensor or the unit is exposed to outdoor temperatures that would cause the sensor reading to drift as heat is lost from, or gained by the unit (ex: on a rooftop). Reviewing the trend data yielded the following graphs for each of the air handling units, plotting the time-series data.

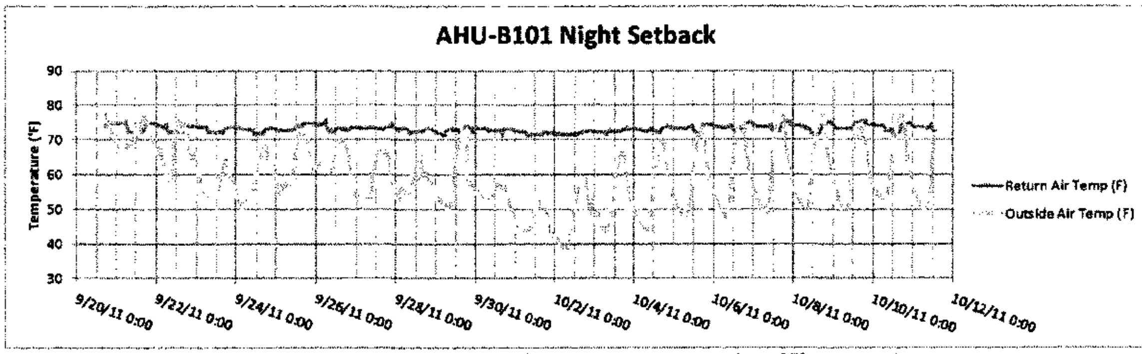


Figure 15: AHU-B101 Space Temperature Trend (Max: 75°, Min: 71°)

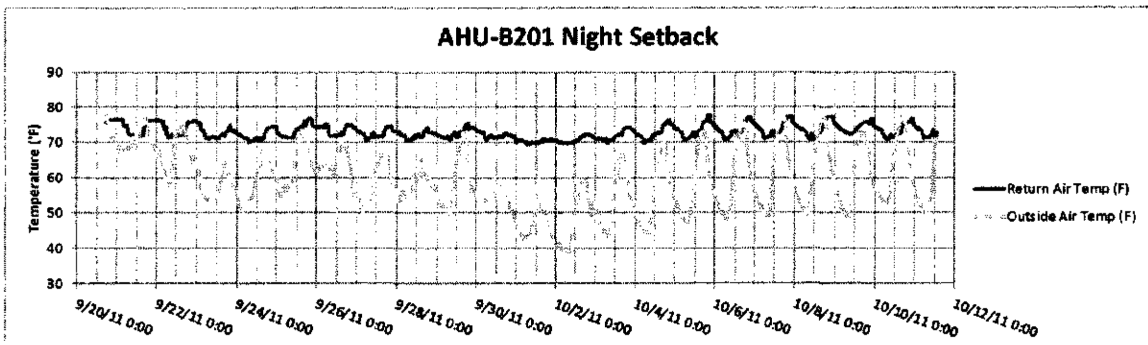


Figure 16: AHU-B201 Space Temperature Trend (Max: 78°, Min: 69°)

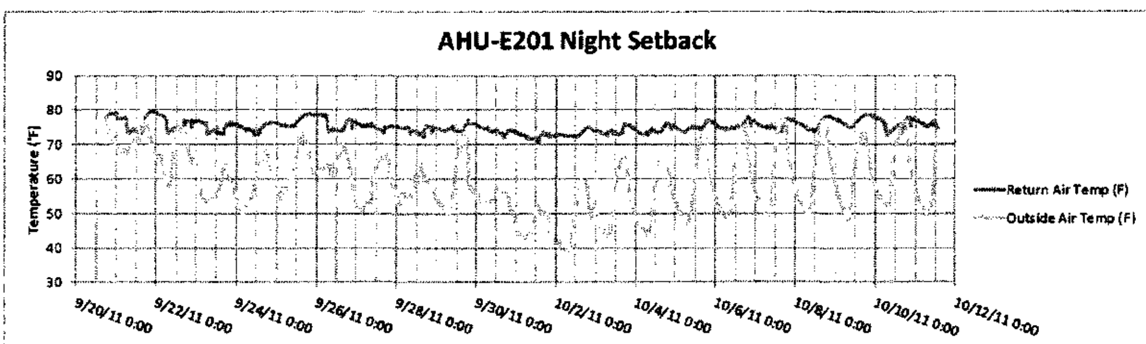


Figure 17: AHU-E201 Space Temperature Trend (Max: 79°, Min: 70°)

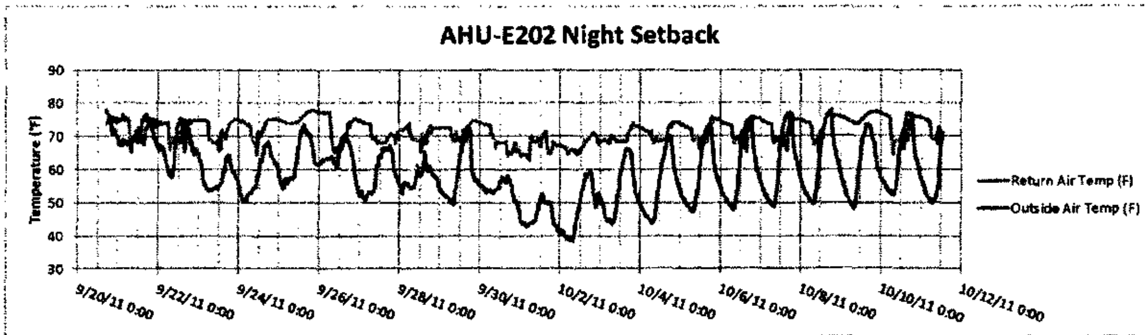


Figure 18: AHU-E202 Space Temperature Trend (Max: 78°, Min: 63°)

Visually, it is difficult to determine from these graphs whether the temperature setpoints in the BAS adjusted to their unoccupied values overnight. With the system setpoints being 75/70°F in occupied mode, each of these units seem to keep the daytime setpoints as requested. However, the outside air temperatures for this trended period do average around 60-65°F throughout. This means that the conditions for the building are such that the system is generally balanced and there is little force to lower of raise unoccupied conditions enough within the interior spaces.

As a result we must look at the coolest period of the data where the outside conditions would have the greatest effect on the unoccupied building. Since the fans are operating for a fair portion of the unoccupied times, it is safe to say that these return temperatures remain accurate to the zone conditions. For the unoccupied times with setpoints of 83/55°F there is a significant temperature drop in E202 (the gym), which is likely due to the setpoints changing in the BAS.

Regardless of the appearance that the space temperatures generally do not sufficiently leave the occupied temperature range in three of the four units, it is assumed that the setbacks are working for all units based on these fluctuations in E202.

ECM-2: Demand Control Ventilation (DCV)

Trend data was used to verify the functionality of the DCV sequences. The following graphs depict the air concentrations in each relative space.

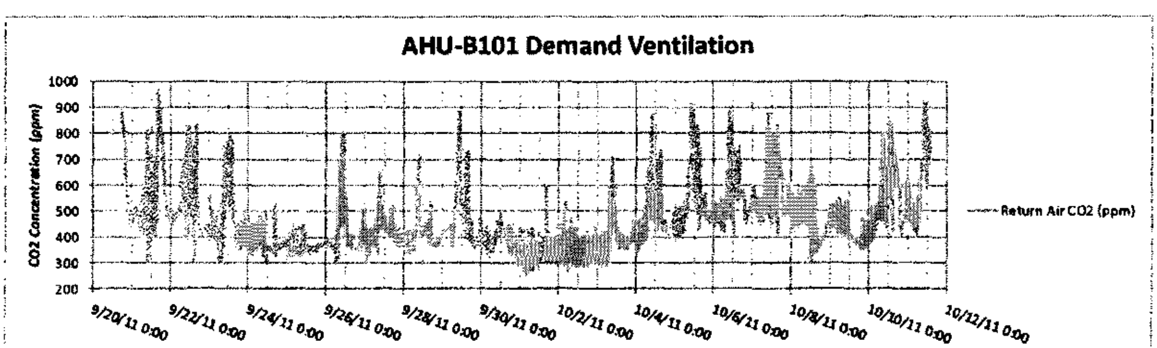


Figure 19: AHU-B101 CO_2 Concentration Trend

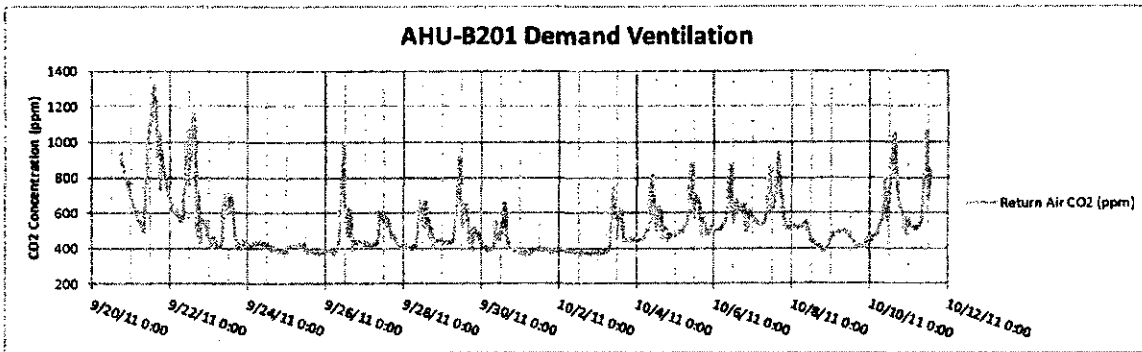


Figure 20: AHU-B201 CO_2 Concentration Trend

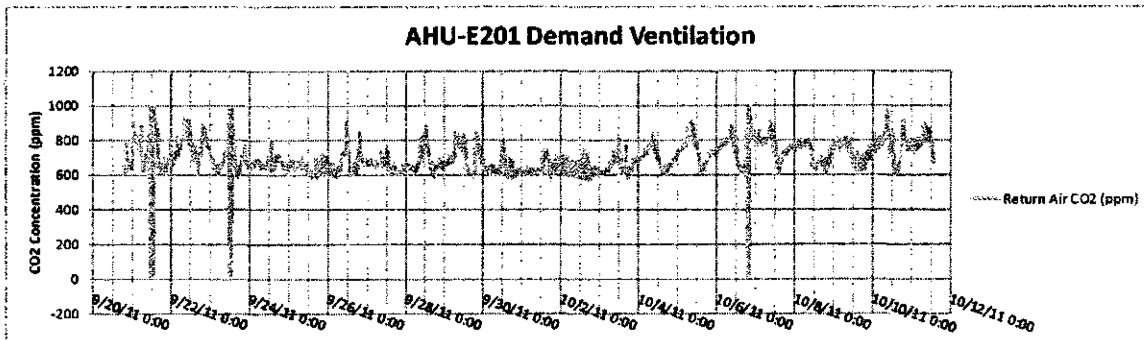


Figure 21: AHU-E201 CO_2 Concentration Trend

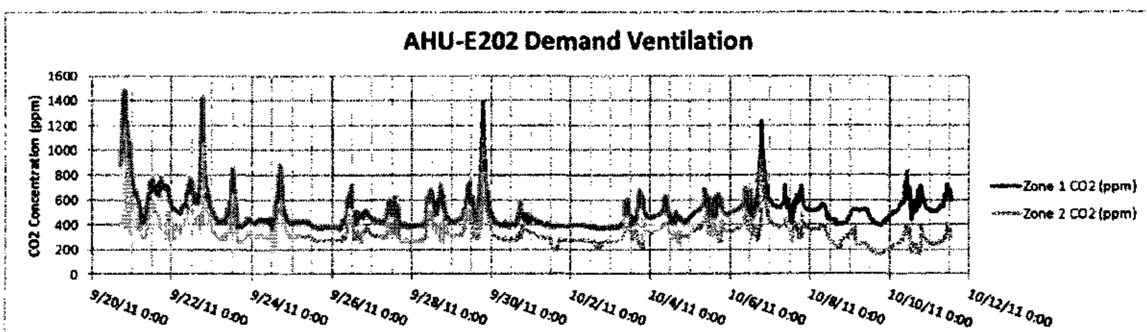


Figure 22: AHU-E202 CO_2 Concentration Trend

The current CO_2 concentration limit in the BAS is 1,000 parts per million (ppm). Knowing this we should see a limit where the concentrations do not exceed the 1,000 ppm value. Through examination of the interior CO_2 levels in the above Figures, it is evident that all units are mitigating indoor CO_2 levels through demand ventilation control. This can be seen through the increased air quality during occupied hours. As people arrive early and CO_2 begins to spike the ventilation is increased to temper the levels through the rest of the day.

One potential issue with the system remains the calibration of the sensors being used. Typical outdoor levels are ~400 ppm CO_2 concentration. While B101 and B201 reach a minimum near that value, units E201 and E202 have a lower limit of 600 and 200ppm respectively. E201 even drops to 0 briefly at a few spots.

ECM-3: Heat Recovery Wheels

The heat recovery systems only apply to three of the four air handlers that condition this building addition. The Gym unit (AHU-E202) was not equipped with energy recovery exhaust. Effectiveness of the wheels can be determined by comparing the temperatures of each air stream using the following equation:

Where: T_{in} = Building Exhaust Air (°F)
T_{out} = Recovery Exhausted Air (°F)
$T_{out}max$ = Entering Outside Air (°F)

$$\epsilon = \frac{(T_{in} - T_{out})}{(T_{in} - T_{out})_{max}}$$

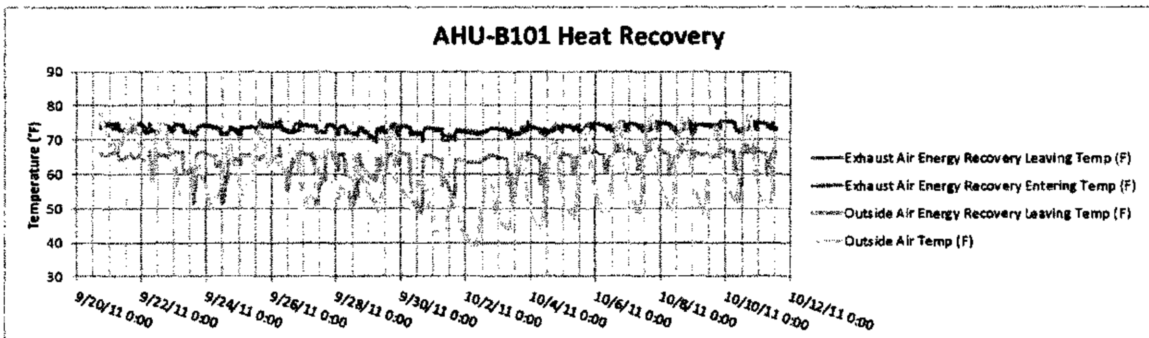


Figure 23: AHU-B101 Energy Recovery Temperatures

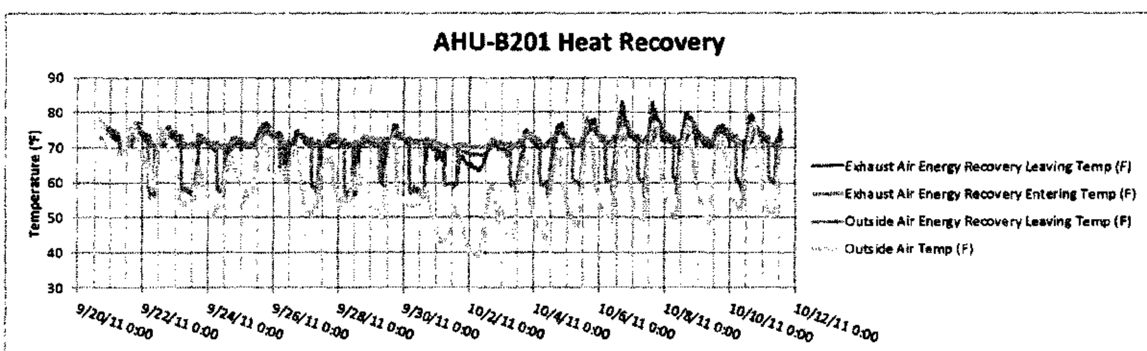


Figure 24: AHU-B201 Energy Recovery Temperatures

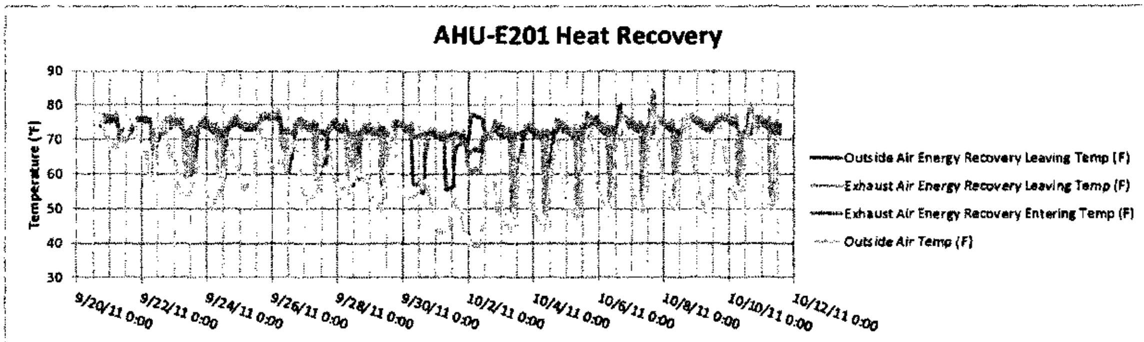


Figure 25: AHU-E201 Energy Recovery Temperatures

Due to the season this data was collected in, there was very limited opportunity for each heat wheel to run. With the outside air often between ~55 and ~75, economizing is an option, but energy recovery would provide little additional value. In addition, to utilize economizer free cooling, the wheel *would not* run so the maximum benefit of the cool air could be used for interior load management. A clearer picture would be provided from either heating or cooling dominant seasons where there is greater optimal conditions to recover heat or 'coolth' from the exhausted air streams.

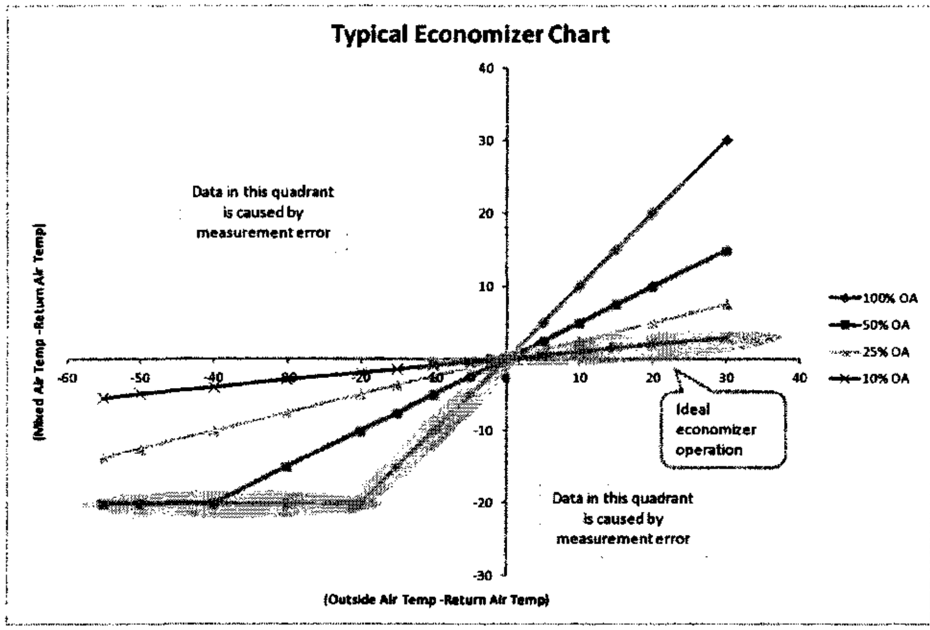
ECM-4: Economizers

Dampers operate in a non-linear fashion compared with the amount of air that actually passes through them. For example, a damper set physically open to 10% means that *more* than 10% of the air volume possible through those dampers is actually entering the airstream. Because of this non-linear relationship, we use the following air ratio equation to determine the true OA fraction.

Where: MAT = Mixed Air Temperature (°F)
RAT = Return Air Temperature (°F)
OAT = Outside Air Temperature (°F)

$$\%\,Outside\,Air = \frac{MAT - RAT}{OAT - RAT}$$

Plotting this ratio on a scatter plot produces a outdoor air fraction graph where the slope of the line is indicative of the outdoor air fraction. In this figure the lines of damper position are placed to show the ideal economizer path.



Comparing the actual graphs below to the example above, we are able to more effectively determine the true functional state of the outside air dampers. Each plot is a scatter of the real time-series data.

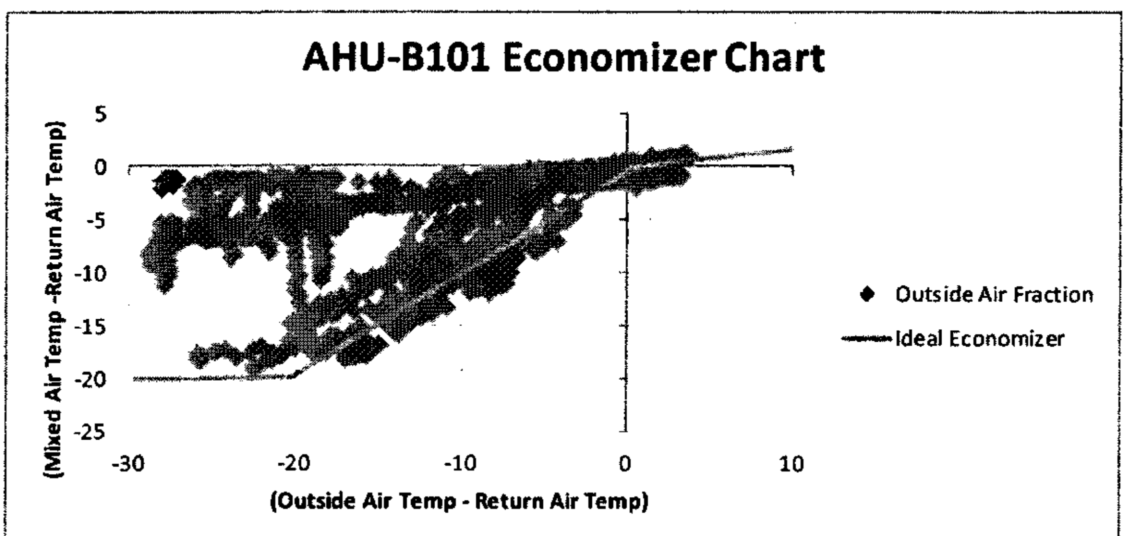


Figure 26: AHU-B101 Temperature Difference Ratios for Outside Air Fraction

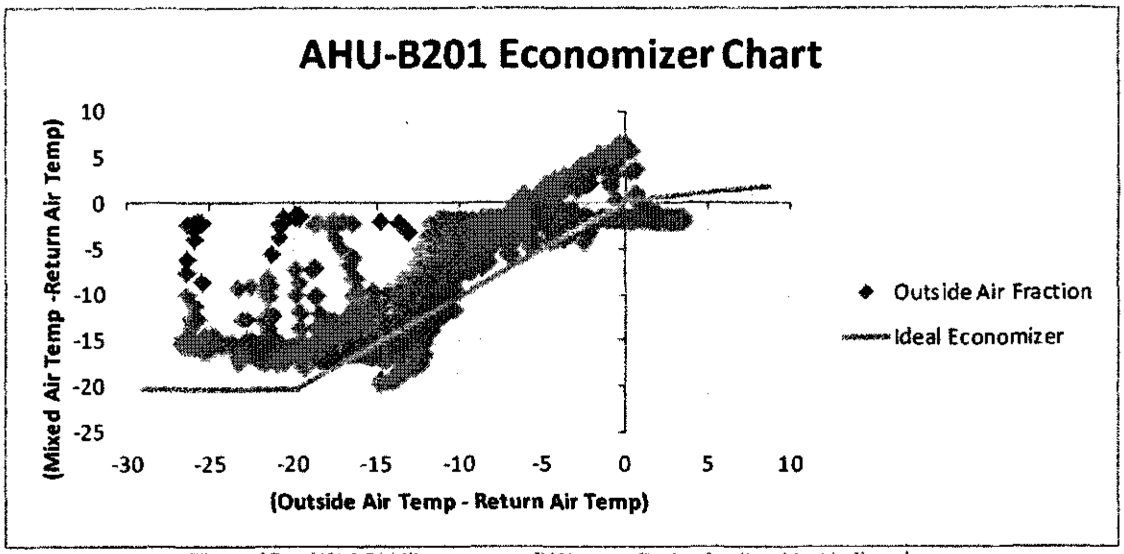


Figure 27: AHU-B201 Temperature Difference Ratios for Outside Air Fraction

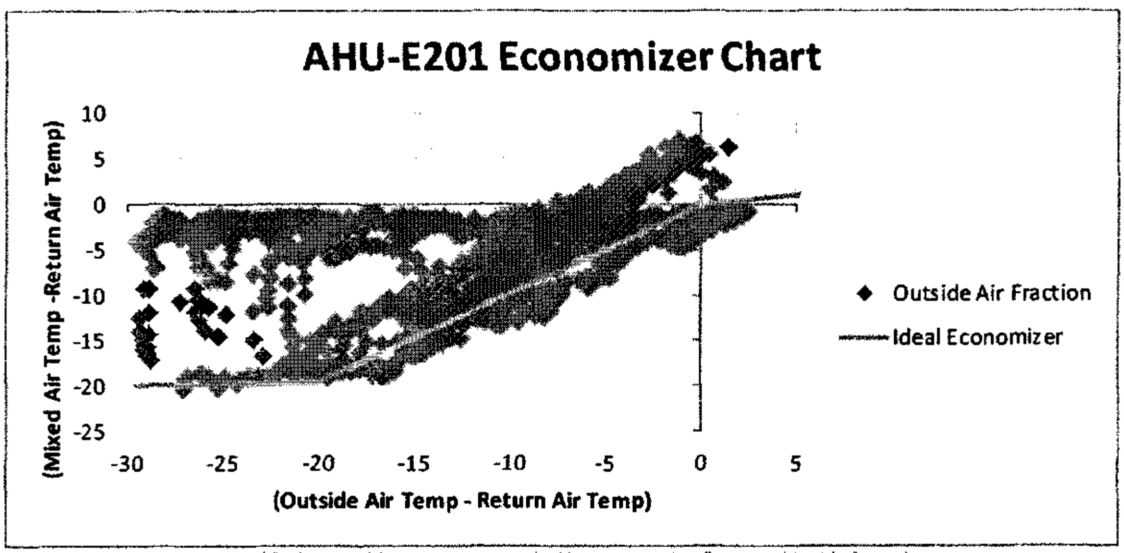


Figure 28: AHU-E201 Temperature Difference Ratios for Outside Air Fraction

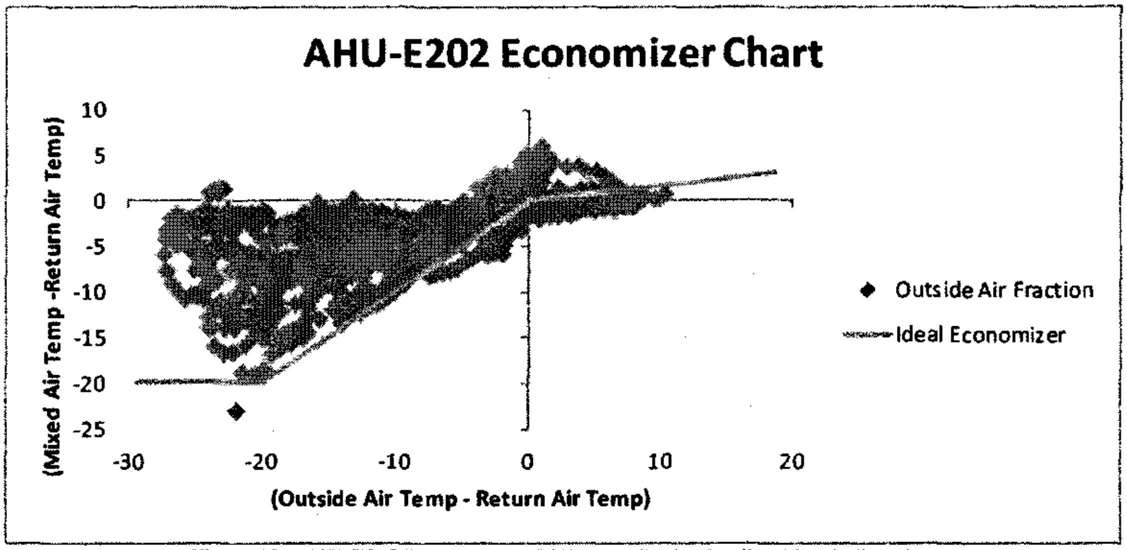


Figure 29: AHU-E202 Temperature Difference Ratios for Outside Air Fraction

All of the points shown are based on the occupied, weekday hours when the fan is operational to remove outliers and non-applicable data. The outside air temperature range for this season is often ideal for economizing (~55 to ~75°F). Since the outside temperature was in this range through the majority of the trend period, these figures are telling of the true economizer operation. We can see that units E201 and B101 tend to operate fairly true to the ideal economizing curve though do spend significant time at minimum position as well. E202 operates fairly consistently around 30% OA while B201 is really the only one that adequately appears to be economizing. The effectiveness of this ECM is reflected in Table 17 below.

Simulation Modeling

All post-retrofit data was entered into Survey-IT and run through the DOE2 energy simulation software to determine annual energy consumption. A baseline energy model was then created by converting all energy efficiency measures and other building attributes to their equivalents in the ASHRAE 90.1-2004 code. Savings are estimated on a "whole-building" basis.

Comparing ASHRAE 90.1 results with the actual building-addition results then determined the annual energy savings. The results for both cases are shown and compared below. Note, heating setback thermostats and economizers are required by code. No savings were attributed to these measures.

Table 15: Energy Model Analysis Results

DOE 2 Building Analysis Results			
Commodity	ASHRAE 90.1 Building	Surveyed Building	Savings
Annual Demand (kW)	731	412	319
Annual Electricity Use (kWh)	670806	433279	237528

Table 16: Comparison of Application Savings vs. Energy Model Results

Savings Comparison		
Commodity	Application	"DOE 2" Model
Annual Demand (kW)	77	319
Annual Electricity Use (kWh)	145834	237528

11. Savings Verification and Realization Rate:

Design and Post-construction information is compared to obtain annual kWh and kW savings for the new facility. Once the savings are calculated, the realization rate is determined by the following formula:

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

It is noteworthy that the Rate is calculated from the output of the Survey-IT energy model completely and not for each ECM specified as part of this project. The detailed ECM analysis described above only ensures the proper building functionality is assigned to the model for analysis.

CALCULATION OUTPUT SUMMARY

Below is a summation of the results discussed through the analysis section above. For the general building model, only electricity savings was included, due to only that commodity being referenced on the Rebate Application.

Each of the four ECMs (Night Setback, Demand Control Ventilation (DCV), Energy Recovery, and Economizers) are tabulated to note which ECMs are operating successfully and the unit(s) they pertain to.

Table 17: ECM Results

Equipment	*Energy Conservation Measures*			
	Setbacks	*DCV*	*Recovery*	*Economizing*
AHU-B101	Active	Active	Inconclusive	Active
AHU-B201	Active	Active	Inconclusive	Active
AHU-E201	Active	Active	Inconclusive	Active
AHU-E202	Active	Active	N/A	Active

It is important to mention that additional trend data in a more heating/cooling dominant season would provide additional insight into these measures due to larger temperature differences throughout system airstreams.

The following Table reveals the Project Realization Rate based on the performance of the model.

Table 18: Savings Realization Rates

Project Realization Rate			
Commodity	Application	"DOE 2" Model	Rate
Annual Demand (kW)	77	319	414%
Annual Electricity Use (kWh)	145834	237528	163%

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
237,527	148,014	1.60	319	80	3.99	22	18	1.22

Site 17

[redacted]

Lighting Retrofit

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011

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

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

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

INTRODUCTION

This report addresses M&V activities for the [redacted] custom program application. The application covered a lighting retrofit at the [redacted] recreation center, and affected an area of 8,000 square feet. This M&V report is based on post-retrofit monitoring only. The measures included:

ECM-1 – [redacted] Gym light fixture retrofit 1

- 15 existing 455-Watt metal halide light fixtures were replaced with induction high bay Spectrum-200 light fixtures. This results in a per-fixture energy reduction of 235W.

ECM-2 – [redacted] Gym light fixture retrofit 2

- 10 existing 455-Watt metal halide light fixtures were replaced with induction high bay Spectrum-165 light fixtures. This results in a per-fixture energy reduction of 255W.

ECM-3 – Raquetball light fixture retrofit

- 14 existing 455-Watt metal halide light fixtures were replaced with 12 high bay Nulite 5x55 light fixtures. This results in a total Wattage reduction of 2,890W.

GOALS AND OBJECTIVES

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

The projected savings goals identified in the application are:

Facility	Proposed Annual kWh savings	Proposed Summer Peak kW savings
[redacted]	60,049	9
Total	**60,049**	**9**

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

- Annual gross energy (kWh) savings
- Peak demand (kW) savings
- Summer Utility coincident peak demand savings (kW)
- Building peak demand savings (kW)kWh & kW Realization Rates

PROJECT CONTACTS

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Cory Gordon	
Customer Contact	[redacted]	[redacted]

SITE LOCATIONS/ECM'S

Site	Address	Sq. Footage	ECM's Implemented
[redacted] Gym	[redacted]	7,200	1, 2
Raquetball Court		800	3

DATA PRODUCTS AND PROJECT OUTPUT

- Average post-retrofit load shapes by daytype for controlled equipment
- Verified fixture counts (post-retrofit), and that all fixtures were upgraded
- Summer peak demand savings (kW)
- Coincident demand savings (kW)
- Annual Energy Savings (kWh)

M&V OPTION

IPMVP Option A

M&V IMPLEMENTATION SCHEDULE

- This measure has already been implemented, so there was no pre-retrofit survey. Rather, fixture types, quantities, and schedules were taken from the application documentation.
  - The field survey verified as much as possible that the pre-retrofit fixture specifications and quantities removed from the project match the application.
- Deployed post-retrofit loggers to monitor lighting current.
  - Collected data between October 10, 2011 to November 1, 2011.

DATA ACCURACY

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

FIELD DATA POINTS

Post-Installation

Survey data

- Verified during the post survey that all pre (existing) fixtures were removed.
- During the post survey, verified that all post (new) fixture specifications and quantities were consistent with the application.

- Determined that nine holidays are observed over the year, and that the lighting zones are disabled during the holidays

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

- Lighting circuit power when lights are on

Time series data on controlled equipment

- Typical lighting load shape
  - Deployed data loggers post survey to measure operating hours.
  - Deployed current measurement CT loggers to measure current at the panelboard. logging individual circuits.
  - Loggers were configured for 5 minute instantaneous readings; loggers operated between October 10 to November 1, 2011.
- Spot measurements of the lighting load connected to the circuit were taken by measuring the kW load and current of the circuit during the post-retrofit survey.

LOGGER TABLE

The following table summarizes all logging equipment needed to accurately measure the above noted ECM's (* this assumes that each ECM has at most 3 lighting control points):

ECM	Hobo U-12	20A CT
1	1	2
2	1	3
3	1	2
Total	**3**	**7**

DATA ANALYSIS

5. Converted time series data on logged equipment into post average load shapes by day type.
6. Fixture types, quantities, and schedules were taken from the application documentation for the pre-retrofit case. The field survey verified that the pre-retrofit fixture specifications and quantities removed from the project match the application. The annual kWh for both pre- and post-retrofit cases was calculated using the following equations:

$$\frac{kWh}{year} = \sum\left[\frac{kW_{spot}}{Ampacity_{spot}} * Ampacity_{time-measured} * \frac{5\min._{intervals}}{\frac{60\min.}{hour}} * \frac{18hours}{day} * \frac{364days}{year} \div \frac{days}{monitoringperiod}\right]$$

Annual Total:

$$\frac{kWh}{year} = \sum \left[\frac{kWh}{year}_{weekday} + \frac{kWh}{year}_{weekend} \right]$$

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

$$\frac{hWh_{saved}}{year} = \frac{kWh_{pre}}{year} - \frac{kWh_{post}}{year}$$

4. Estimated the peak demand savings

Verification and Quality Control

38. Visually inspected the logger data for consistent operation. No inconsistencies were noted.
39. Verified that the post retrofit lighting fixture specifications and quantities were consistent with the application. No inconsistencies were noted.
40. Verified that the pre-retrofit lighting fixtures were removed from the project. All fixtures had been removed from the site.
41. Verified the electrical voltage of post lighting circuits.

Recording and Data Exchange Format

34. Post-installation Lighting Survey Form and Notes.
35. Hobo logger binary files
36. Excel spreadsheets

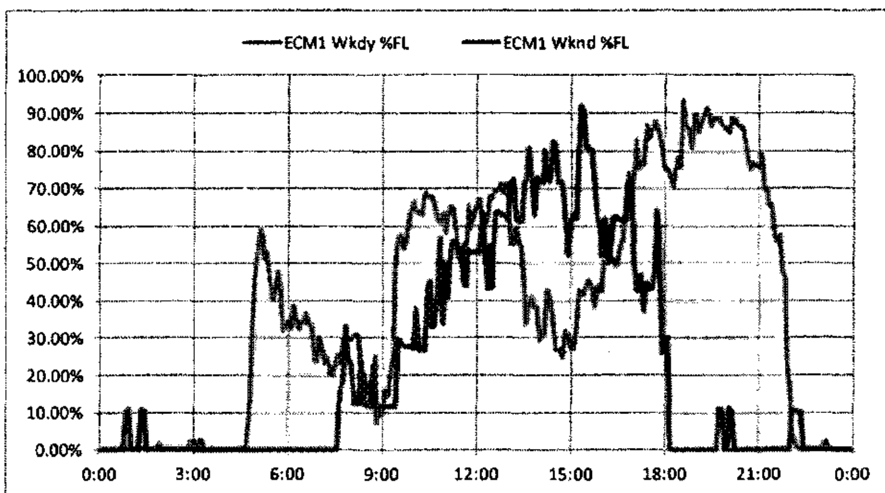
Post-Data Results

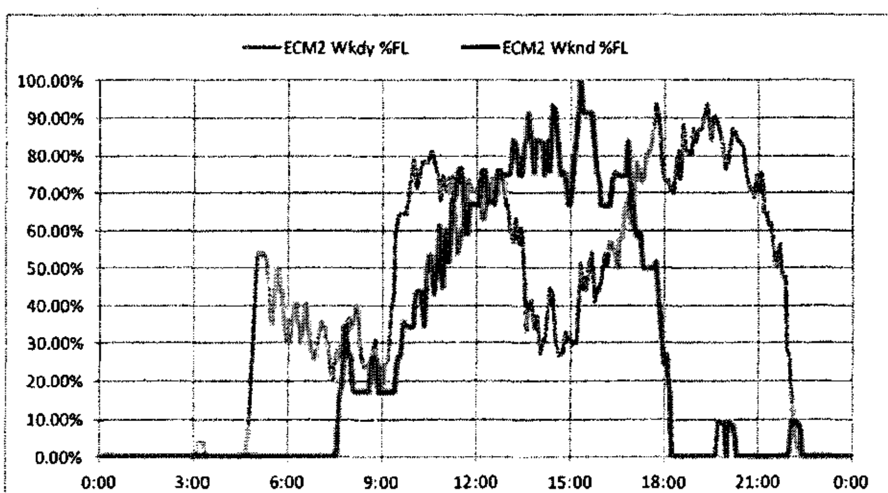
This project was based on the replacement of (25) 455watt metal halide fixtures in the [redacted] Gym and (14) 455 watt metal halide fixtures in the racquetball area. The pre-install estimated savings based on the installation of (10) 165 watt and (15) 200 watt high bay induction lighting in the [redacted] gym with occupant sensors for control is 60,049 kWh annual savings. The following table summarizes the savings associated with these ECMs. Since controls were not part of these ECMs, the run hours for both the pre and post-retrofit conditions were assumed to be the same.

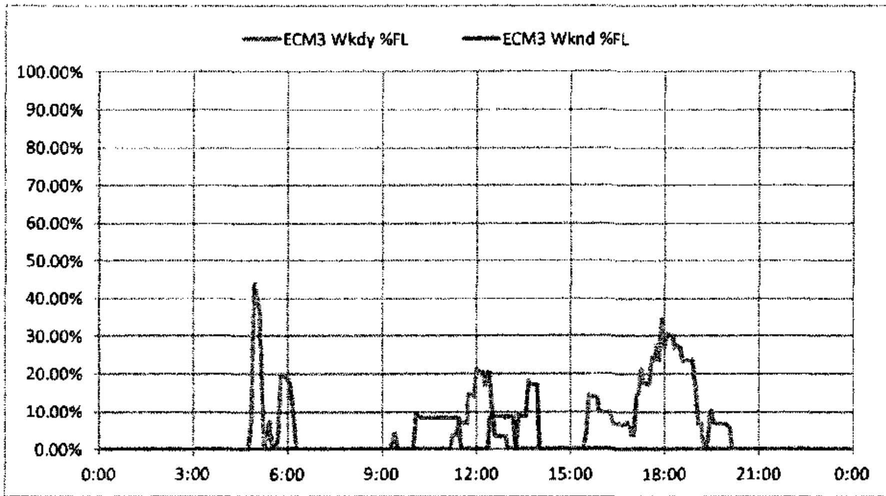
ECM	Pre-retrofit Existing Fixtures				Post Retrofit Performance					Savings	
	Qty	Watts per Fixture	Total Watts	Annual KWh based on post hours	Qty	Average Watts per Fixture	Total Watts	Projected Annual Full Load Run Hours	Annual kWh	Annual Savings based on post hours for pre and post kWh	Demand Savings kW
1	15	455	6825	19,391	15	212	3173	2841	9,016	10,375	3.7
2	10	455	4550	14,120	10	171	1710	3103	5,307	8,813	2.8
3	14	455	6370	5,886	12	246	2958	924	2,733	3,153	3.4
Total				39,397					17,056	22,341	[illegible]

Savings Realization Rate		
	kWh	Peak kW savings
Projected	60,049	9.0
Actual	22,341	9.9
Realization rate:	37.2%	110.0%

In summary the projected savings are less than the estimated savings, primarily due to the measured run hours (924 to 3,100 hrs/year) being substantially less than the projected run hours (6,255 hrs/year). The estimated annual energy savings is 22,341 kWh, with 9.9 kW of demand savings. The following graphs show the average daily load shapes for weekdays and weekends. ECM3, the racquetball court lighting ECM, shows the racquetball court usage was very low.







From the load profiles show above, the coincident peak demand is calculated as follows:

ECM	NCP demand Savings (kW)	% on at 2pm	CP Demand Savings (kW)
1	3.7	40%	1.5
2	2.8	40%	1.1
3	3.4	0%	0.0
Total	9.9		2.6

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
22,341	60,259	0.37	10	9	1.08	3	9	0.28

Site 18

[redacted]

Energy Savings Compressed Air Project

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011
Version 1

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

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

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

INTRODUCTION

This plan addresses M&V activities for the [redacted] custom program application. The application covers an air compressor VFD retrofit at one location in [redacted], Ohio. The measure includes:

ECM-1 – Air Compressor with VFD

- Two inefficient, out-of date air compressors will be replaced with a new, modern variable frequency drive 150hp compressor. The existing 100hp SSREP-11 compressor will remain for back-up purposes only. The existing compressor utilizes a dryer which may or may not be integral to the unit. The new compressor was provided with an integral dryer. In addition, two new 660 gallon air receiver tanks will be added.

Note: ECM's have already been installed for this application. Data collection will be for Post only.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are:

Application Estimated Annual Savings (kWh)	Application Estimated Peak Savings (kW)	Duke Projected Annual Savings (kWh)	Duke Projected Peak Savings (kW)
713,614	77.9	713,614	**82**

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

- Annual gross kWh savings
- Peak kW savings
- kWh & kW Realization Rates

PROJECT CONTACTS

Approval has not yet been granted from the Duke Energy contacts listed below to plan and schedule the site visit with the Customer.

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Mike Harp	
Customer Contact	[redacted]	[redacted]

Site Locations/ECM's

Site	Address
[redacted]	[redacted]

Data Products and Project Output

- Average pre/post load shapes by daytype for controlled equipment
- Summer peak demand savings
- Coincident demand savings
- Annual Energy Savings

M&V Option

IPMVP Option A

M&V Implementation Schedule

- Survey site personnel to obtain information on pre-retrofit system operations.
  - Obtain and verify the pre-retrofit sequence of operations and/or operating schedule for the compressed air system.
- Survey site personnel to obtain information on post-retrofit system operations.
  - Obtain and verify the post-retrofit sequence of operations and/or operating schedule for the compressed air system.
  - Deploy post-retrofit loggers to record current on the new VFD compressor to determine post-retrofit load shapes and energy consumption.
- Collect data during normal operating hours (avoid holidays or atypical operating hours).
- Evaluate the energy savings of the retrofit measure.

Data Accuracy

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

Field Data Points

Post – installation

Survey data (for both new and existing compressor)

- Compressor make/model/serial number
- Compressor VFD make/model (New compressor only)
- Compressor cut-in/cut-out pressure setpoint (pre and post)

One-time measurements for new and existing compressor (to check and validate Elite Pro data)

- Compressor volts, amps, kW and power factor

Time series data on new and existing compressor

- Compressor volts, amps, kW and power factor

Field Data Logging

Post – installation

- **ECM-1**
    - Install one Elite-Pro logger to monitor new compressor current.
    - Install one Elite-Pro logger to monitor existing compressor current.
    - Install one Hobo logger to monitor existing compressor dryer current (if not integral to unit)
    - Set up loggers for 5 minute instantaneous readings. Deploy for 3 weeks.

Logger Table

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

Elite-Pro	Hobo U-12	20A CT	150A CT
2	1	1	6

Note: CT sizes are approximations. Field verification will need to be performed in order to verify logging equipment needed.

Data Analysis

8. Use time series data gathered by Compressed Air Technologies to estimate Pre operating conditions.
9. Convert time series data on logged equipment into pre/post average load shapes by day type.

10. The annual kWh will be calculated using the following equations:

Weekdays: $$\frac{kWh}{year} = \sum \left[kW_{time-measured} * \frac{5\min._{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{312days}{year} \div \frac{weekdays}{monitoringperiod} \right]$$

Weekends: $$\frac{kWh}{year} = \sum \left[kW_{time-measured} * \frac{5\min._{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{52days}{year} \div \frac{WEdays}{monitoringperiod} \right]$$

Annual Total:

$$\frac{kWh}{year} = \sum \left[\frac{kWh}{year_{weekday}} + \frac{kWh}{year_{weekend}} \right]$$

11. Estimate average daily cfm from pre and post data collection, and adjust pre kWh for changes in daily cfm (if any changes are noted). Use the following equation to adjust pre kWh for increased production during post monitoring period:

$$kWh_{preadj} = kWh_{pre} \times \frac{cfm_{pre}}{cfm_{post}}$$

12. Determine kWh/CFM for both pre and post conditions. Use CAGI Compressor Data Sheet to determine CFM values from monitored kW.

13. The annual kWh ***saved*** will be calculated using the previous data in the following equation:

$$\frac{kWh}{year_{savings}} = \frac{kWh}{year_{pre}} - \frac{kWh}{year_{post}}$$

4. Estimate peak demand savings

VERIFICATION AND QUALITY CONTROL

42. Visually inspect logger data for consistent operation. Sort by day type and remove invalid data. Look for data out of range and data combinations that are physically impossible.

43. Verify pre-retrofit and post retrofit equipment specifications and quantities are consistent with the application. If they are not consistent, record discrepancies.
44. Verify electrical voltage of equipment circuits.

Recording and Data Exchange Format

37. Elite Pro logger binary files
38. Excel spreadsheets

Post-Data Results

The post-data results are based on two loggers deployed for the new Kaeser Compressor and the existing Ingersol-Rand as shown in the logger table above. The logger data collection occurred from August 15, 2010 thru September 9, 2010. The show that at least one of the compressors operate 24/7 including weekends and holidays.

The post-retrofit data are shown in the following graphs. An anomaly is shown in Figure 30 below, which shows both compressors operating during the trending period. The peak demand in this case would have been 132kW. Since the backup compressor was documented to only run when the primary compressor is off, this event will be treated as an anomaly.

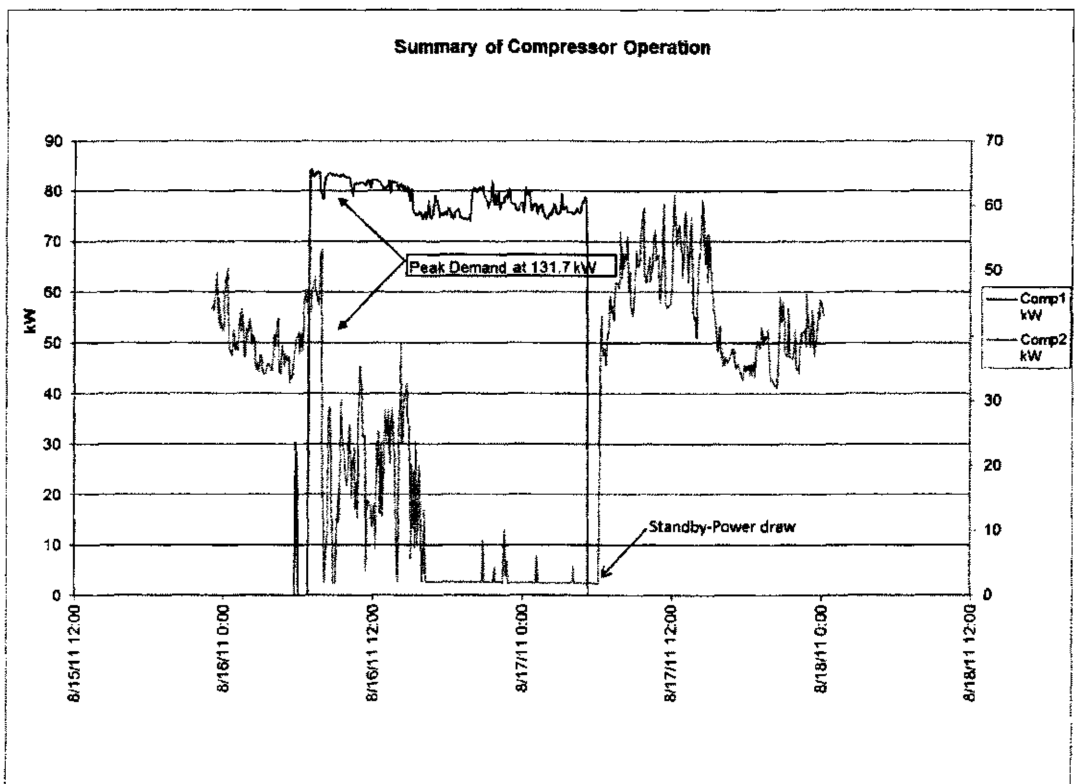


Figure 30. Anomalous high peak demand

The following graph shows the average daily load shapes for the new compressor. These plots average the entire monitoring period into the three day types shown.

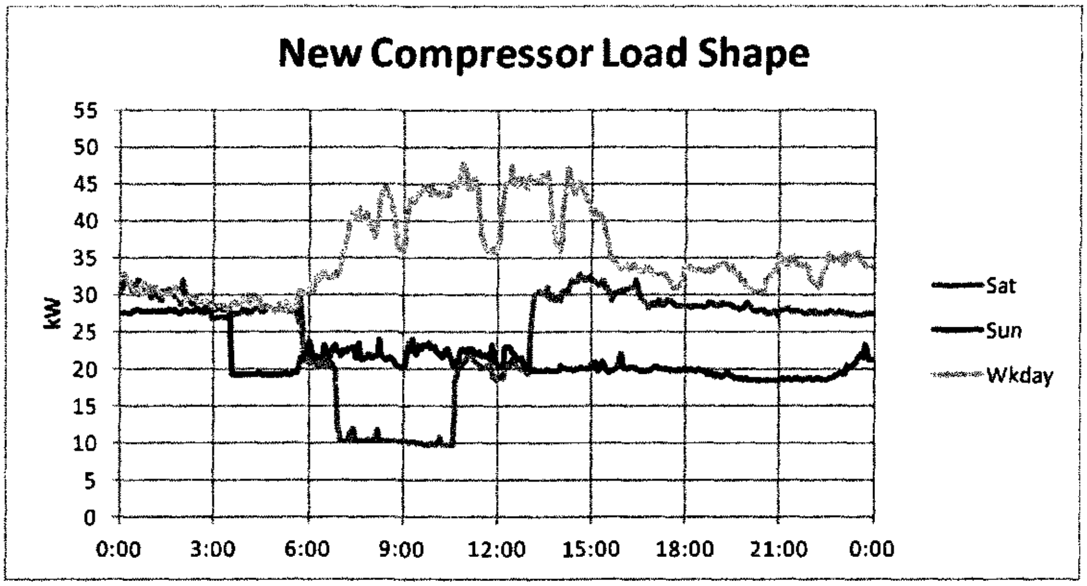


Figure 31. Average daily load shape: new compressor

Figure 32 shows the average load shape for the backup compressor. This load shape graph is misleading since this compressor only ran a few times during the monitoring period. More representative operation is displayed in Figure 33 that shows for the entire monitoring period for both compressors. The backup compressor typically draws between 70 and 80 kW, rather than the 10 to 25 kW shown in the average load shape chart.

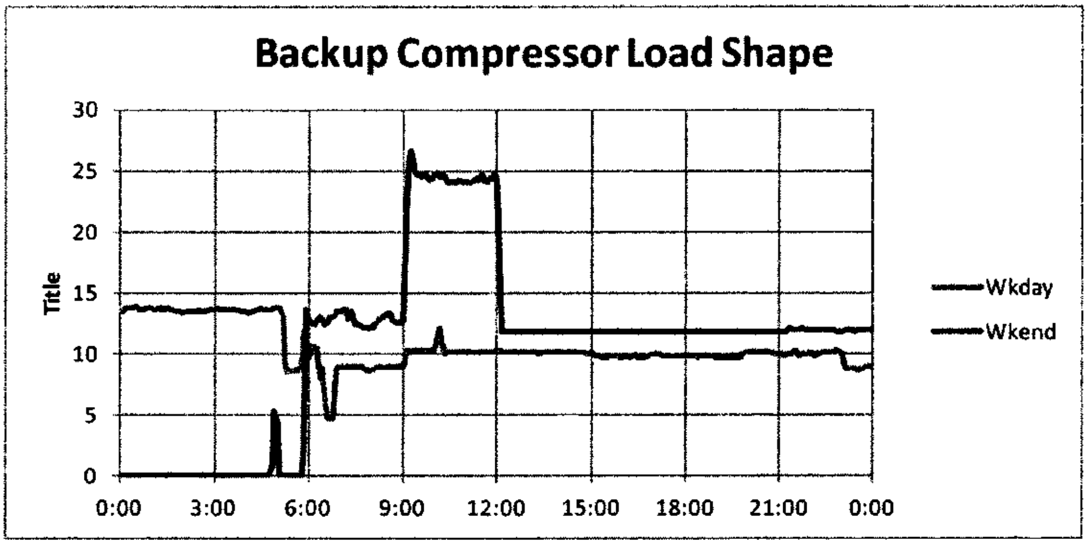


Figure 32. Average daily load shape; backup compressor

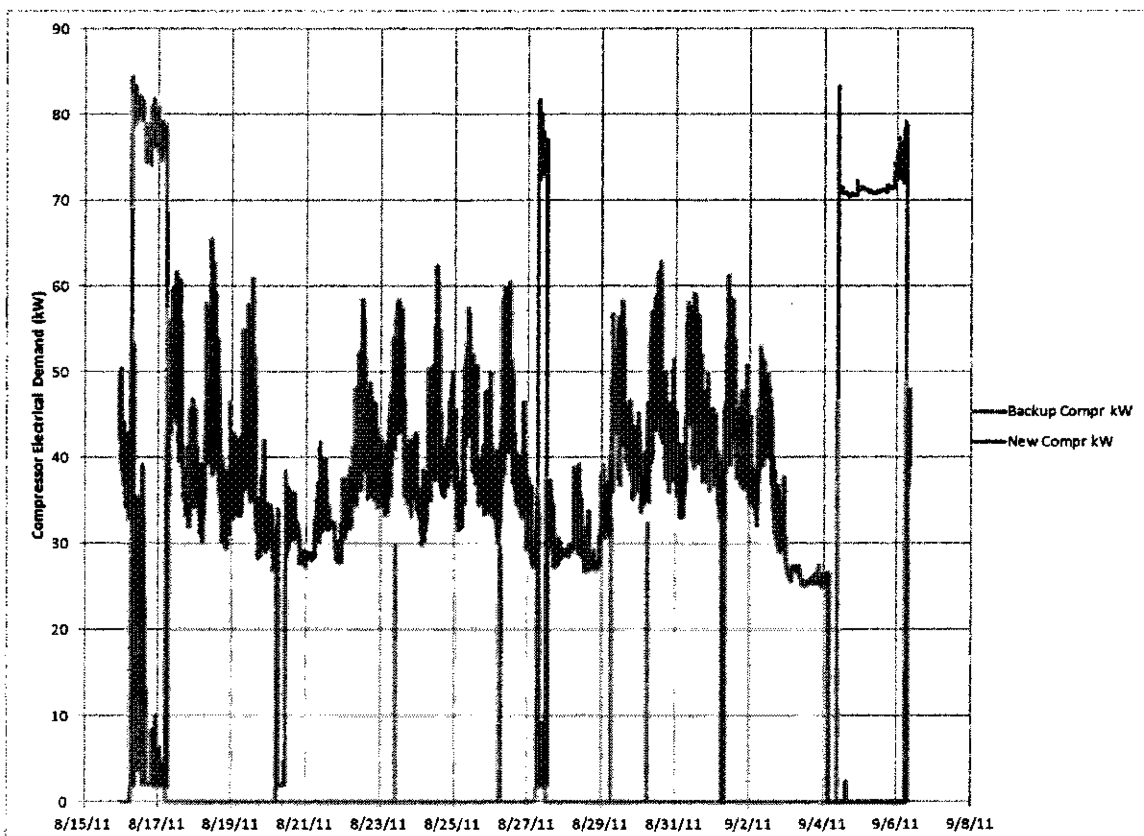


Figure 33. Electrical demand during monitoring period

The following table summarizes the energy and demand savings resulting from the new compressor installation. The projected annual savings based on post install trend data is 719,314 kWh.

	Avg. kW	Peak kW	Annual kWh
Pre-Retrofit			
Compr 1 and 2	**127.0**	**159**	**1,112,537**
Post-retrofit			
New Compr		65.42	
Weekday	35.45		236,781
Saturday	24.72		33,971
Sunday	21.51		29,966
Backup Compr (old)		84.423	
Weekday	10.56		65,900
Saturday	6.62		8,260
Sunday	14.70		18,345
Total Post-retrofit	**35.45**	**84.42**	**393,223**
Projected Savings	**92**	**75**	**719,314**

The pre-condition data shown in the above table was developed by Kaeser Compressors based on measured data during February 2010, during an atypical production level, and adjusted upward for typical production levels.

The realization rates for ECM1 are shown below.

Realization Rate	Energy	Demand
Application	101%	96%
Duke	101%	91%

Note: the demand savings was evaluated based on the peak demand of the backup compressor, which is shown to run periodically. It is not know which compressor will be operating during the utility coincident peak, so the coincident demand savings are assumed to be equal to the non-coincident demand savings.

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
719,314	716,028	1.00	75	82	0.92	75	78	0.96

Site 19

[redacted]

- Ultrasonic Humidifiers -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
January 2012

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

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

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

INTRODUCTION

This report addresses Measurement and Verification (M&V) activities for the [redacted] custom program application, at the [redacted] facility in [redacted], Ohio, and presents the results of the investigation.

The Energy Conservation Measures (ECMs) include:

ECM-1 – Replace Steam Generators

- Replace two existing oversized 300 kW electric steam generators with two new smaller 250 kW electric HW boilers.

Note: ECM-1 has been put on hold and is not yet implemented.
It is not being verified at this time.

ECM-2 – Replace Steam Humidification with Ultrasonic

- Remove computer server rooms humidification loads from the steam generators and install four Humidifirst DT-60 ultrasonic humidifiers in the air handling unit.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are:

	Application Proposed Annual Savings (kWh)	Application Proposed Peak Savings (kW)	Duke Projected Savings (kWh)	Duke Projected Peak Savings (kW)
ECM-1 Boiler Replacement	354,400 [1]	0 [2]	None Noted	None Noted
ECM-2 Ultrasonic Humidifiers	361,388	0 [3]	None Noted	None Noted

Note 1: ECM-1 savings are not being verified at this time since the measure has not been implemented.
Note 2: No peak demand savings are expected; this ECM is effective for winter heating conditions only.
Note 3: No peak demand savings are expected; this ECM is effective for humidification conditions only.

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

- Annual energy savings (kWh)

- Peak demand savings (kW)

PROJECT CONTACTS

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Mike Harp	[redacted]
Customer Contact	[redacted]	[redacted]

SITE LOCATION

[redacted]

DATA PRODUCTS AND PROJECT OUTPUT

- Average humidification load shape (weather dependent)
- Model predicting pre/post kWh and kW as a function of outdoor temperature
- Annual energy savings
- kWh savings Realization Rate
- kW savings Realization Rate

Note: Utility coincident peak demand savings (kW) are expected to be zero. ECM-2 does not claim any peak demand savings.

M&V OPTION

IPMVP Option A

M&V IMPLEMENTATION SCHEDULE

- Only Post-installation data is available.
- Obtained sequence of operations for humidifiers.
- Installed temporary dataloggers to monitor humidifiers' energy usage and outdoor air conditions.
- From the collected data, evaluated post-retrofit energy usage of humidifiers and correlated with outdoor air conditions.
- Extrapolated collected energy usage performance to annual values using Cincinnati weather data.
- Estimated equivalent pre-retrofit annual energy usage using steam equivalent of humidifier performance.
- Evaluated the energy savings of the retrofit measure.

FIELD SURVEY POINTS

Survey data

- Nameplate data for the new humidifiers
- Sequence of operations for the humidifiers including temperature and humidity setpoints.
- Overall sequence of operation for the Air Handling Unit (AHU) in which the humidifiers are installed.
- AHU fan air flow capacity. Unit is constant air volume (CAV). Determine from Customer's records or EMS, as available.

One-time measurements

- Humidifier volts, amps and kW (4 units)
- Coincident datalogger readings (amps and kW)
- Outside air temperature (OAT) and humidity
- Date and time of measurements.

FIELD DATA LOGGING / EMS TRENDING

- **ECM-2**

  11. Installed ElitePro dataloggers to measure and record humidifiers' kWh at 5-minute intervals. Each humidifier was monitored individually.

  12. It was planned to record the following data in the customer's on-site energy management system (EMS). Trends were set up, but ultimately the data could not be delivered. A screen shot showing short-term temperature data was provided, but did not yield useful information.

      a. Air flow volume (CFM)
      b. Air dry-bulb temperature upstream of humidifiers
      c. Air humidity upstream of humidifiers
      d. Air dry-bulb temperature downstream of humidifiers
      e. Air humidity downstream of humidifiers
      f. Outside air dry-bulb temperature
      g. Outside air humidity.

  13. Trend for 3 weeks.

- **Outdoor Air**

  1. NOAA weather data was used, due to failure of the EMS to provide trend data.

Data Accuracy

Measurement	Sensor	Accuracy	Notes
kW, kWh	Dent ElitePro	±1%	
Current	Magnelab CT	±1%	Current being measured should be >10% of CT rating

Data Analysis

- **ECM-2 (Humidifiers)**

6. From communications with the customer, humidifiers are 277-Volts, 40 amp.
7. Converted time series data on logged equipment into average daily load shapes.
8. Regressed data into a temperature dependent load model. Form of the regression equation is:

$$kWh/day = a + b \times T_{avg}$$

where

kWh/day = daily energy consumption
T_{avg} = Daily average wet-bulb temperature

9. Applied equation above to TMY3 data processed into average wet-bulb or dewpoint temperature for each day of the year. Used correlation that gives the best fit. Determined total annual post-retrofit energy consumption.
10. Estimated total humidification load provided by humidifiers, based on psychrometric conditions (humidity ratio) upstream and downstream of humidifiers, as determined from temperature and humidity trended or logged data.
11. From humidifier logger kWh, estimated humidifier electric energy input per pound of water delivered.
12. Estimated total pre-retrofit steam load from the humidification load.
13. Estimated total pre-retrofit energy consumption of electric steam generators to provide the steam load.
14. Calculated the avoided cooling energy benefit resulting from ultrasonic water injection in lieu of steam injection.
15. Estimated total annual energy savings by subtracting post-retrofit energy consumption from pre-retrofit energy consumption, and adding cooling energy savings.

VERIFICATION AND QUALITY CONTROL

45. Visually inspected time series data for gaps
46. Compared readings to nameplate and spot-watt values to identify out of range data

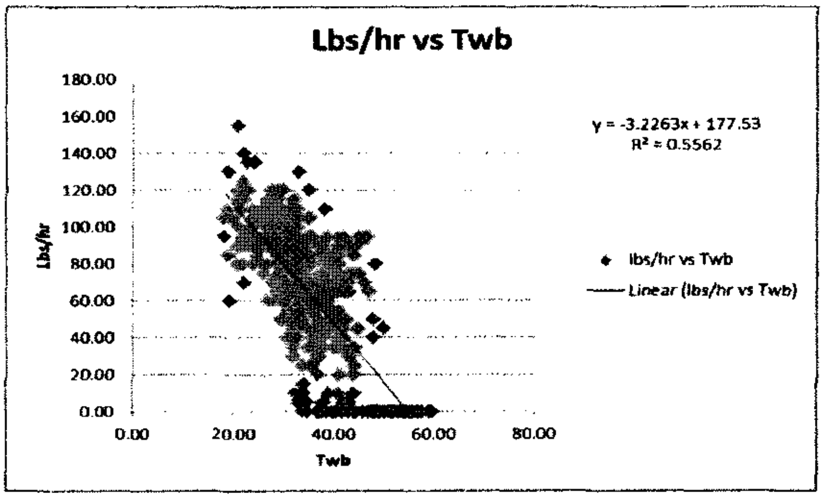
RECORDING AND DATA EXCHANGE FORMAT

39. ElitePro logger and weather station binary files
40. Excel spreadsheets

POST-DATA RESULTS

The post data results were based on two loggers deployed as shown in the logger table above. There are four Humidifirst Ultrasonic DT-60 humidifiers installed at a single air-handler (AHU2) serving the data center. Manufacturer's specifications state that humidifier can generate 60lbs/hr of moisture at 1.2 kW input. Since it was not possible to confirm these values with the desired airstream measurements, this specification was used to establish the humidification requirements. All four new humidifiers replace steam dispersion tubes with direct steam supplied by two electric boilers. Hourly weather data from the NOAA was used in place of EMS trend data since that data was not obtained. The pre-install proposed annual savings is 361,388 kWh.

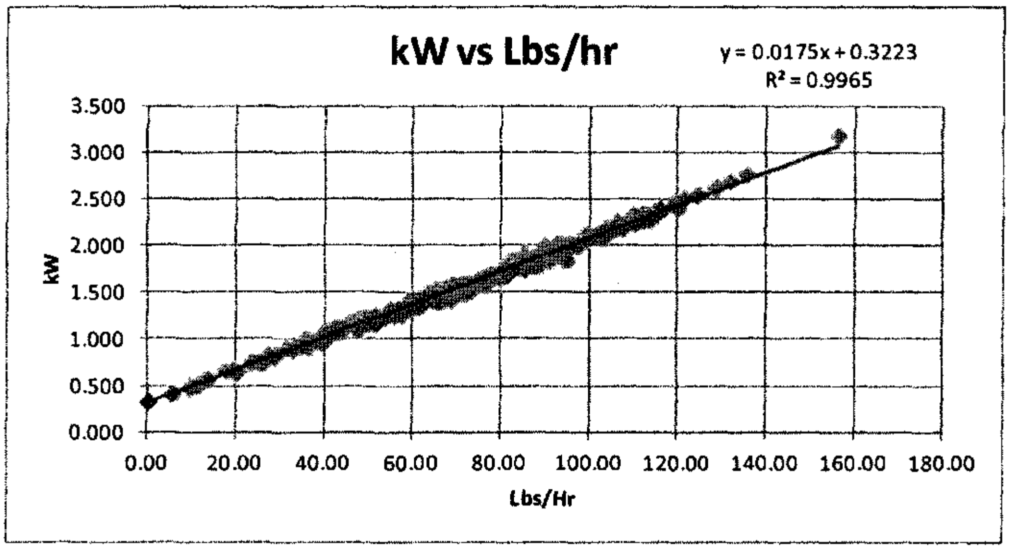
The following tables and graphs summarize the projected energy and demand savings resulting from the installation of the ultrasonic humidifiers. The projected annual savings based on post install logger data and hourly weather data is 113,766 kWh which includes the avoided cooling energy benefit of 26,748 kWh. Using TMY3 weather data, an hourly bin analysis was used to determine the space humidification load based on outdoor wet bulb temperature conditions. Using the ultrasonic humidifier manufacture data, weather data and logger power trends, the relationship between humidifier load (lbs/hr) and outdoor wet bulb temperature was established in graph below.



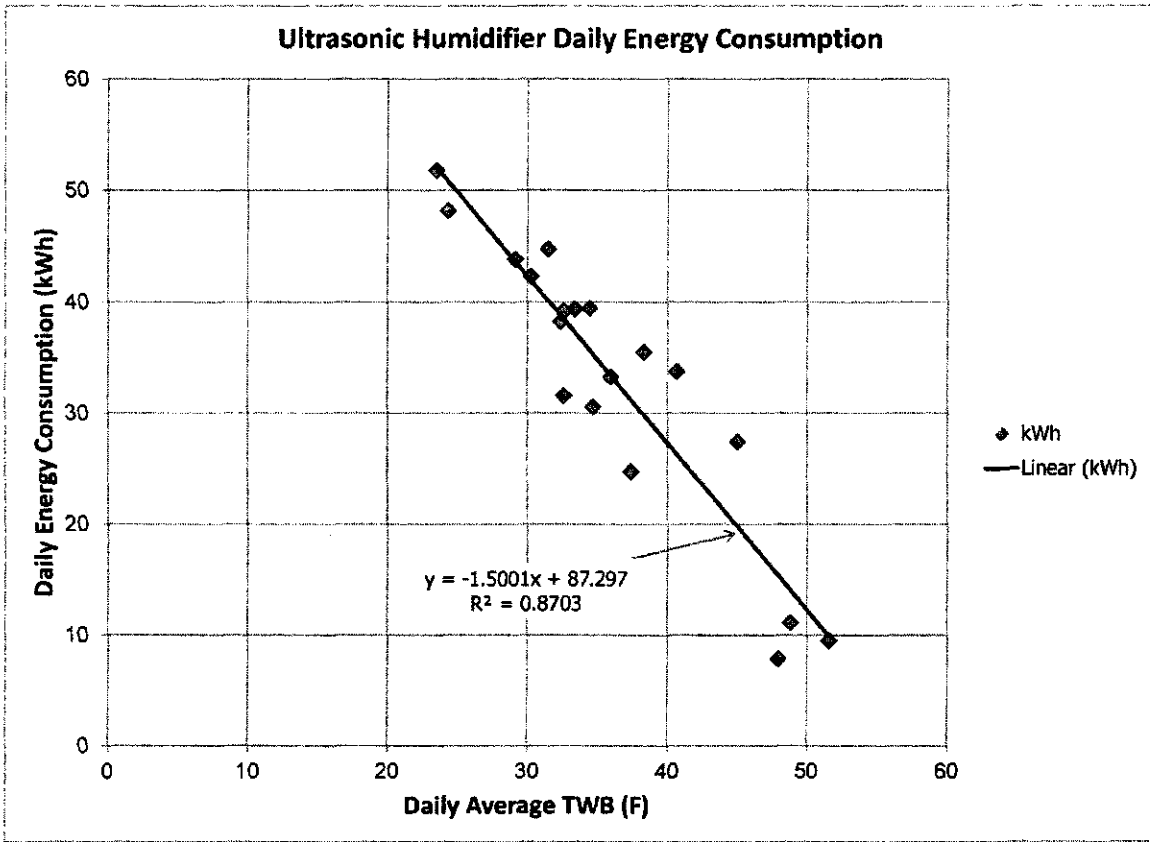
Using the linear regression equation above, the space humidity load (lbs/hr) is now a function of ambient wet bulb temperature conditions. The data show that humidification is not applied when the ambient wet bulb temperature is above 55°F. The table below summarizes the bin analysis based on wet bulb temperature conditions. The total possible operating bin hours with wet bulb temperature below 55°F is 5231 hours.

		Humidification Load		Electric Steam Humidifier	New Humidifier				SAVINGS		
TwbF	Bin Hours	Space Lbs/hr Required	Total Lbs	Elec steam (Base) kWh	Avg kW	Total kWh	Adiabatic cooling Effect (BTU)	Avoided Cooling Benefit (kWh)	Humidification Savings (kWh)	Savings including Cooling (kWh)	Demand Savings (kW)
0	2	177.5	355	118	3.43	7	344,408	-34	111	145	72
2	10	171.1	1,711	567	3.32	33	1,659,451	-162	534	696	70
4	10	164.6	1,646	546	3.20	32	1,596,861	-156	514	670	67
6	22	158.2	3,480	1,154	3.09	68	3,375,395	-330	1,086	1,416	64
8	22	151.7	3,338	1,107	2.98	66	3,237,696	-316	1,042	1,358	62
10	37	145.3	5,375	1,783	2.86	106	5,213,633	-509	1,677	2,186	59
12	24	138.8	3,332	1,105	2.75	66	3,231,599	-316	1,039	1,355	56
14	41	132.4	5,427	1,800	2.64	108	5,264,029	-514	1,692	2,206	54
16	52	125.9	6,547	2,172	2.53	131	6,350,860	-620	2,040	2,660	51
18	77	119.5	9,198	3,051	2.41	186	8,922,213	-871	2,865	3,736	49
20	108	113.0	12,204	4,048	2.30	248	11,838,299	-1,156	3,799	4,956	46
22	186	106.6	19,819	6,573	2.19	407	19,224,004	-1,878	6,167	8,044	43
24	171	100.1	17,117	5,677	2.07	355	16,603,388	-1,622	5,323	6,944	41
26	170	93.6	15,920	5,280	1.96	333	15,442,258	-1,508	4,947	6,455	38
28	223	87.2	19,444	6,449	1.85	412	18,860,848	-1,842	6,037	7,879	35
30	210	80.7	16,956	5,624	1.74	364	16,446,942	-1,606	5,259	6,866	33
32	276	74.3	20,504	6,800	1.62	448	19,888,490	-1,942	6,353	8,295	30
34	264	67.8	17,909	5,940	1.51	398	17,371,392	-1,697	5,541	7,238	27
36	291	61.4	17,863	5,925	1.40	406	17,326,636	-1,692	5,518	7,210	25
38	225	54.9	12,359	4,099	1.28	289	11,988,603	-1,171	3,810	4,981	22
40	321	48.5	15,561	5,161	1.17	376	15,094,595	-1,474	4,786	6,260	20
42	367	42.0	15,423	5,115	1.06	388	14,960,622	-1,461	4,727	6,188	17
44	363	35.6	12,913	4,283	0.94	343	12,525,539	-1,223	3,940	5,163	14
46	346	29.1	10,076	3,342	0.83	288	9,773,322	-955	3,054	4,008	12
48	325	22.7	7,367	2,443	0.72	234	7,145,961	-698	2,210	2,908	9
50	371	16.2	6,016	1,995	0.61	225	5,835,292	-570	1,770	2,340	6
52	327	9.8	3,192	1,059	0.49	161	3,096,536	-302	898	1,200	4
54	390	3.3	1,291	428	0.38	148	1,252,097	-122	280	402	1
56	314	0	0	0	0	0	0	0	0	0	0
58	311	0	0	0	0	0	0	0	0	0	0
60	251	0	0	0	0	0	0	0	0	0	0
TOTAL	6107		282,341	93,645		6,627	273,870,967	-26,748	87,018	113,766	72

The graph below is a regression of the ultrasonic kW vs. Lbs/hr humidification load. This regression was used for the power required to generate the humidifier load.



The graph below summarizes the daily energy consumption of the ultrasonic humidifier based on outdoor wet bulb temperature during the trend period. Three weeks of trend data was recorded during the month of December, 2011.



The base case electric boiler steam humidifier (kWh/Lbs) is based on the post-retrofit humidification load and the enthalpy difference between liquid water at 50°F and steam at 212°F. (0.3316 kWh/lb of water).

Energy savings calculated for the Ultrasonic Humidifier along with expected savings from the application are shown in the Table below:

Post Data Projected Annual Savings (kWh)	Application Proposed Annual Savings (kWh)
113,766	361,388

The realization rate for the Ultrasonic Humidifier is shown in the following table. The energy savings do not meet the projected savings. No peak demand savings are expected since all of the savings occur during the winter months.

Realization Rate	Energy	Demand
Ultrasonic Humidifier	32%	N/A

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
113,766	217,522	0.52	0	74	0.00	0	0	

Site 20

[redacted]

- Digital Controls for Existing Water Source Heat Pumps -

M&V Results Summary

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
January 2012

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

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

INTRODUCTION

This report addresses Measurement and Verification (M&V) activities for the [redacted] facility custom program application. The application and supporting documents describe the project as the installation of a web-based Energy Management System (EMS) and other work, including the following Energy Conservation Measures (ECMs):

ECM-1 – EMS Control of 250 Heat Pumps

- The new EMS provides automated control and central monitoring of 250 existing water-source heat pumps. Prior to this control, the heat pumps were available to operate continuously. With the EMS, they will be operated only from 7:00 AM to 7:00 PM (12 hr/day) on Monday through Friday, plus from 7:00 AM to 1:00 PM (6 hr/day) on Saturday. (Note: In the application this ECM is named "Unoccupied Scheduling.")

ECM-2 – Thermostat Relocation and Calibration

- Existing thermostats were relocated from the return air grilles into the occupied spaces they are monitoring. The supporting documents estimate the space temperatures were offset by two degrees from the desired temperatures with the thermostats in their previous locations.

ECM-3 – Condenser Water Temperature Reset

- The new EMS allows condenser water setpoint temperature reset control to be implemented.

DISCUSSION

ECM-1. Each heat pump has its own small water-circulation pump. The electric energy required to operate the pumps was determined in the M&V investigation to account for the circulation pump energy properly.

ECM-2. *An incentive payment was not approved by Duke Energy for this ECM; therefore, no M&V investigation is required.*

ECM-3. *An incentive payment was not approved by Duke Energy for this ECM; therefore, no M&V investigation is required.*

Additional Equipment on EMS Control. In addition to the 250 heat pumps, the proposed EMS was also to control and/or monitor additional HVAC and central plant equipment, including:

- The central cooling tower

- Two cooling tower pumps
- Two heat pump loop pumps
- The loop heat exchanger
- Three rooftop make-up air units
- Two exhaust fans
- Two hot-water boilers
- The CO system
- A weather station

No savings were claimed in the application for the EMS control of this equipment. However, to the extent possible, differences in the pre-EMS and post-EMS controls were taken into account in the building energy models.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are presented in the following table. The original total savings are shown, as well as the savings for ECM-1 only, since it was the only ECM approved for an incentive. Finally, a correction is presented based on recalculating the number of annual operating hours; the original number of hours included one hour of operation on Saturday instead of the actual six hours.

Figure 34: Projected Savings Comparisons

	Annual Energy Savings (kWh)	Peak Demand Savings (kW)	Annual Electric Energy Cost Savings ($)
Application Proposed (6-26-2009), ECMs 1 - 3	700,097	31.9	$ 54,976
Application Proposed (6-26-2009), ECM-1 Only	389,930	0.0	$ 32,007
M&V Review Correction to Calculation, ECM-1 Only	371,788	0.0	$ 30,518

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

- Annual gross energy savings (kWh)
- kWh savings Realization Rate
- Peak demand savings (kW)
- kW savings Realization Rate

Note: Peak demand savings (kW) were expected to be zero. ECM-1 does not claim any peak demand savings.

PROJECT CONTACTS

The following individuals have helped in coordination of M&V activities for this project.

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Roshena Ham	[redacted]
Customer Contact	[redacted]	[redacted]

SITE LOCATION

Site	Address
[redacted]	[redacted]

DATA PRODUCTS AND PROJECT OUTPUT

- Model predicting pre/post energy consumption in kWh as a function of outdoor temperature
- Annual energy savings

M&V OPTION

IPMVP Option D – Calibrated Simulation

FIELD SURVEY POINTS

Personnel Interview:

- Interviewed the facility contact regarding:
  - Information required for filling out the Survey-IT forms.
  - Obtaining a copy of the heat pump manufacturer's product information.

Survey Data for all Trended/Monitored Equipment (Post-Installation):

Nameplate Data: *For a representative sample of the 250 existing heat pumps, nameplate and trended data for 16 heat pumps was obtained.* For the 16 heat pumps listed in the table, "Heat Pumps Selected for Trending / Monitoring" in the EMS Trending / Field Datalogging section below, the following information was collected.

- Heat pump tag number
- Heat pump manufacturer, model number and serial number
- Nominal cooling capacity (Btu/hr and tons)
- Nominal heating capacity (Btu/hr)
- Heat pump compressor nameplate volts and amps
- Heat pump evaporator fan nameplate volts and amps
- Heat pump fan air volume capacity (CFM)
- Circulation pump manufacturer and model number
- Circulation pump nameplate volts and amps
- Discharge air temperatures in cooling and heating modes
- Return air temperature
- Discharge water temperature
- Return water temperature

Survey-IT Data: *All other information was recorded in the AEC Survey-IT data form.* This form includes detailed information about all building systems, including:

- Building wall, window and floor area
- Space types and uses, HVAC zoning
- Occupancy schedules and operations (daily, weekly, annually, holidays)
- Lighting loads and schedules
- Equipment loads and schedules
- Temperature setpoints, Energy Management Systems
- HVAC system controls
- Pressurization fan and condenser water pump operation
- Shading and blinds
- Chillers, cooling towers, boilers, central air handlers, and water heating
- Building envelope, including windows, walls, areas, and construction types

Utility Data: Actual building utility energy consumption and electric demand history for a minimum of 12 months preceding the EMS installation. However, the information received was not complete and could not be used for calibration.

EMS TRENDING

For the 16 heat pumps listed in the table, "Heat Pumps Selected for Trending / Monitoring" one week of trended data was downloaded from the new EMS as described below.

- Heat pump on-off indication.
- Discharge air temperature (DAT).
- Data was recorded in approximately 7-minute intervals.

These units were selected using a "systematic sampling with random start" approach. One unit could not be trended because it had an invalid unit number. Another unit in close proximity having the same capacity was substituted.

Figure 35: Heat Pumps Selected for Trending / Monitoring

Sequence # 1 - 250	Floor	TAG No.	Capacity (TONS)	Tag No. of Substituted Unit (if required)	Reason for Substitution (if required)
6	1	HP1-2.5-6	2.5	--	
22	1	HP1-2.0-22	2	--	
37	1	HP1-3.0-37	3	HP1-2.5-36	No "37" Found
53	2	HP2-2.0-13	2	--	
69	2	HP2-2.0-29	2	--	
84	3	HP3-2.0-4	2	--	
100	3	HP3-3.0-20	3	--	
115	3	HP3-3.0-35	3	--	
131	4	HP4-2.5-9	2.5	--	
147	4	HP4-2.0-25	2	--	
162	4	HP4-2.0-40	2	--	
178	5	HP5-3.0-14	3	--	
194	5	HP5-3.0-30	3	--	
209	6	HP6-2.0-3	2	--	
225	6	HP6-1.0-19	1.5	--	
240	6	HP6-2.5-34	2.5	--	

Verification and Quality Control

47. Compared trend data to nameplate and one-time measurements; no invalid or out of range data was identified.
48. Visually inspected trend data for consistent operation.
49. Verified pre-retrofit and post-retrofit equipment specifications and quantities are consistent with the application.

Recording and Data Exchange Format

- Heat pump nameplate and one-time measurement data collection forms.
- Post-installation Survey-IT Form and Notes.
- Energy Management System data files, if collected.
- Survey-IT and Model-IT database files.
- DOE-2 energy model data files.
- Generated Excel spreadsheets.

Data Analysis

13. Entered all data from the Survey-IT forms into the Survey-IT software, making any adjustments needed to reflect pre-EMS conditions.
14. Ran Model-IT to determine pre-EMS annual energy consumption.
15. Plotted the trended heat pump operating data to determine actual post-retrofit operating schedules by day-type. Reviewed data for operation during unoccupied hours.
16. Adjusted the simulation model for post-retrofit conditions by entering post-retrofit changes in sequence of operations for the new heat pump operating schedules as determined from trended data.
17. Ran the model to determine post-EMS annual energy consumption and average peak kW demand during the on-peak period.
18. Compared pre-retrofit annual energy consumption with the post-retrofit consumption to determine annual energy savings.
19. Determined the energy savings Realization Rate by dividing the annual energy savings found in the step above to the savings estimated in the application.

20. Compared pre-retrofit average peak kW demand with the post-retrofit demand to determine annual demand savings. *Note: No demand savings were claimed in the application for this project.*

Results Discussion

General Building Energy Use

All post-retrofit data were entered into Survey-IT and run through the DOE2 energy simulation software to determine annual energy consumption. A baseline energy model was then created by converting the building condition to an appropriate approximation of the facility's pre-EMS system operation. Comparing both results then determined the annual energy savings. The results for both cases are shown for comparison below.

Value	Baseline	As-built	Savings
Peak demand (kW)	1,423	1,522	-99
Annual consumption (kWh)	5,301,338	4,830,958	470,380

Figure 36: Energy Model Analysis Results

Value	Application	DOE-2 Model
Peak demand (kW)	0	-99
Annual consumption (kWh)	371,788	470,380

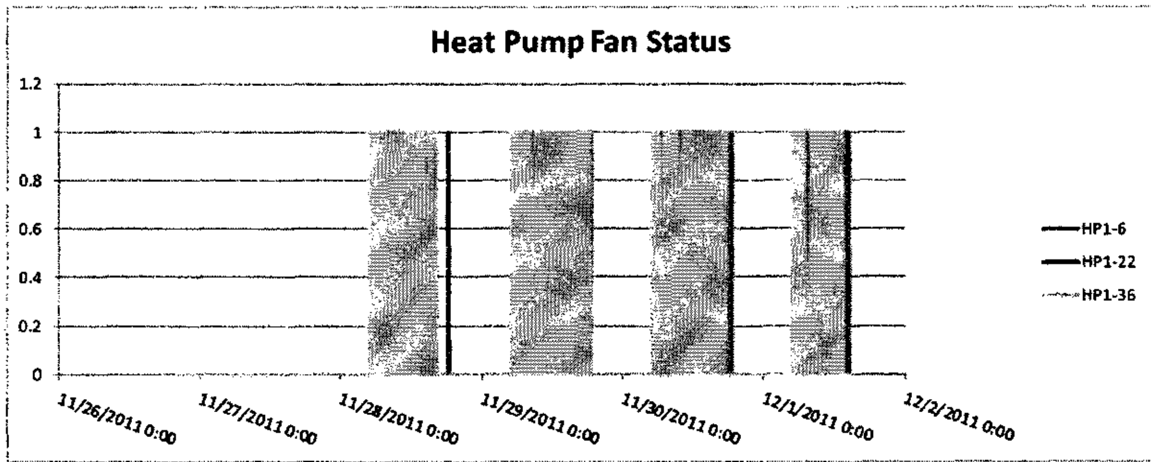
Figure 37: Comparison of Application Savings vs. Energy Model Results

Within the general building operation, the calculation also included verification of the controls ECM as it applied to each of the heat pumps and related schedule effects units. Analysis for each measure was performed as described below to input accurate current operation of building systems.

ECM-1: EMS Control of 250 Facility Heat Pumps

Trend data was assumed to be the most accurate representation of equipment operation across each floor, more so than schedules recorded through interviews or set up within the new Building Automation System (BAS). This allows a better understanding of the actual runtime to maintain setpoints in the spaces. Graphs of the units trended on each floor are included here with some comment as necessary.

First Floor



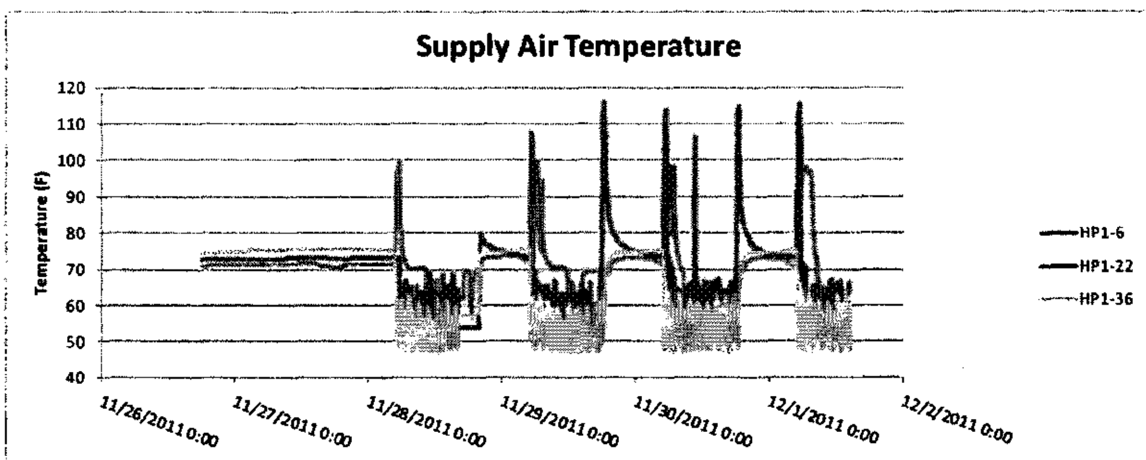
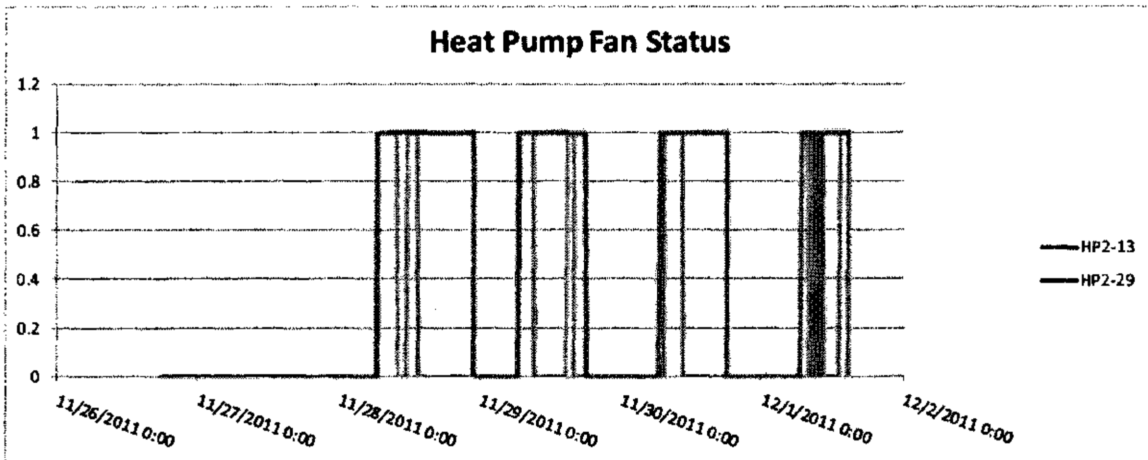


Figure 38: 1st Floor Heat Pump Units

Generally for these units, each unit operates for a majority of the daytime occupied schedule. Based on the temperatures of the supply air they also were predominantly cooling at 55°F with the occasional warm-up spike in the early morning hours each day.

Second Floor



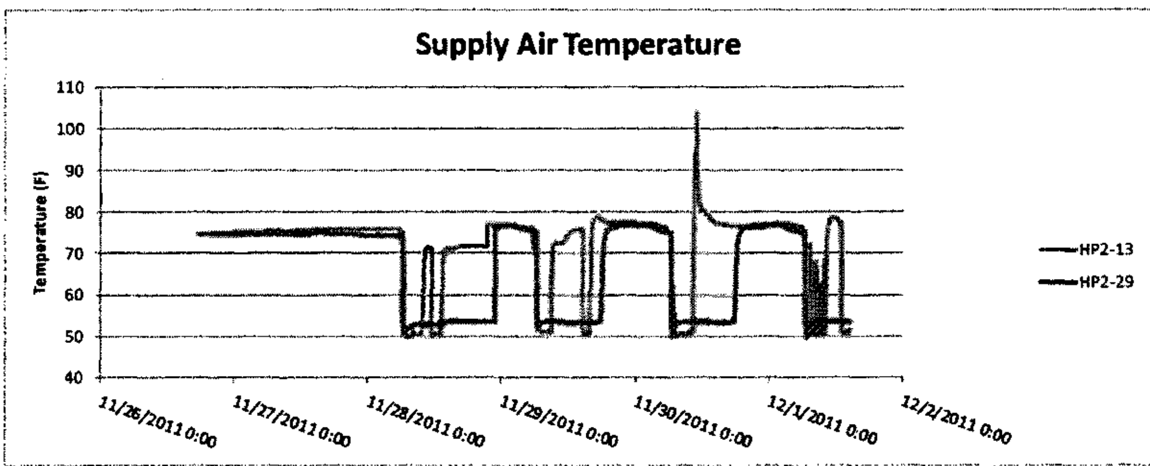
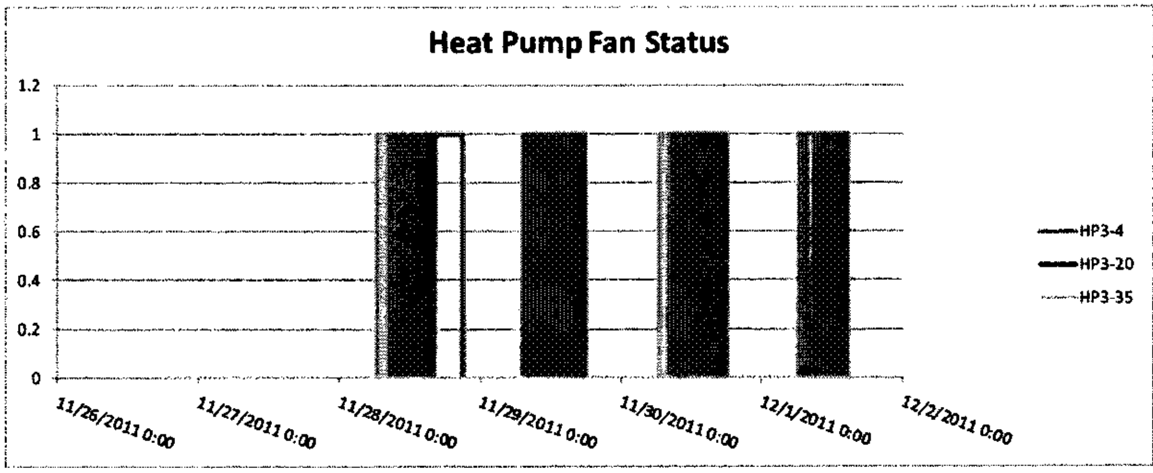


Figure 39: 2nd Floor Heat Pump Units

In contrast to the first floor, these units did not operate as often to condition the spaces but they remained in cooling mode once the fan came on. There is also little drift during the unoccupied times when the fan is shown as off. Assuming that room air can migrate back to the supply side of the heat pump this may be an adequate measure of the space temperatures during this time also.

Third Floor



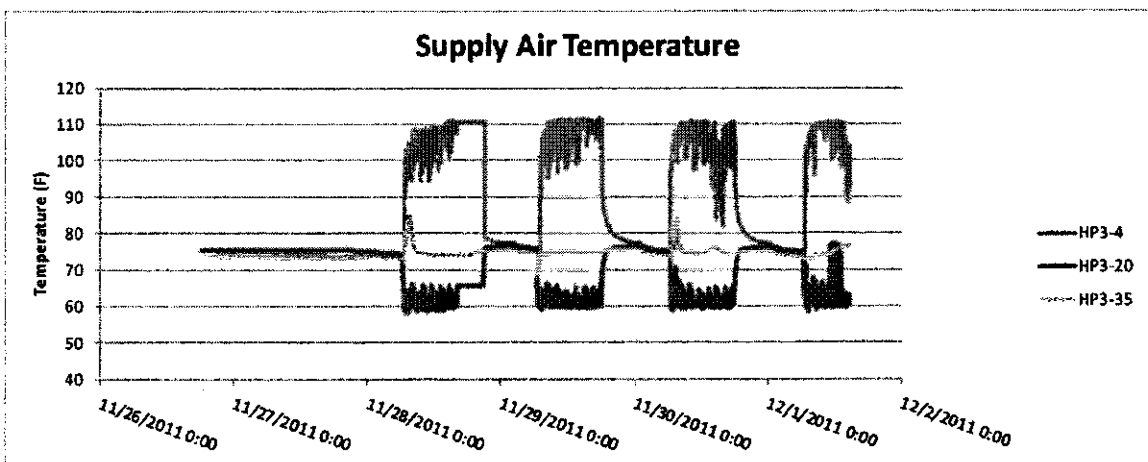
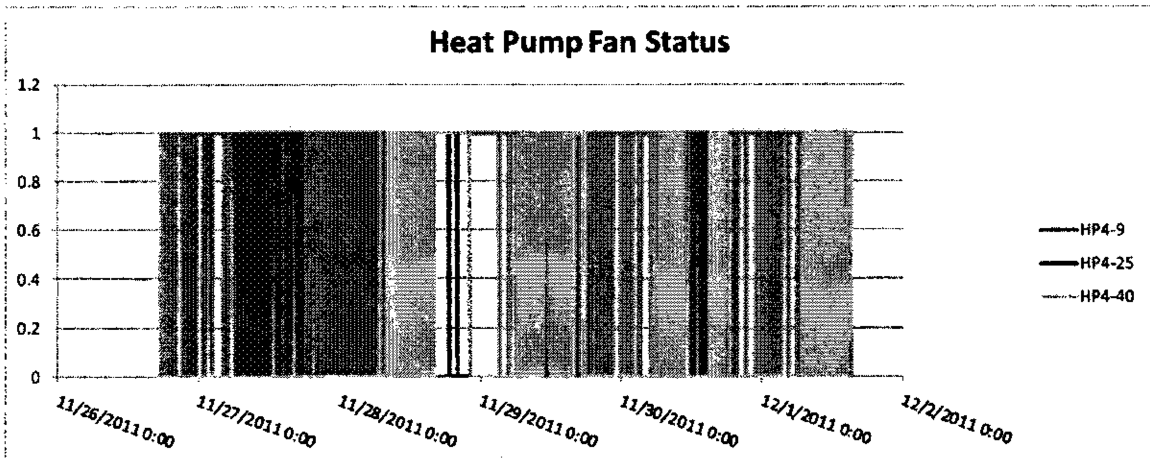


Figure 40: 3rd Floor Heat Pump Units

Floor three is very similar to the first in terms of organization of on/off schedules. However, one unit (HP3-4) does operate in heating mode for the entire day. This difference may be due to the effects of building orientation and hint at location of different heat pumps meeting different load profiles.

Fourth Floor



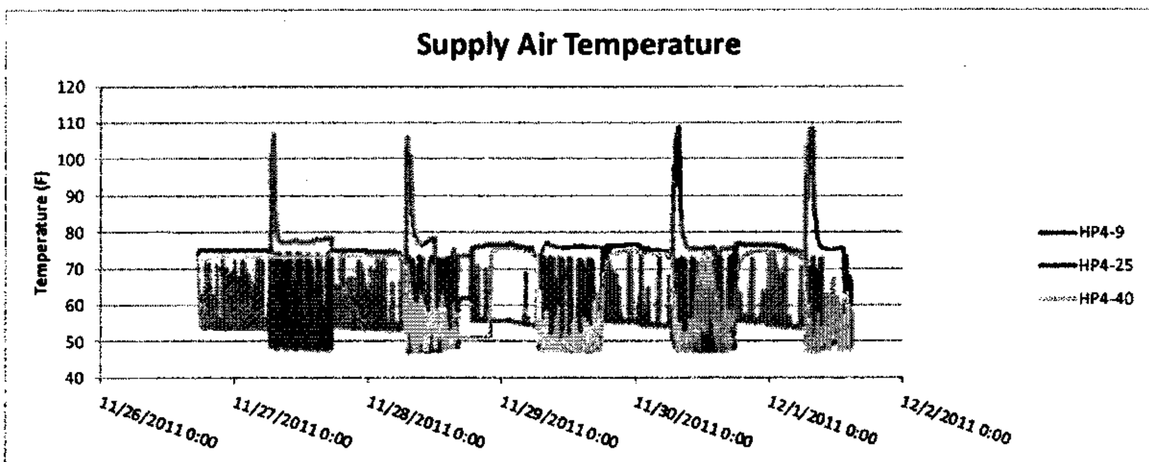
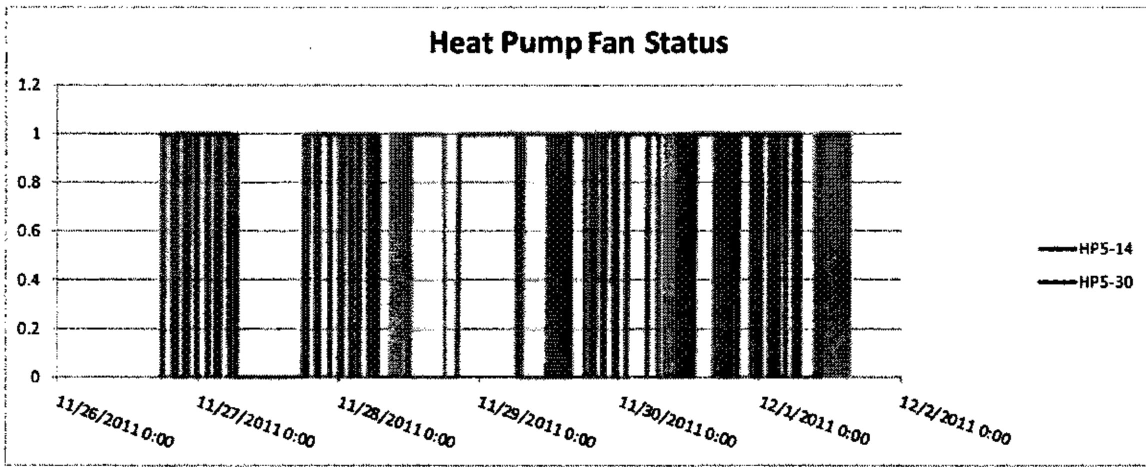


Figure 41: 4th Floor Heat Pump Units

After the first floors of sample units operating so cleanly, these heat pumps had a much more varied operating schedule between them. HP4-9 primarily cooled its zone during unoccupied hours and also has a brief morning warm up period while two of the three also cooled the air almost 10 degrees lower (near 45°F) than the other units thus far, which have only been approaching 55°F.

Fifth Floor



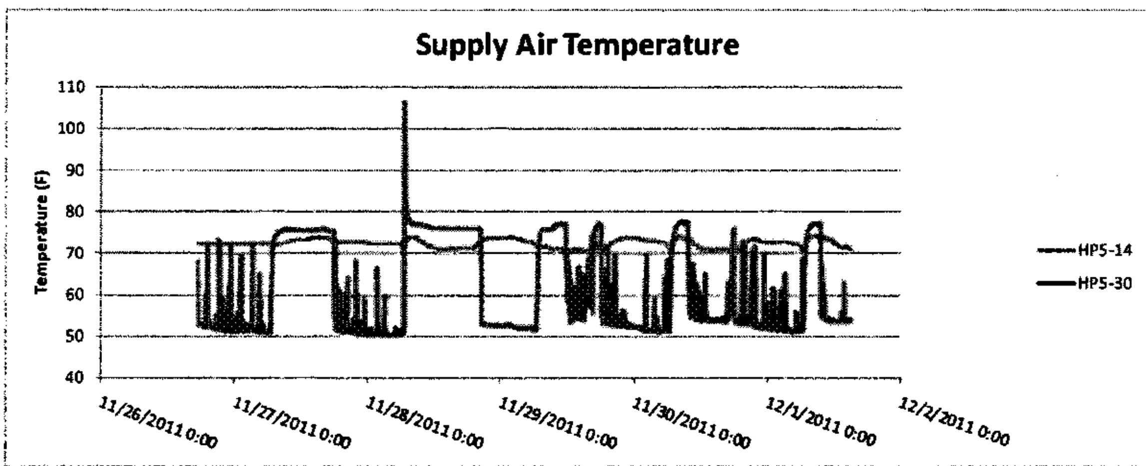
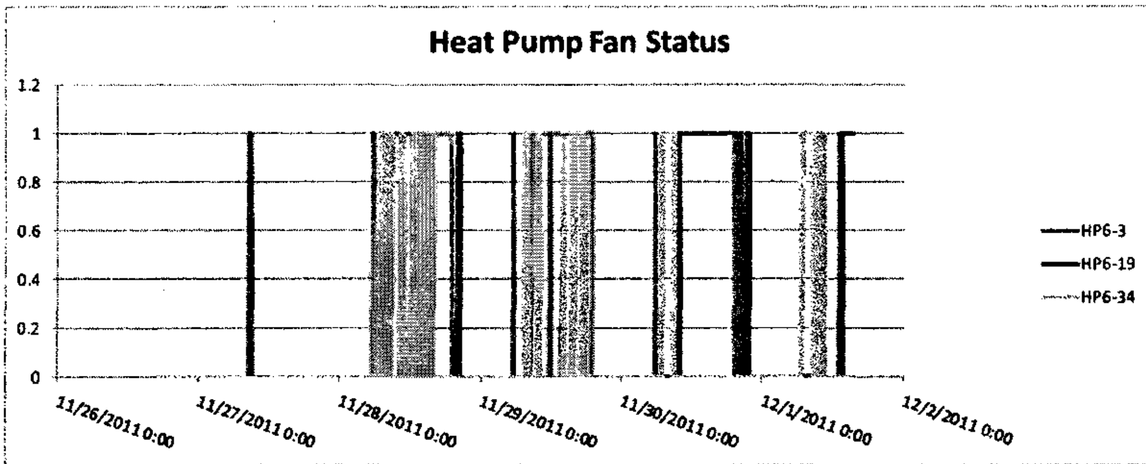


Figure 42: 5th Floor Heat Pump Units

The two units sampled on this floor seem to operate less frequently than those of the 4th Floor, though they do operate on relatively random schedules and through typically unoccupied periods of the day.

These two floors (4th and 5th) are the only two of the set that operate during the 'light' and 'closed' days of Saturday the 26th and Sunday the 27th.

Sixth Floor



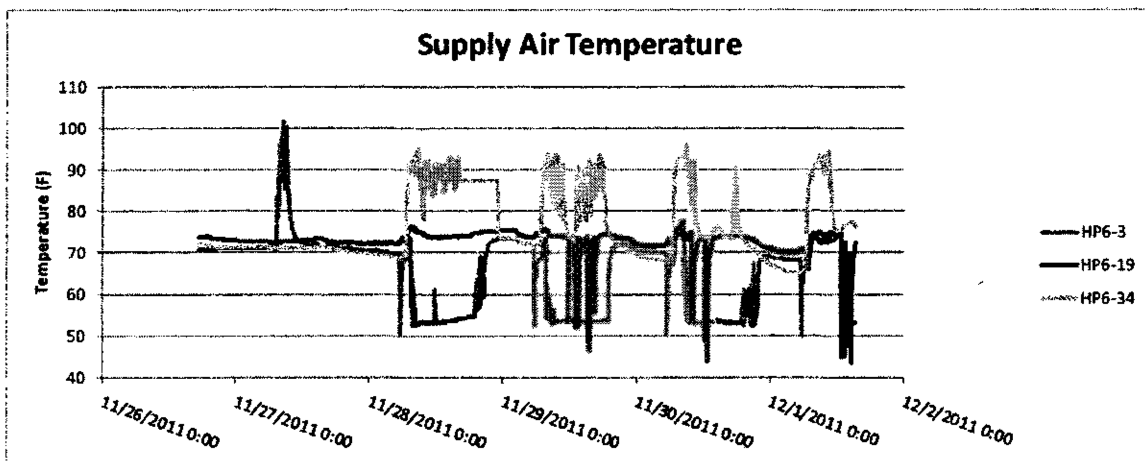


Figure 43: 6th Floor Heat Pump Units

These units operate fairly infrequently. There is a mix of heating and cooling again, though that may be due to varied loads through different parts of the building.

Important Notes:

- In late November there should be less cooling necessary than is being revealed in the 16 limited heat pump trends collected. Some of these units may be located in spaces with large internal loads, but the quality of the Facility Drawing images made it difficult to determine areas served by each of the trended boxes.
- Trend data only included a fan start/stop log and the supply air temperature. This supply air temperature was then assumed to approximate the space temperature when the

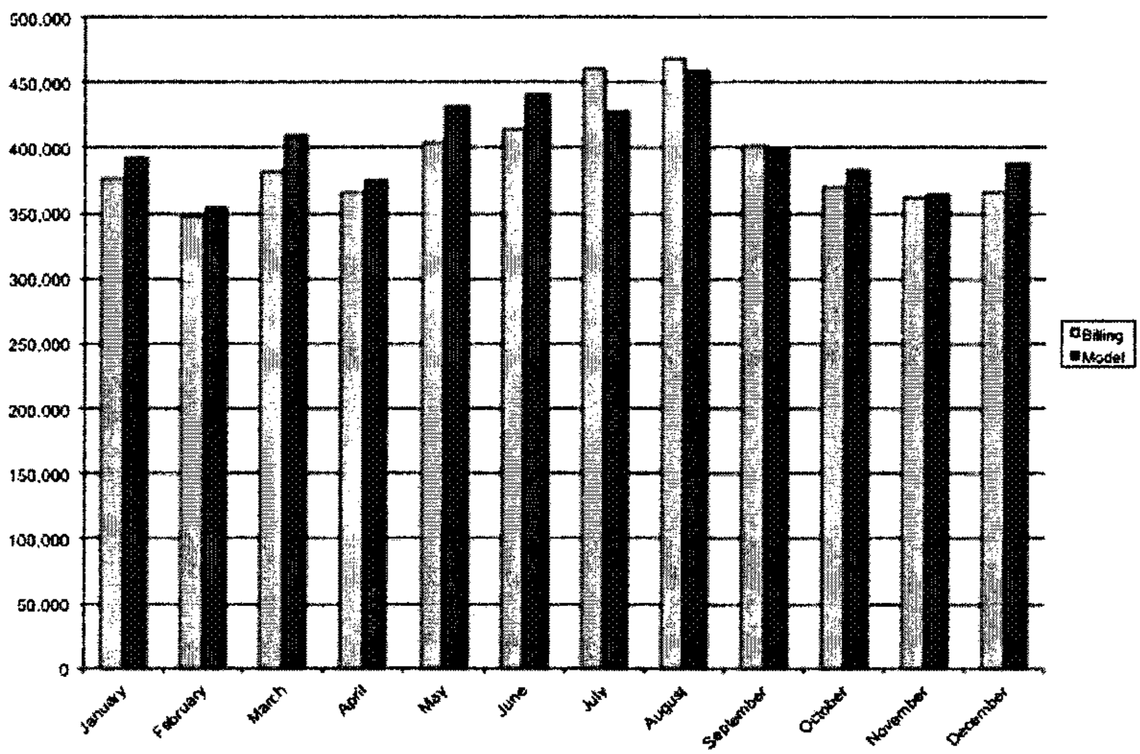
heat pump fan was off and air could stagnate at the unit. Using the supply air temperature sensor as a proxy for zone temperature provided information only during periods of non-operation (unoccupied periods). There was no outdoor air temperature data collected, as mentioned above under "EMS Trending". Data was also only collected for about one week instead of the recommended three.

Below is a Table of the variations in assumptions used in each case of the model. Some changes are noted on a per-floor basis due to the variation in schedules (predominantly) that each floor's sample of trended heat pumps operated by, and seen in the graphs above.

Model		
Category	*Baseline*	*ECM---1*
Supply Air Temp. Control	Zone Thermostats	BAS Setpoints
Occ. Heat Setpoint	Zone level	70
Occ. Cool Setpoint	Zone level	73
Unocc. Heat Setpoint	Zone level	60
Unocc. Cool Setpoint	Zone level	85
Zone 1		
Fan Schedule (Full---day)	Always Available	5am---5pm M---
Fan Schedule (Partial---day)	Always Available	Off
Min SAT (Floor 1)	50	50
Nighttime Fan Control	Cycle on Call	Off
Zone 2		
Fan Schedule (Full---day)	Always Available	6am---6pm M---
Fan Schedule (Partial---day)	Always Available	Off
Min SAT (Floor 2)	50	50
Nighttime Fan Control	Cycle on Call	Off
Zone 3---5		
Fan Schedule (Full---day)	Always Available	3am---11pm M---
Fan Schedule (Partial---day)	Always Available	3am---11pm S---
Min SAT (Floors 3---5)	60	60
Nighttime Fan Control	Cycle on Call	Off
Zone 6		
Fan Schedule (Full---day)	Always Available	7am---3pm M---
Fan Schedule (Partial---day)	Always Available	Off
Min SAT (Floor 6)	55	55
Nighttime Fan Control	Cycle on Call	Off

Model Calibration

Once the inputs were defined, as-built model was calibrated to billing data. A comparison of the simulated monthly kWh from the calibrated model and the monthly utility bills is shown below:



The calibration statistics are summarized below. Note, the calibration statistics are better than the targets established by ASHRAE Guildeline 14 - Measurement of Energy and Demand Savings.

Parameter	Calibration Result	ASHRAE Guideline 14 Target
RMS Error	0.41%	+/- 15%
Mean Bias Error	-2.3%	+/- 5%
Maximum monthly deviation	-7.7%	Not addressed

Savings Verification and Realization Rate:

Design and Post-construction information is compared to obtain annual kWh and kW savings for the new facility. Once the savings are calculated, the realization rate is determined by the following formula:

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

It is noteworthy that the savings are calculated from the output of the Survey-IT whole-building energy models, not just estimates of heat pump energy usage. Negative demand savings are due to additional "pick-up" load from the heat pump units when they return from nighttime to daytime operation.

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
470,380	463,752	1.01	-99	106	-0.94	-52	32	-1.63

Site 21

[redacted]

Lighting Replacement

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
December 2011
Version 1.0

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

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

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

Introduction

This plan addresses M&V activities for new exterior lighting fixtures at the [redacted].

The net effect will be a reduction in power consumption by the lighting fixtures.

The measures include:

ECM-1 – Area Lighting

ECM-1 involves replacing (145) existing 400w HID fixtures with 205w Ceramic Metal Halide lamps and Ballasts.

Goals and Objectives

The projected savings goals identified in the application are:

Application Proposed Annual savings (kWh)	Application Proposed Peak Savings (kW)	Duke Projected Savings (kWh)	Duke Projected Peak Savings (kW)
132,736	30	116,870	27

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

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

Project Contacts

Approval has not yet been granted from the Duke Energy contacts listed below to plan and schedule the site visit with the Customer.

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Wes Needham	[redacted]
Customer Contact	[redacted]	[redacted]

Site Locations/ECM's

Address	Area

[redacted]	80,000

DATA PRODUCTS AND PROJECT OUTPUT

- Pre and Post retrofit survey of lighting fixtures
- Pre and Post retrofit time series data on logged equipment to be converted into average load shapes by day type
- Summer peak demand savings
- Coincident peak demand savings
- Annual Energy Savings

M&V OPTION

IPMVP Option A

M&V IMPLEMENTATION SCHEDULE

- The monitoring period included both weekday and weekend periods.

FIELD SURVEY POINTS

Pre and Post – installation

The following data was collected for all equipment logged:

- Lighting survey
    - Fixture Type
    - Fixture Count
    - Fixture wattage
    - Current lighting on/off scheduling

- Pre retrofit survey was conducted before the customer performed the lighting retrofit.
- The lighting load connected to the circuit was spot measured by measuring the kW load and current of the circuit during both the pre-retrofit and post retrofit survey.
- Lighting control settings were noted and recorded
- Verified that all existing fixture specifications and quantities are consistent with the application.
- Verified that all pre (existing) fixtures were removed

- Verified that all post (new) fixture specifications and quantities are consistent with the application
- Determined what holidays the building observes over the year

One-time measurements for all equipment logged (to establish ratio of kW/amp and simultaneous logger amp readings) were taken

- Lighting circuits volts, amps, kW and power factor

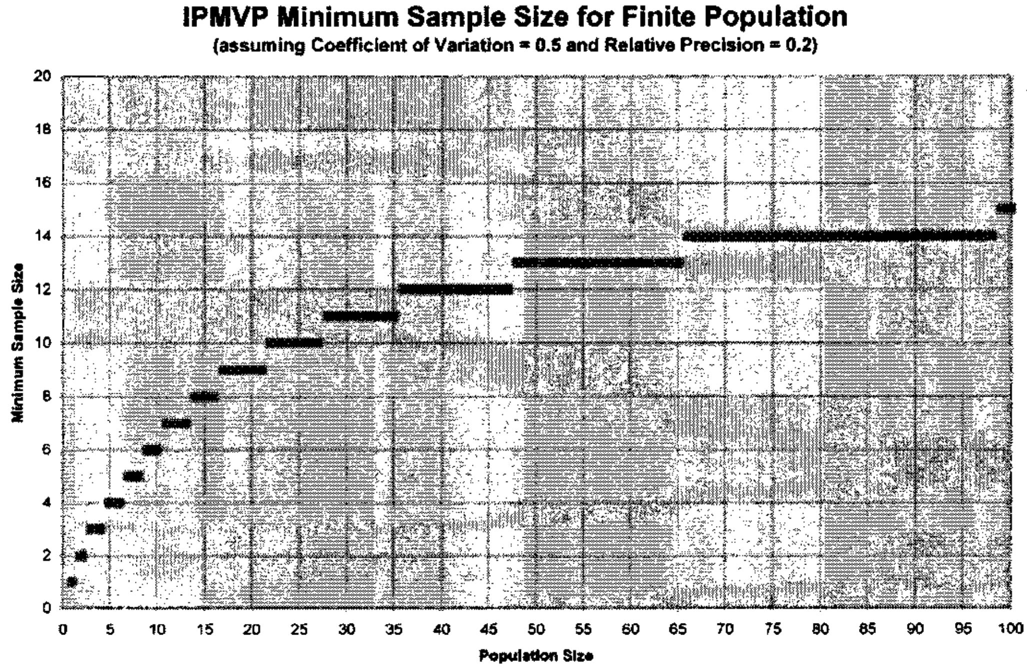
.DATA ACCURACY

Measurement	Sensor	Accuracy	Notes
Spot Watt	Fluke Meter	±1%	
Current	Magnelab CT	±1%	> 10% of rating

FIELD DATA LOGGING

- **ECM-1**

14. Deployed dataloggers during pre survey to measure operating hours
    a. Installed one lighting logger at each lighting control zone.
15. Loggers were set up for 5 minute instantaneous readings and allowed to operate for a period of three weeks.



LOGGER TABLE

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

Hobo U-10 or Energy Logger Pro (4CH)	20 amp CT's
1	4

DATA ANALYSIS

21. Converted time series data on logged equipment into pre/post average load shapes by day-type.
22. Estimated peak demand savings by subtracting pre/post time series data. Calculated coincident peak savings by subtracting pre/post kW values at the grid peak at 4pm local time.

- **ECM-1**

12. Converted time series data on logged equipment into pre/post average load shapes by day type.

13. The Pre & Post annual kWh was calculated using the following equations:

$$\frac{kWh}{year} = \sum\left[No._{Fixtures} * kW_{Fixture} * \frac{runhours}{day}\right]$$

Note: Run hours/day will be determined daily from sunrise/sunset times for Cincinnati, Ohio for the entire year of 2011.

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

$$\frac{kWh_{saved}}{year} = \frac{kWh_{pre}}{year} - \frac{kWh_{post}}{year}$$

15. The Pre & Post peak kW was calculated using the following equation:

$$kW_{Peak} = Max\left[\frac{kWh / day}{RunHrs / day}\right]$$

Verification and Quality Control

50. Visually inspected time series data for gaps
51. Compared readings to mfg. catalog data and spot-watt values; identified out of range data

Recording and Data Exchange Format

41. Hobo logger binary files
42. Excel spreadsheets

Results Summary

The following results account for benefits of the lighting replacement. These results are based on the following assumptions:

- The lighting duration is based on the period from sunset to sunrise, according to published sunrise-sunset times for Cincinnati, OH, reduced by 0.37 hours due to an average difference between the measured lighting duration and the sunset-sunrise duration. See Figure 44, for an illustration of the difference.
- The pre-retrofit demand of each light fixture is 434 watts, from the application.
- The post-retrofit electrical demand of each light fixture is 277 watts, which was the average per-fixture demand during the monitoring period. This deviates from the 225 watt per fixture input power listed in the application.

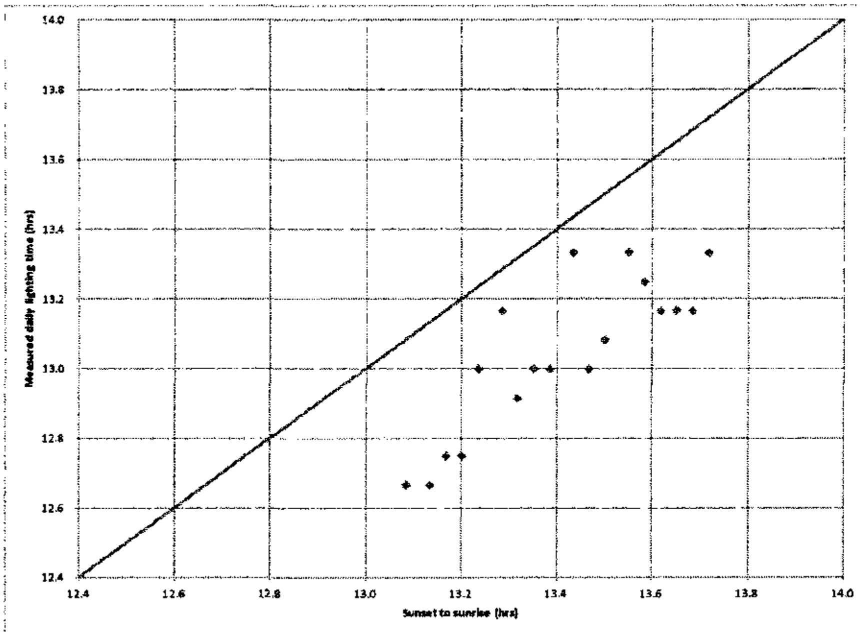


Figure 44. Comparison of measured daily lighting duration and sunset to sunrise duration during monitoring period

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

Table 1. Energy savings and realization rate

[redacted] kWh Totals		
	Pre (kWh) 262,549	Post (kWh) 167,442
Total Savings (kWh)	95107	
Application Realization Rate	71.7%	
Duke Realization Rate	81.4%	

A summary of the peak demand reduction is shown in Table 2.

Table 2. Demand savings and realization rate

[redacted] Peak kW Totals		
	Pre (kW) 62.9	Post (kW) 40.1
Total Savings (kw)	22.8	
Application Realization Rate	76.0%	
Duke Realization Rate	84.4%	

Figure 45 depicts a graph of energy consumption for four (4) metered circuits each serving three (3) wall pack fixtures during the monitoring period. The positive slope of the trend data indicates evidence of photocell control. As the length of the nights increases, the lighting circuits are energized for longer periods of time.

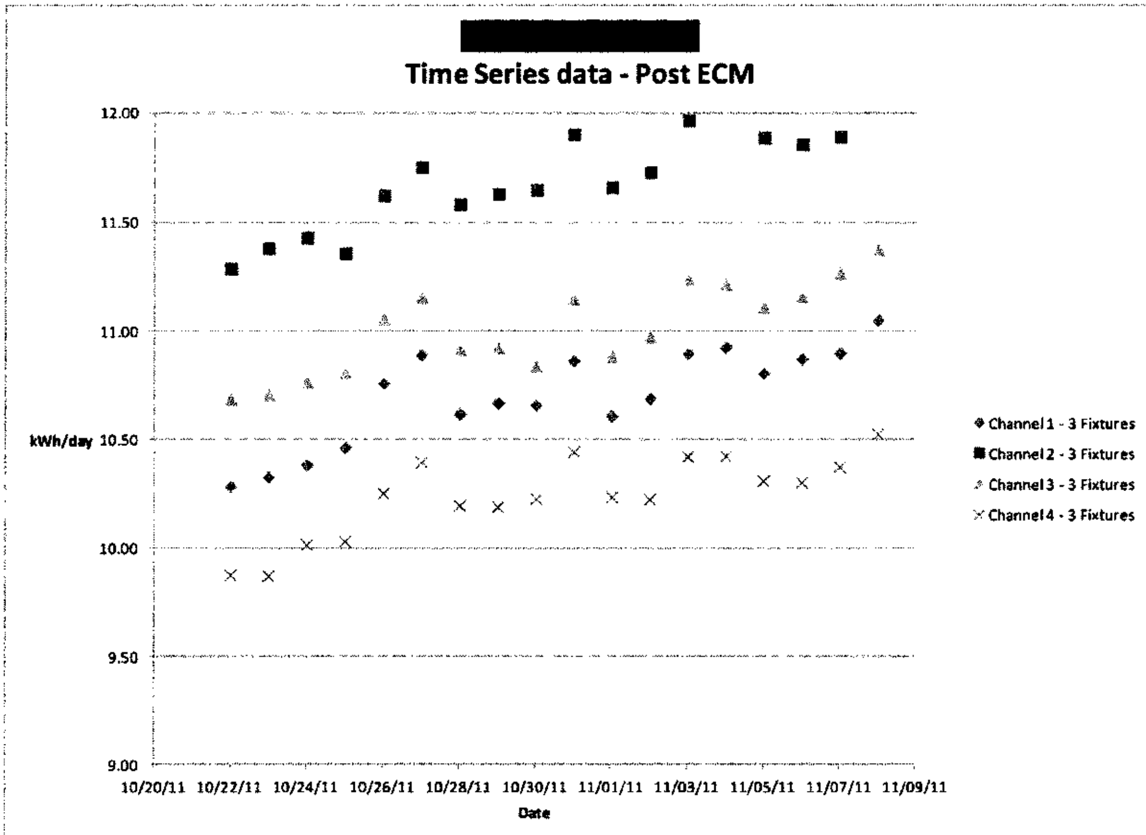


Figure 45. Time series lighting demand

Figure 46depicts a graph of kWh/day for the population of 145 lights included in the application over the course of 1 year. Daily sunrise/sunset times were used to determine the daily run hours for the fixtures.

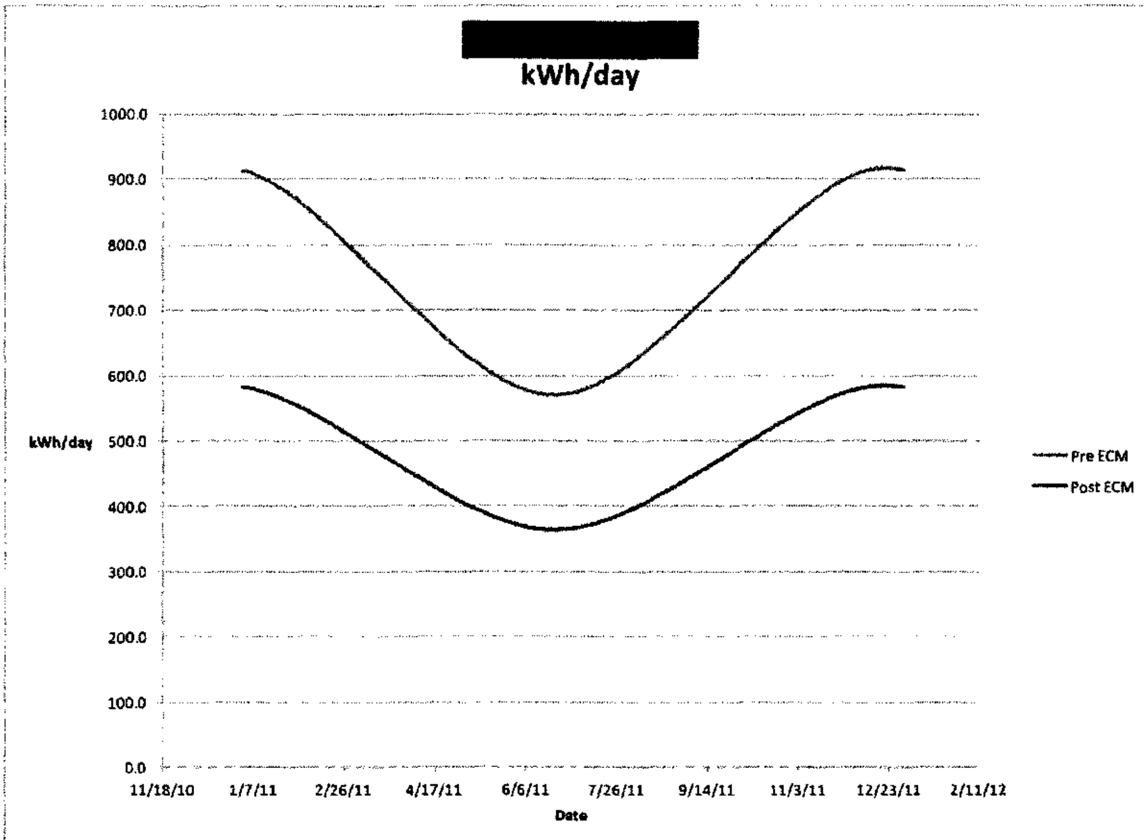


Figure 46. Predicted annual lighting energy consumption

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
95,107	61,296	1.55	23	5	4.29	0	0	

Site 22

[redacted]

- Energy Savings Compressed Air Project -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
August 2011

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

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

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

INTRODUCTION

This report addresses M&V activities for the [redacted] custom program application. The application covers an air compressor VFD retrofit at two locations in [redacted], Ohio. This M&V report is for post-retrofit only. The measure includes:

ECM-1 – Plant 1: 75hp screw air compressor replaced with 40hp VFD air compressor

- *Inefficient compressed-air equipment, specifically the existing Sullair 16BF-75L 75hp modulating screw air compressor was replaced with a new, modern variable frequency drive compressor. The new system is a Kaeser SFC30ST 40hp dual-control compressor. In addition, storage was increased, and the existing system has become the new backup (running approximately 192 hours per year). System demand ranged from 100 to 200 CFM, with pressure variations between 41 and 116 psig. Hours of operation are 7am to 5pm, Monday – Friday, with negligible weekend operation. Four no-loss condensate drains were installed in place of ¼" drains venting for 10 seconds per hour, at a system pressure of 110psi.*

ECM-2 – Plant 2: 50hp screw air compressor replaced with 40hp VFD air compressor

- *The existing Ingersoll Rand EP50 rotary screw air compressor system was replaced with a new, variable frequency drive Kaeser ASD40 40hp compressor. The existing system became the new backup (running approximately 192 hours per year). System demand ranged from 35 to 170 CFM, with pressure variations between 90 and 113 psig. Hours of operation are 7am to 5pm, Monday – Friday, with negligible weekend operation. However, in the pre-retrofit case, the compressor appeared to run without producing air even when the facility is shut down, using unnecessary energy.*

  Additionally, four no-loss condensate drains were installed in place of ¼" drains venting for 10 seconds per hour, at a system pressure of 110psi.

GOALS AND OBJECTIVES

The projected savings goals identified in the application were:

Facility	Duke Projected Annual kWh savings	Duke Projected kW savings
[redacted]	109,384	**41**
Total	**109,384**	**41**

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

- Average post-retrofit load shapes by daytype for controlled equipment
- Facility peak demand (kW) savings
- Summer utility coincident peak demand (kW) savings

- Annual energy (kWh) savings

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	[redacted]	
Duke Energy BRM	Wes Needham	[redacted]	
Customer Contact	[redacted]	[redacted]	

Site Locations/ECM's

Site	Address
[redacted]	[redacted]

Data Products and Project Output

- Average post-retrofit load shapes by daytype for controlled equipment
- Facility peak demand (kW) savings
- Summer utility coincident peak demand (kW) savings
- Annual energy (kWh) savings
- kWh & kW Realization Rates

M&V Option

IPMVP Option A

M&V Implementation Schedule

Post-Retrofit

- Conducted the post-retrofit survey after the customer performed the compressed air system retrofit.
    - Collected data during normal operating hours.
    - Obtained and verified the post-retrofit sequence of operations and/or operating schedule for the compressed air system.
    - Deployed post-retrofit loggers to record kW on the new VFD compressor(s) and backup compressors to determine post-retrofit load shapes and energy consumption.
- Evaluated the energy savings of the retrofit measure.

DATA ACCURACY

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

FIELD DATA POINTS

Post – installation

Survey data

- Compressor nameplate data for the new VFD compressors and backup compressors
- Sequence of operations and/or operating hours for the compressed air system.
- Determined how many holidays the facilities observe throughout the year, and whether the compressed air system is disabled during those holidays.

Time series data on controlled equipment

- Compressor kW

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

FIELD DATA LOGGING

- **ECMs-1 & 2**

  Loggers were installed to monitor compressor kW on both the primary and backup compressors, monitoring each leg of the power cable with separate current transducers. Loggers were in place for 3 weeks.

LOGGER TABLE

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

ECM	Elite Pro loggers	Current Transducers (100A)
1	2	6
2	2	6
Total	**4**	**12**

DATA ANALYSIS

14. Converted time series data on logged equipment into post-retrofit average load shapes by day type.
15. The annual kWh (PRE- numbers taken from the application and POST-with collected logger data) was calculated using the following equations:

Weekdays: $$\frac{kWh}{year} = \sum \left[kW_{time-measured} * \frac{5\min._{intervals}}{\frac{60\min.}{hour}} * \frac{24hour}{day} * \frac{260days}{year} \div \frac{weekdays}{monitoringperiod} \right]$$

Annual Total:

$$\frac{kWh}{year} = \sum \left[\frac{kWh}{year_{weekday}} + \frac{kWh}{year_{weekend}} \right]$$

16. In the PRE-retrofit case, additional compressor load was added to the described schedule, based upon the drain venting schedule, system pressure, and orifice sizes. This additional load does not apply to the POST case, as zero-loss drains have been installed.
17. The annual kWh ***saved*** was calculated comparing the data extrapolated from pre-retrofit application data, and post-retrofit logger data, using the following equation:

$$\frac{hWh_{saved}}{year} = \frac{kWh_{pre}}{year} - \frac{kWh_{post}}{year}$$

5. Estimate peak demand savings

VERIFICATION AND QUALITY CONTROL

52. Visually inspected logger data for consistent operation. No inconsistencies were noted.
53. Verified that pre-retrofit and post retrofit equipment specifications and quantities were consistent with the application. No discrepancies were noted.
54. Electrical voltage of equipment circuits was verified.

RECORDING AND DATA EXCHANGE FORMAT

43. Elite Pro logger binary files
44. Excel spreadsheets

POST-DATA RESULTS

The post-data results were based on four loggers deployed as shown in the logger table above.

Plant#1 is comprised of two compressors: a new Kaeser SFC30, 40hp-vfd, and the existing backup: Sullair 16BF-75, 75hp.

Plant#2 consists of a new Kaeser SFC30, 40hp vfd, and the backup, an Ingersoll-Rand EP50, 50hp rotary screw compressor.

The new compressors replace 75hp and 60hp screw compressors respectively, at each plant.

In the pre-retrofit monitoring and analysis performed by Kaesar Compressors, the electrical impact of the four ¼" condensate drain valves was accounted for in both Plant#1 and#2, since the monitoring measured the total electrical consumption of the compressor with the condensate drains performing normally.

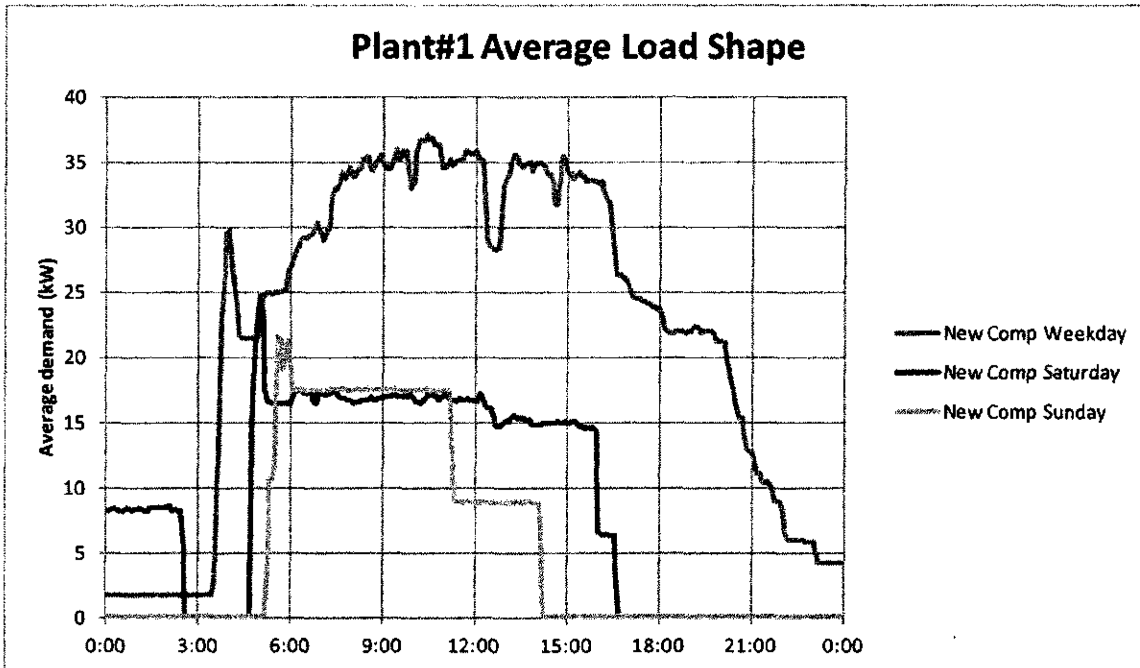
The following table summarizes the energy and demand savings as a result from these ECMs. The projected annual savings based on the post-install trend data for the combined plants is 287,240 kWh and 28.9 kW demand.

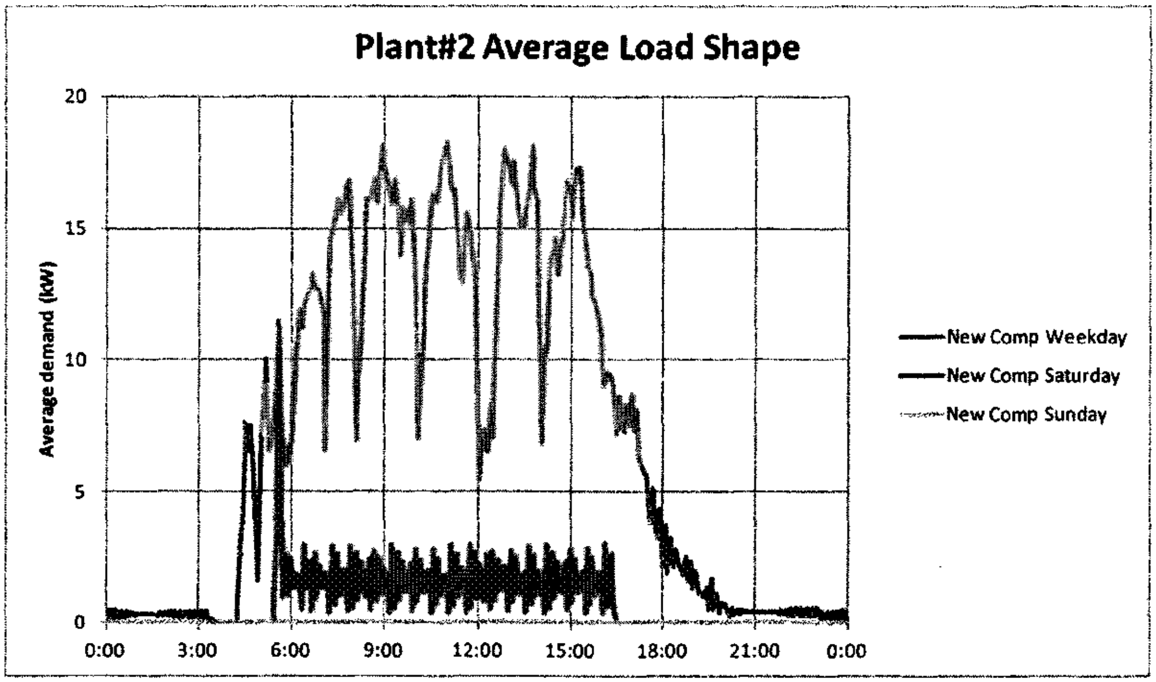
		Peak kW	Annual kWh
	Pre-Retrofit		
	PLANT#1	62.4	312,391
	PLANT#2	37.3	171,324
	Plants 1 and 2 Combined	99.7	483,715
	Post-Retrofit		
PLANT#1	Compr1 Weekday	39.1	134,178
	Compr2 Weekday	**	409
	Compr1 Weekend		17,767
	Compr2 Weekend		0
	Plant 1 Summary	39.1	152,354
PLANT#2	Compr1 Weekday	34.4	43,037
	Compr2 Weekday		0
	Compr1 Weekend		1,084
	Compr2 Weekend		0
	Plant 2 Summary	34.4	44,121
	Plant#1 Savings	**23.3**	**160,036**
	Plant#2 Savings	**2.9**	**127,203**
	Plant 1 and 2 Combined	70.8	196,475
	Plant 1 and 2 Combined Savings	28.9	287,240

The realization rate for ECM1 is shown in the following table.

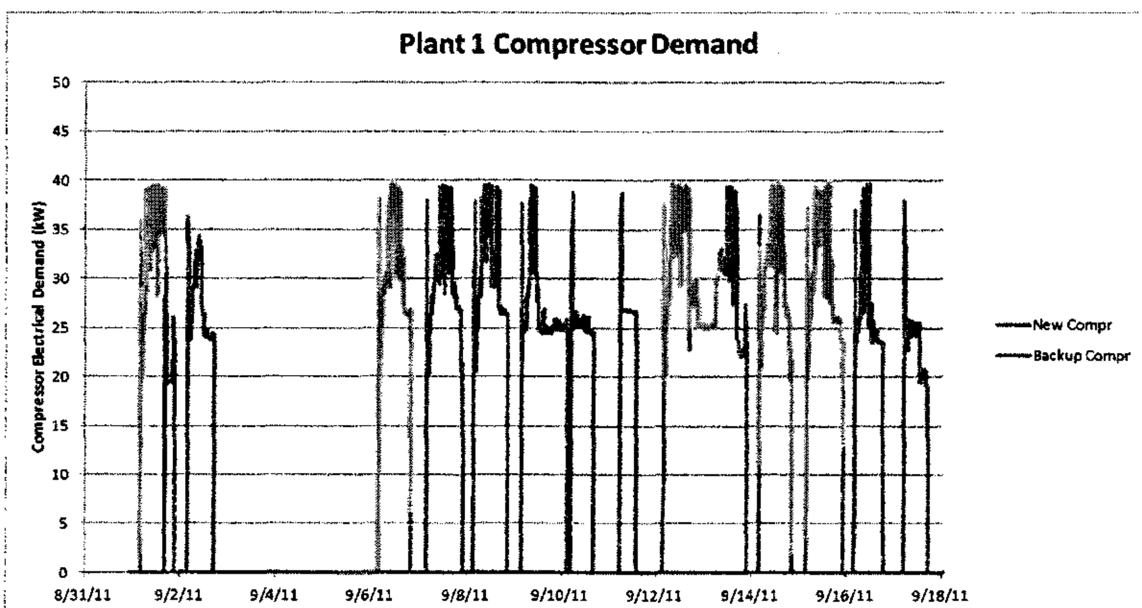
Realization Rate	Energy	Demand
ECM1 & 2	179.62%	70%

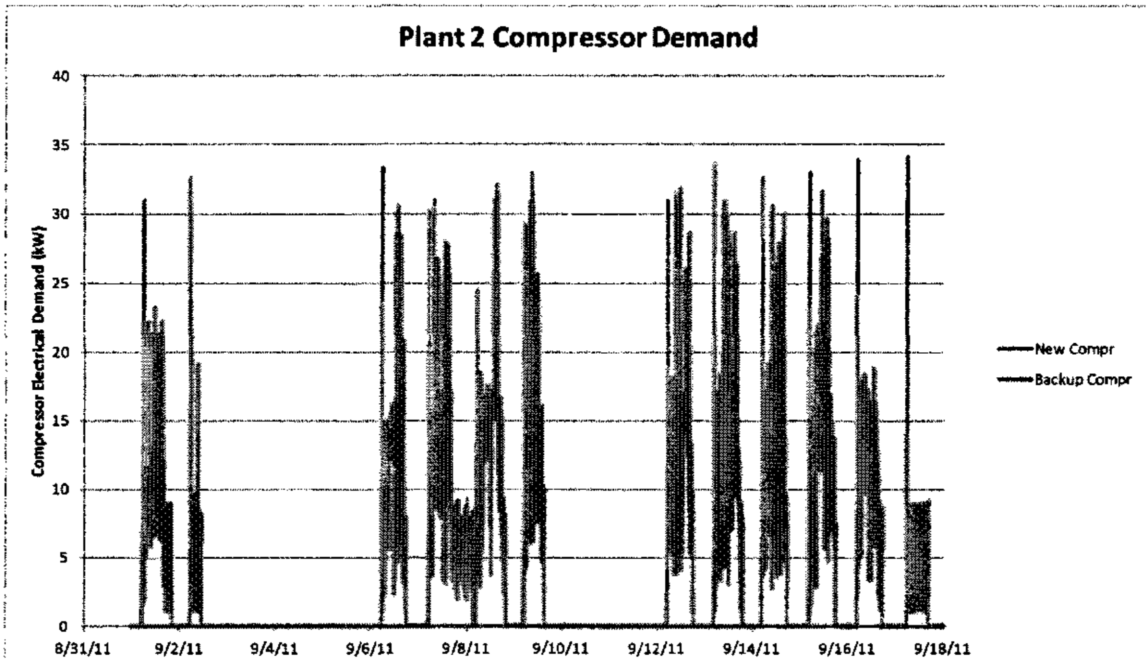
The graphs below show the average daily load shapes for the monitored compressors. These plots average the entire monitoring period into the three day types shown. Plant#2 backup compressor did not operate during the trend period. Both backup compressors are scheduled to operate only 16hrs per month during the 1st shift on weekdays, although there was not enough data collected to confirm this schedule.





The following plots show the compressor demand for both plants 1 and 2 during the entire monitoring period.





Although the plant 2 load shape is highly variable, the maximum demand and the demand at the 2pm peak hour are about the same. The coincident peak demand savings are equal to the non-coincident demand savings.

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
287,240	271,999	1.06	29	77	0.38	29	85	0.34

Site 23

[redacted]

\- Digital Control System

M&V Results Summary

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED:
January 2012

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

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

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

INTRODUCTION

This report addresses Measurement and Verification (M&V) activities for the [redacted] custom program application, and presents the results of the investigation. The application covers the installation of a digital control system at the [redacted] facility in [redacted], Ohio.

This plan is pre- and post-retrofit. The project is on a 5-year timeframe, with one floor being implemented per year (and 1 year of front end control installation). Currently, the project is in Year 3.

The measure includes:

ECM-1 – Digital Control System

- Replacement of existing pneumatic building controls with a digital control system. The existing control system is 26 years old, experiences frequent air leaks, and has an air compressor that runs constantly. Thermostats are out of calibration, and show a 4-6 degree variation.

  The pre-retrofit HVAC systems ran from 5am to 9pm on weekdays, with no weekend runtime. The systems did not set back at night.

  The proposed system includes state-of-the-art DDC controls with daytime, nighttime, and holiday scheduling capabilities. There will be limited access to system adjustments by tenants. The system will reduce equipment runtimes, eliminate the air compressor, and retain tighter control tolerances.

  The system will control two air handling units (AHUs) per floor (4 floors total), interior VAV boxes with fans and electric heat, a DX compressor in each AHU, a cooling tower and the associated pump. The systems have no air-side economizers, but do have water-side economizers with tower water delivered directly to coils at the return air inlets of the AHUs. The building is 100% electric.

  The proposed schedule will be changed to 6am to 7pm on weekdays, with no weekend runtime.

GOALS AND OBJECTIVES

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

The projected savings goals identified in the application were:

Facility	Proposed Annual kWh savings	Proposed Summer Peak kW savings
[redacted]	180,810	26

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

- Annual gross kWh savings
- Building peak demand savings
- Coincident peak demand savings
- KWh and kW Realization Rates.

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Cory Gordon	[redacted]
Customer Contact	[redacted]	[redacted]

Site Location

Site	Address	Building Area (sqft)	Facility Age	ECMs Implemented
[redacted]	[redacted]	100,000	26 years	#1

Data Products and Project Output

- Average pre- and post-retrofit load shapes by daytype for controlled equipment
- Energy consumption pre- and post-retrofit for controlled equipment
- Annual Energy Savings
- Peak demand savings
- Coincident peak demand savings

M&V Option

IPMVP Option D

M&V Implementation Schedule

The survey effort and subsequent analysis consisted of the following activities and information gathering:

- Pre-retrofit survey
  - Identified equipment originally on the pneumatic control system that will be controlled by new DDC system.
  - Obtained pre-retrofit sequence of operations documentation for all controlled equipment.
  - Collected billing data (monthly kWh and demand only) for at least 1 year before any retrofits had taken place.
  - Conducted the pre-retrofit survey on one of the floors that has not yet had the control retrofit. The M&V Plan called for logging pre-retrofit schedules with individual data loggers, and deploying loggers for three weeks. Logging pre-retrofit conditions was not possible, as all air handling units are already on post-retrofit operating schedules.

- Post-retrofit survey
  - Conducted the post-retrofit survey on one of the floors that has already had the control retrofit.
  - Verified that equipment moved to the new control system is operating properly.
  - Obtained post-retrofit sequence of operations documentation for all controlled equipment.
  - Deployed loggers to monitor operation of supply fans, compressor kW, fan and heater kW on sampled reheat boxes, cooling tower fan and pump kW, and outdoor air temperature and relative humidity.
  - Logged post-retrofit schedules with individual data loggers, and deployed loggers for three weeks. The BAS was not capable of these data points; only a very basic front end system had been installed at the time of the survey. Therefore, dataloggers were installed.

- Constructed and calibrated the building energy model.
- Evaluated the energy impacts of the building retrofit in the energy model.

DATA ACCURACY

Measurement	Sensor	Accuracy	Notes
Current	Magnelab CT	±1%	> 10% of rating
Temperature	Onset Temp/RH	±0.36F	

FIELD DATA POINTS

Pre-Installation

Survey data

- Utility bills (kWh and kW) for at least 1 year.
- Nameplate data and quantity for all equipment.
- All other information in the AEC Survey-IT data form. This form includes detailed information about all building systems, including:
    - Building wall, window and floor area
    - Space types and uses
    - HVAC zoning
    - Occupancy schedules and operations (daily, weekly, annually, holidays)
    - Lighting loads and schedules
    - Equipment loads and schedules
    - Temperature setpoints, Energy Management Systems
    - HVAC system controls
    - Fan and pump operation
    - Shading and blinds
    - Chillers, cooling towers, boilers, central air handlers, and water heating
    - Building envelope, including windows, walls, areas, and construction types

Time series data on controlled equipment

Deployed loggers to monitor:

- Outdoor air temperature and relative humidity
- Pneumatic control system air compressor kW
- Supply fan kW (Monitor each of the 2 pre units selected for compressor kW measurements).
- Fan kW and reheat kW in sampled reheat boxes. It was not possible to separate the fan and reheat measurements as both items were served by the same electrical circuit.

- Cooling tower fan kW
- Cooling tower pump kW
- We had planned to monitor the DX compressor kW for both units on the "pre" floor and both units on the "post" floor; however, because of the time of year when the monitoring took place (mid-Dec. 2011 to early Jan. 2012), all cooling was being provided by the cooling tower loop and the compressors were not operating.
- Loggers were set up for five-minute instantaneous readings and collected data for three weeks.

Post-Installation

Survey data

- Details of new thermostat schedule including temperature setback information.
- Details of holidays (number, and when) and if operation is any different during holidays.

Time series data on controlled equipment

Deployed loggers to monitor all the same points defined in the pre-installation logging section.

Data Analysis

Survey data was entered into the Survey-IT database and Model-IT was run to determine annual energy consumption. Comparing the pre-retrofit case with the post-retrofit changes in the thermostat setpoints determines the annual energy and demand savings.

This includes plotting gathered data to verify occupancy schedules and other HVAC system control parameters.

The pre-retrofit energy model was calibrated to the actual building utility performance. In order to match the computer model to the actual results, only those parameters that are not known with a high level of uncertainty were modified. These parameters include plug loads, certain schedules, and infiltration, among others. Any parameters which are directly affected by the retrofit and have been explicitly monitored during pre-retrofit data collection were not modified during model calibration.

Verification and Quality Control

55. Logger data was visually inspected for consistent operation.

56. Pre-retrofit and post retrofit equipment specifications, quantities, and schedules were verified as consistent with the application.

RECORDING AND DATA EXCHANGE FORMAT

45. Survey-IT Forms and Notes.
46. Building Automation System data files OR data logger files
47. Excel spreadsheets
48. Survey-IT and Model-IT database files
49. DOE-2 energy model data files

RESULTS

Upgrading the existing controls to DDC achieves energy savings by:

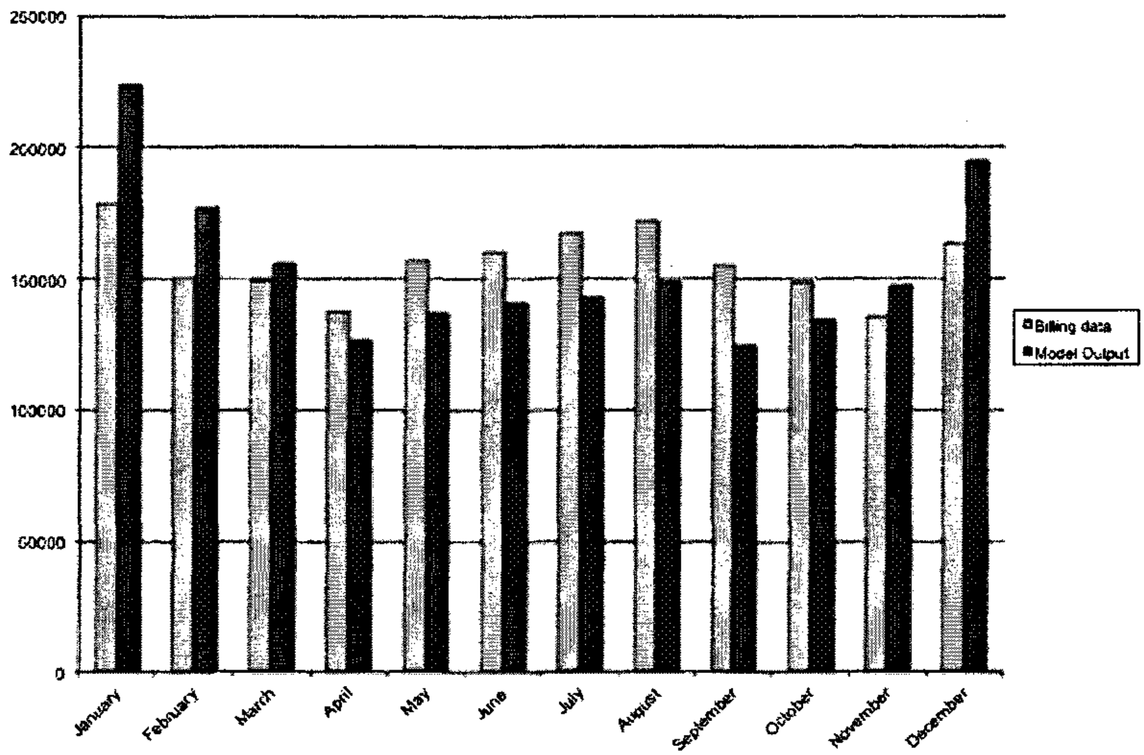
- Eliminating the control air compressor (3.65 kW).
- Changing all AHU operating schedules from 5 AM - 9 PM to 6 AM - 6 PM.
- Re-enabling all systems to operate as VAV systems. Only interior zones have VAV terminals. Pre-retrofit, most of these terminals had stopped modulating. This functionality is being restored by the upgrade. Allow minimum CFM of 50%.
- Adding night setback/up setpoints.
- Allowing units to cycle on at night to maintain these setpoints.
- Adding holiday scheduling.

Calibrating thermostats does not typically save energy. When thermostats are out of calibration, occupants set them wherever they need to be to maintain comfort.

Existing air conditioning DX compressors in each AHU are being rebuilt as part of the retrofit (those that have not been rebuilt already in the past few years because of failures). Replacing compressors with like-for-like rebuilt compressors is likely to produce only minimal efficiency gains, so no energy savings have been attributed to this part of the retrofit.

Model Calibration

All post-retrofit data was entered into Survey-IT and run through the DOE2 energy simulation software to determine annual energy consumption. The as-built model was calibrated to billing data. A comparison of the simulated monthly kWh from the calibrated model and the monthly utility bills is shown below:



The calibration statistics are summarized below. Note, the calibration statistics are better than the targets established by ASHRAE Guildeline 14 - Measurement of Energy and Demand Savings.

Parameter	Calibration Result	ASHRAE Guideline 14 Target
RMS Error	1.1%	+/- 15%
Mean Bias Error	1.3%	+/- 5%
Maximum monthly deviation	25.3%	Not addressed

After constructing and calibrating the model, the verified electric energy and demand savings, as determined by this M&V project, are as follows:

Application Proposed Annual savings (kWh)	**180,810**
M&V Results	**203,477**
Energy Realization Rate	**1.12**

Application Proposed Peak Savings (kW)	**None noted**
M&V Results	**77**
Demand Realization Rate	**N/A**

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
203,477	63,041	3.23	77	14	5.48	65	14	4.67

Note: there is a significant discrepancy between the savings in the application and the final DSMore savings estimate. The kWh savings in the application is with 12% of the evaluated savings. The DSMore values should be investigated.

Site 24

[redacted]

- Integrated Energy Design for Electric Efficiency -

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
January 2012
Revision 1.1

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

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

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

Introduction

This report summarizes M&V activities for the [redacted] - [redacted] Elementary School facility custom program application.

[redacted] Elementary is a new school. The application and supporting documents describe the project as an "integrated design" project, with many energy-related features that exceed the requirements of the ASHRAE Standard 90.1-2004. The design is being treated as one "combined" Energy Conservation Measure (ECM) that includes the following features:

ECM-1 –integrated design

- Increased wall and roof insulation (reduced U-values)
- A white roof to reduce the roof summer cooling load
- Low-e glass assemblies with reduced U-values for the fixed windows
- Some operable windows in lieu of fixed
- Windows with integral shades between the glass panes
- High efficiency fluorescent lighting
- Occupancy sensors to control lighting in enclosed classrooms and office spaces Daylighting sensors to provide continuous dimming for lighting in classrooms and several of the offices
- High efficiency parking lot and exterior lighting
- Enthalpy-based heat recovery
- Series fan-powered VAV boxes with ECM motors
- CO2 sensors to regulate the amount of outside air in the dining area and gymnasium
- Increased HVAC unit cooling efficiency
- Increased boiler efficiency

The design also included some items that save energy but that are already required by the standard, such as air-side economizers and variable frequency drives (VFDs) for supply air fans.

Goals and Objectives

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

Projected Savings Comparisons

	Annual Energy Savings (kWh)	Peak Demand Savings (kW)	Annual Electric Energy Cost Savings ($)
Application Proposed (10-21-2009), ECM 1	103,514	189.6	$ 15,694
Duke Projections	None Noted	None Noted	None Noted

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

- Annual gross energy savings (kWh)
- Summer peak demand savings (kW)
- Utility coincident peak kW savings
- kWh and kW savings Realization Rate

Project Contacts

Approval has been granted from the Duke Energy contacts listed below to plan and schedule the site visit with the Customer.

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Mike Heath	
Customer Contact	[redacted]	[redacted]

Site Location

Site	Address
[redacted] Elementary School	[redacted]

Data Products and Project Output

- AEC Survey-IT data form
- Model predicting pre- (ASHRAE 90.1-2004 baseline) and post- (as-built) electric energy consumption in kWh
- Annual energy savings
- Summer building peak demand savings
- Coincident peak demand savings

M&V Option

IPMVP Option D – Calibrated Simulation

M&V Implementation Schedule

The following bullet points were completed during the data collection and data analysis periods:

- This is a new building; only post-installation data is available.
- ECMs dictate that this plan should be implemented while school is in session.
- Verify that equipment connected to the control system is working properly.
- Fill out the "Survey-IT" data collection forms attached in the Appendix.
- Set up EMS trends of air handling unit (AHU) operations as described below in "EMS Trending / Field Datalogging" section. If trending is not possible, install temporary dataloggers to monitor supply fan operation.
- Install temporary dataloggers to monitor lighting operation where occupancy sensors and daylighting controls are installed.
- Construct the building energy model.
- Modify the energy model to create a baseline energy model compliant with ASRHAE 90.1-2004 code.
- Evaluate the energy impacts of the building improvements in the energy model.

Field Survey Points

Personnel Interview:

- The Facility Manager was interviewed to determine the following:
  - Information required to fill out the Survey-IT forms
  - Review energy management system (EMS) programming to verify sequences of operations and setpoints for all controlled equipment
  - Obtain copies of manufacturers' product information for major HVAC equipment items, if available.
  - Obtain copies of building lighting plans and lighting electric panel schedules.

The following data was collected on all trended/monitored equipment:

Nameplate data. Refer to Survey-IT forms and collect mechanical equipment nameplate data as indicated.

Survey-IT Data. *Record building and systems information in the AEC Survey-IT data form.* Complete the form as accurately as possible. This form includes detailed information about all building systems, including:

- Building wall, window and floor area
- Space types and uses
- HVAC zoning
- Occupancy schedules and operations (daily, weekly, annually, holidays)
- Lighting loads and schedules
- Equipment loads and schedules
- Temperature setpoints, Energy Management Systems
- HVAC system controls
- Pressurization fan and condenser water pump operation
- Shading and blinds
- Chillers, cooling towers, boilers, central air handlers, and water heating
- Building envelope, including windows, walls, areas, and construction types

The following points were determined during survey for lighting:

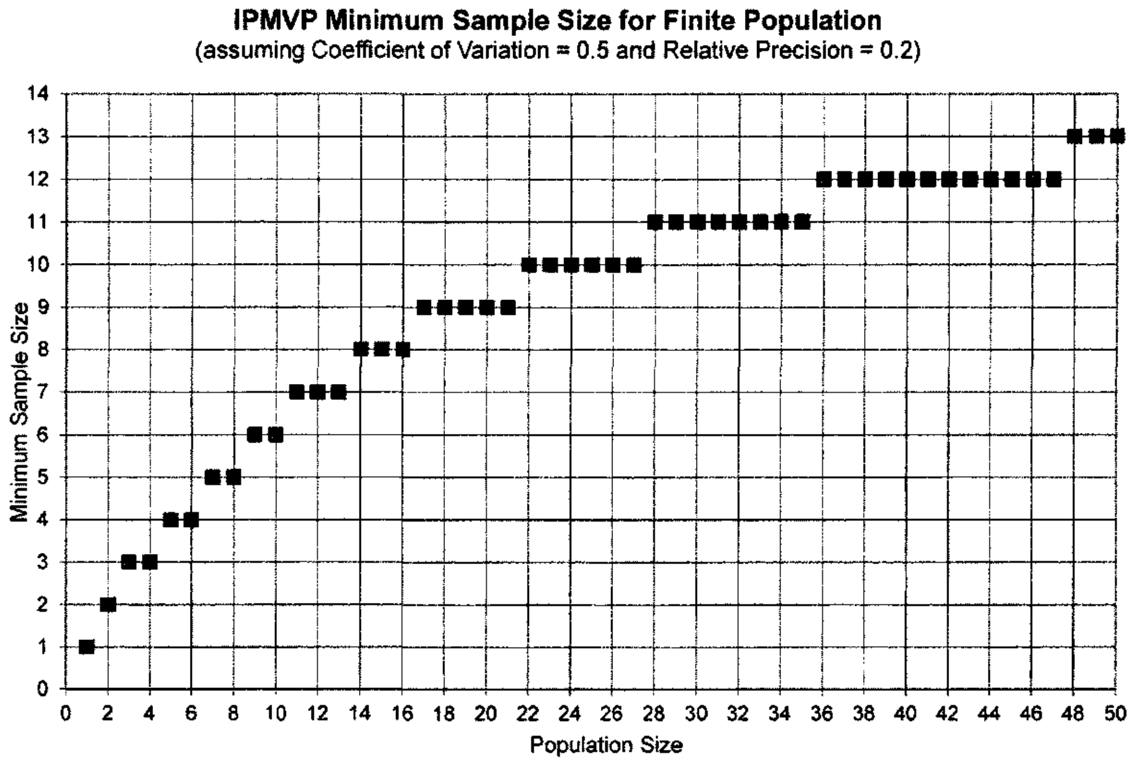
- Verify the installed lighting fixtures and layout are reasonably represented by the lighting plans.
- From the plans, identify the number of lighting circuits with the following controls:
  - Occupancy sensors only (without daylighting controls)
  - Daylighting controls (with or without occupancy sensors)
- The number of circuits in each case is its "Population Size" for the sampling graph in the next section.

EMS Trending / Field Datalogging

Sample Sizes

The following graph was used to determine the control zone sample size for survey/logging for:

- Occupancy sensor zones
- Daylighting zones
- Air handling units



Time-series data

All time-series data was measured and recorded in 5-minute intervals for 3 weeks.

NOTE: Trended data for the AHU's and ERV's was not received in time to analyze and include in this report. Lighting circuits were logged and an analysis of that data can be found in the results section of this report.

<u>Lighting</u>

Time-series data was collected for a sample of the lighting circuits having occupancy sensor and/or daylighting controls by using the following methodology:

- Select the number of occupancy sensor circuits, and the number of daylighting circuits, to be sampled according to the above chart.
- Identify circuits for temporary monitoring according to the determined sample sizes.
- Deploy current measurement CT dataloggers to measure the current of the circuits to be sampled at the lighting panels. Log the individual circuits, not the entire panel.

- After installing the dataloggers, spot measure the lighting loads connected to the selected circuits by measuring the voltage, current, kW and power factor of each circuit (to establish ratio of kW/amp). Also record the simultaneous logger amp readings.

<u>Air Handling Units (Proposed monitoring plan; data not received in time for report):</u>

The total number of AHUs installed at the site is not stated in the application documents.

- Obtain a list of AHUs from the customer <u>*prior to arrival on-site*</u>.
- The list should include the following information:
  - AHU ID No.
  - The area of the building served
  - Supply fan motor horsepower
  - Electric service voltage (e.g., 460 V / 3 phase).

Time-series data was collected for a sample of the installed AHUs. The number of AHUs to be sampled was selected according to the above chart. Preference was given to AHUs with dissimilar schedules for monitoring. In addition, AHUs with Demand Control Ventilation (DCV) control (the dining area and the gymnasium), and units with enthalpy heat recovery were included in the sample.

Trended data from the EMS was gathered as described below, if possible.

- Unit Operation
  - Supply fan amps. If amps are not available, trend on-off flag instead. Actual operation must be trended; "availability" flag is not acceptable.
  - Supply fan VFD output signal (percent of full frequency or Hertz)
- Demand Controlled Ventilation (dining area and gymnasium AHUs)
  - Set up trend logs for each unit with DCV control
  - Establish trend logs to monitor:
    - Fan air flow, fan speed or amps
    - Outdoor air damper position
    - Indoor and outdoor CO_2 levels
    - Outside air fraction (if available) OR <u>all three</u> of:
      - Outside air temperature
      - Mixed air temperature
      - Return temperature

- Heat Recovery Units
  - Set up trend logs for each unit with heat recovery
  - Establish trend logs to monitor:
    - Fan air flow, fan speed or amps
    - Outdoor air damper position
  - Establish trend logs to monitor air dry-bulb temperatures and humidity of the following air streams into and out of the heat recovery units:
    - Incoming Outdoor air
    - Discharge (Supply) air
    - Outgoing Return air
    - Exhaust air

- Economizers
  - Set up trend logs for additional AHUs as needed to complete the sample
  - Establish trend logs to monitor ALL of the same temperature setpoints listed in the Demand Controlled Ventilation measure.

LOGGER TABLE

The following table summarizes the types of logging equipment that were used to measure the above noted data, if EMS trending is not available.

	Hobo U12	20A CT	50A CT	Hobo U10 T/RH Sensor
Lighting	10	20	0	0
AHUs with Enthalpy Heat Recovery	3		3	12
AHUs with DCV or Econo. Only	3		3	9

DATA ACCURACY

Measurement	Sensor	Accuracy	Notes
Current	CTV-A/B/C	±4.5%	Current being measured should be

			>10% of CT rating
Temperature	Hobo U10	1 °F	
Humidity	Hobo U10	±3.5%	

DATA ANALYSIS

23. Plot the lighting circuit current data for each occupancy sensor and daylighting circuit monitored.
24. Determine the peak circuit power as follows:

$$kW_{peak} = (kW_{spot} / Amps_{spot}) * Amps_{peak}$$

25. Use the above peak circuit power and the lighting plans to estimate the Lighting Power Densities (LPD) of the spaces served by each circuit.
26. Use the circuit current data to determine lighting schedules (hourly average fraction of peak lighting power) for each space type by day type.
27. Plot the AHU fan operating data to determine actual operating schedules by unit and by day-type. (Not performed)
28. Plot the trended / logged economizer data vs. outdoor air temperature to verify economizer enable temperatures. (Not performed)
29. Use trend data to verify the functionality of the DCV system, by examining the outdoor damper operation to verify that it is in fact varying based upon CO2 levels. (Not performed)
30. Determine the heat recovery effectiveness by comparing the temperature and humidity of separate air streams as in the following equation: (Not performed)

$$\epsilon = \frac{(T_{in} - T_{out})}{(T_{in} - T_{out})_{max}}$$

31. Enter all data from the Survey-IT forms into the Survey-IT software. Include the LPDs, lighting schedules, fan schedules, etc., as determined from the preceding steps.
32. Run Model-IT to determine annual energy consumption and average peak kW demand during the on-peak period.
33. Calibrate the energy model to the actual building utility performance to within 10% on a monthly basis. In order to match the computer model to the actual results, only those parameters that are not known with a high level of uncertainty shall be modified. These parameters include plug loads, certain schedules, and infiltration, among others. Any

parameters which are directly affected by the retrofit and have been explicitly monitored during pre-retrofit data collection will NOT be modified during model calibration.

34. Adjust the simulation model for baseline conditions by changing envelope, lighting and equipment performance parameters to ASHRAE 90.1-2004 minimum requirements. Baseline occupancy, lighting and equipment operating schedules are to be the same as the actual schedules.
35. Rerun the model to determine baseline annual energy consumption and average peak kW demand during the on-peak period.
36. Compare existing building annual energy consumption with the baseline consumption to determine annual energy savings.
37. Determine the energy savings Realization Rate by dividing the annual energy savings found in the step above to the savings estimated in the application.
38. Compare existing building average peak kW demand with the baseline demand to determine annual demand savings.

Verification and Quality Control

57. Visually inspect trend/logger data for consistent operation. Sort by day type and remove invalid data. Look for data out of range and data combinations that are physically impossible.
58. Verify equipment specifications and performance parameters are consistent with the application. If they are not consistent, record discrepancies.

Recording and Data Exchange Format

- Post-installation Survey Form and Notes.
- Energy Management System data files, if collected
- Datalogger files
- Survey-IT and Model-IT database files
- DOE-2 energy model data files
- Excel spreadsheets

Results

Lighting Control

Lighting control was verified to be operating properly as can be seen in Figures 1&2. Both figures depict the lighting kW and control as observed over the course of the three week logging period. A distinct 3 consecutive days of operation can be seen followed by the weekend, followed by a 5 day school week. The lack of operation that is represented at the far right of the graphs is due to Christmas vacation.

Figure 1 represents a portion of the Administration wing. This area includes occupancy sensor control, but no photocells to utilize natural daylight for space lighting. As can be seen by the load-shape, the lighting comes on when the sensors determine there is occupancy in the morning and the lights stay on for the majority of the day. The slight reductions shown on Friday of the first week and Monday/Tuesday of the second week can be accounted for by a portion of the circuit de-energizing perhaps due to some of the faculty leaving the area for lunch.

Figure 1

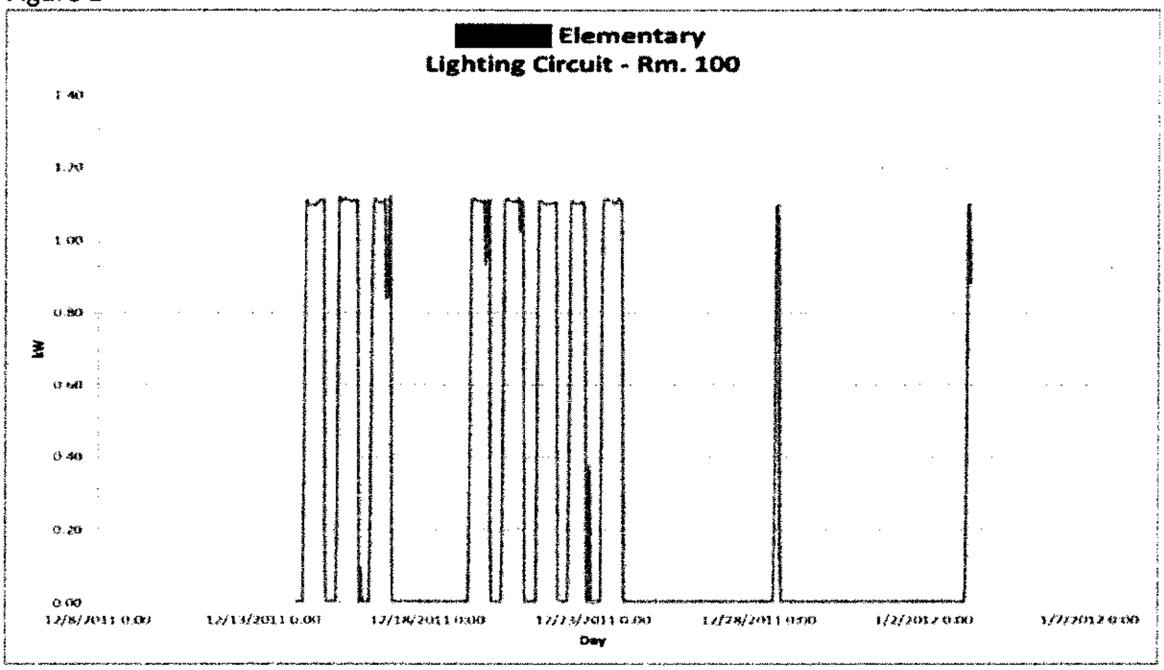
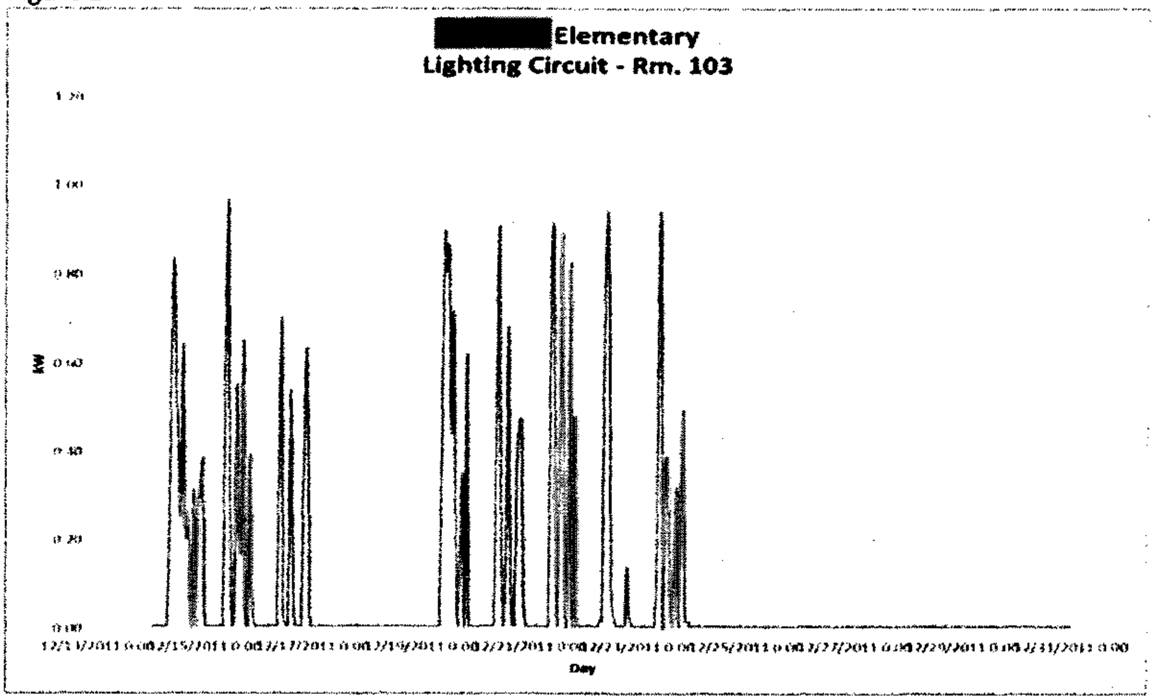


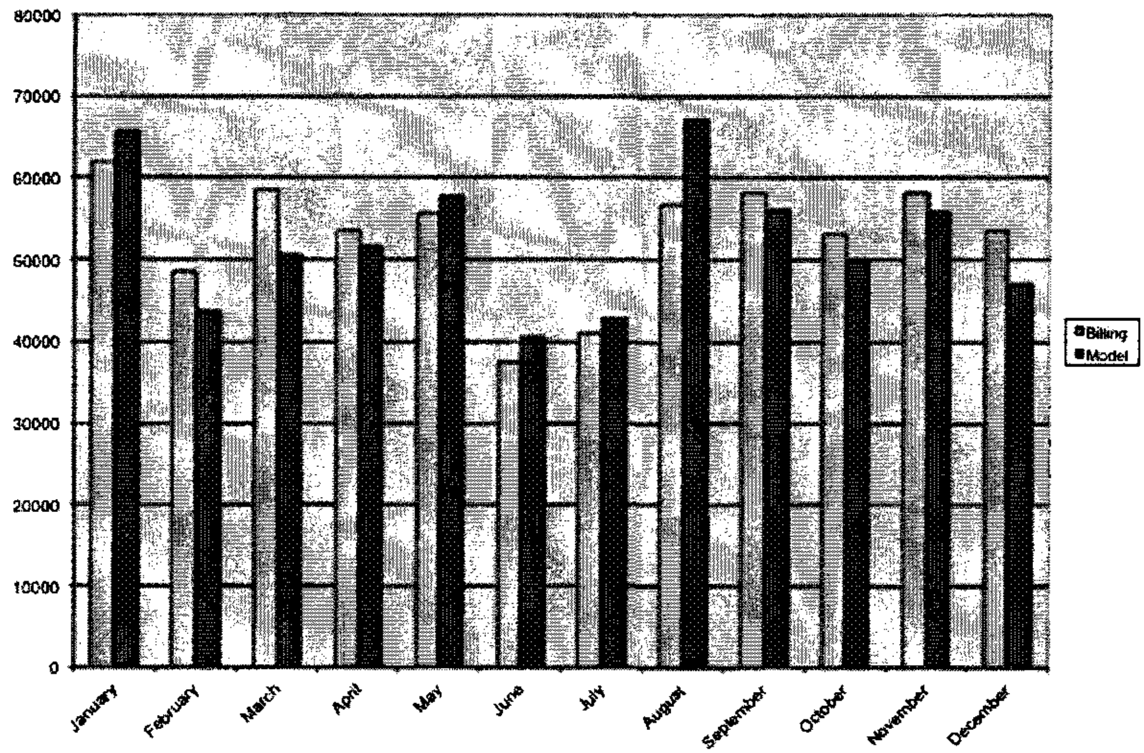
Figure 2 represents Pre-Kindergarten Classroom 103. This area includes both occupancy sensors and photocell control to dim a portion of the lights when there is enough natural daylight in the space to do so. This load shape indicates that both of these types of control are working properly. The spikes up to the maximum circuit kW and back down to zero indicate occupancy sensor operation. This classroom was occupied on and off during the school day through the logging period. The reductions in circuit kW that fluctuate up and down, but not necessarily to zero indicate the proper operation of photocell control. The lighting is being dimmed to accommodate the natural daylight in the space over the course of the school day. This room also has two levels of photocell control. One photocell is approximately 3 feet from the perimeter, which dims the bank of lights closet to the perimeter. Another photocell approximately 14 feet from the perimeter dims the second and third banks of lighting.

Figure 2



Model Calibration

All post-retrofit data was entered into Survey-IT and run through the DOE2 energy simulation software to determine annual energy consumption. The as-built model was calibrated to billing data. A comparison of the simulated monthly kWh from the calibrated model and the monthly utility bills is shown below:



The calibration statistics are summarized below. Note, the calibration statistics are better than the targets established by ASHRAE Guildeline 14 - Measurement of Energy and Demand Savings.

Parameter	Calibration Result	ASHRAE Guideline 14 Target
RMS Error	0.8%	+/- 15%
Mean Bias Error	1.1%	+/- 5%
Maximum monthly deviation	18.5%	Not addressed

A baseline energy model was then created by converting all energy efficiency measures and building attributes to their equivalents in the ASHRAE 90.1-2004 code. Comparing ASHRAE 90.1 results with the actual building model results then determined the annual energy savings. The results for both cases are shown and compared below.

Table 19: Energy Model Analysis Results

[redacted] Elementary School Results			
	ASHRAE 90.1-2004 Model	As-built Model	Savings

Annual Peak Demand (kW)	428.5	267.2	161.3
Annual Electric Use (kWh)	760,072	629,923	130,149

Table 20: Comparison of Application Savings vs. Energy Model Results

	[redacted] Elementary School Realization Rate		
	Application	DOE 2 Model	Realization Rate
Annual Peak Demand (kW)	189.6	161.3	0.85
Annual Electric Use (kWh)	103,514	130,149	1.26

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
130,149	103,510	1.26	161	189	0.85	199	14	14.57

Note, the coincident peak savings from the simulation model greatly exceeded the expected savings. This is caused by the increased summertime use of the building as recorded by the surveyor during the onsite survey and interview with building operations personnel.

Site 25

[redacted]

EMS Upgrade

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED:
January 2012

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

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

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

INTRODUCTION

This report addresses Measurement and Verification (M&V) activities for the [redacted] custom program application, and present the results of the investigation.

The measures include:

ECM-1 – EMS Upgrade

- Upgraded INNCOM thermostats will be installed that feature a passive infrared motion sensor and door switch. When a room is determined to be unoccupied, the logic in the thermostat will automatically widen the temperature band +/- 4 degrees from the setpoint. The thermostats will also be connected to a central network with an interface to the hotel's property management system. When a guest checks out of the room, the network will automatically place the room into an unrented mode and the temperature band will be increased to 62 degrees on the low end and 78 on the high end. Should occupancy be low, the network will also allow rooms to be put into "hibernation" or "Off" mode, with the temperature range at 50 degrees on the low end and 90 on the high end.

Note: The ECM has already been implemented for this application. Data collection was for post-implementation only.

GOALS AND OBJECTIVES

The projected savings goals identified in the application are:

Application Proposed Annual savings (kWh)	Application Proposed Peak Savings (kW)	Duke Projected savings (kWh)	Duke Projected Peak savings (kW)
507,265	None noted	507,265	202

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

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

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM	Terry Holt	
Customer Contact	[redacted]	[redacted]

Site Location

Address
[redacted]

Data Products and Project Output

- Average pre/post load shapes by day-type for controlled equipment
- Pre- and post-retrofit energy models
- Summer peak demand savings
- Coincident peak demand savings
- Annual Energy Savings

M&V Option

IPMVP Option D – Calibrated Simulation[3]

M&V Implementation

The "Post-retrofit" survey and subsequent analysis consisted of the following activities and information gathering:

- Interviewed the chief engineer and completed the SurveyIT data collection form.
- Surveyed the shell of specified guestrooms. This information was collected from copies of original construction drawings.
- Some data were collected for the non-guestroom spaces in the hotel, but these spaces do not influence the ECM results.
- Determined how thermostats were controlled during un-occupied and un-rented hours in guestrooms, including temperature setpoints and dead band ranges.

[3] The project affected the guest rooms, which represent a subset of the total floorspace associated with the billing data. Monitored data were used to define model inputs, but billing data calibration was not possible.

- Gathered trend data from selected room sample to determine occupancy and room rental status, as well as temperature setpoints, fan status, heating/cooling status and temperature dead band settings. This data consist of hard copies of room histories and the thermostat manufacturer's operator's manual.
- Constructed the building energy model.
- Evaluated the energy impacts of the building retrofit in the energy model.

FIELD SURVEY POINTS

Survey data

Recorded all pertinent information in the AEC Survey-IT data form. Completed as accurately as possible, surveying sampled rooms (or alternates), as well as central plant equipment. This form includes detailed information about all building systems, including:

- Building wall, window and floor area
- Space types and uses
- HVAC zoning
- Occupancy schedules and operations (daily, weekly, annually, holidays)
- Lighting loads and schedules
- Equipment loads and schedules
- Temperature setpoints, Energy Management Systems
- HVAC system controls
- Shading and blinds
- Air handlers and water heating
- Building envelope, including windows, walls, areas, and construction types

Survey data (for all sampled equipment monitored via the BAS)

- Sampled room FCU unit make/model numbers

FIELD DATA TRENDING

ECM-1

The M&V Plan called for setting up trends in the BAS to record all sampled FCU fan status in 5 minute intervals. If the BAS was capable, trends were to be set up to measure and record the status (Rented & Occupied, Rented & Unoccupied, and Unoccupied) in 5 minute intervals. Also, fan speed, heating/cooling mode, and temperature dead bands were to be trended. The on-site EMS was not capable of these trends. Hard-copy printouts of room FCU operation, rental status and occupancy histories were obtained to use for analysis purposes. Arrangements were made for the thermostat vendor to trend the above data remotely; however, at this time the data has not been received. The hard-copy information proved to be adequate for the needed analysis.

Data was available for a 1-week period post-installation.

Trending Sample Table

The following table summarizes the room sample for which trending was needed to accurately measure the above noted ECM. Data was obtained for all of the noted rooms; alternate rooms were not required.

Room Number	
407	(Alternate = any other 07 room except 1607)
523	(Alternate = any other 23 room except 1623)
927	(Alternate = any other 27 room except 1627)
1004	(Alternate = any other 04 room except 1604)
1032	(Alternate = any other 32 room except 1632)
1126	(Alternate = any other 26 room except 1626)
1221	(Alternate = any other 21 room except 1621)
1406	(Alternate = any other 06 room except 1606)
1525	(Alternate = any other 25 room except 1625)
1604	(Alternate = 1601)
1606	(Alternate = none)
1610	(Alternate = 1613, 1624, or 1625)
1621	(Alternate = 1615, 16, 17, 19, or 1620)
1626	(Alternate = none)
1632	(Alternate = 1628, 29, 30, 33, 34, or 1636)
1627	(Alternate = none)
1608	(Alternate = none)
1623	(Alternate = none)

Data Analysis

Survey data was entered into the Survey-IT database and Model-IT was run to determine annual energy consumption. Comparing the pre-retrofit case with the post-retrofit changes in the thermostat setpoints determines the annual energy and demand savings.

Verification and Quality Control

59. Post-retrofit equipment and quantities are consistent with the application.

RESULTS

Before the INNCOM thermostats were installed, housekeeping's instructions were to set the room thermostats "straight up" if the room had been vacated. This essentially maintained constant temperatures throughout the guest room floors.

The new INNCOM thermostats communicate with a central EMS program, which is tied into the front desk computers. When a guest checks in, this information is communicated to the EMS program, which then sets the room status to "rented." The EMS program allows any guest room thermostat to be in one of four different states:

- **Rented and Occupied**. – When a guest checks in, the thermostat is automatically set to 72 °F. After entering the room, the guest may set the thermostat to his or her personal preference. The thermostat is interlocked with a door switch, so the system will remain in Occupied mode even if motion is not detected regularly, as long as the guest room door remains closed. The room temperature is maintained within +/- 1 degree in this mode.

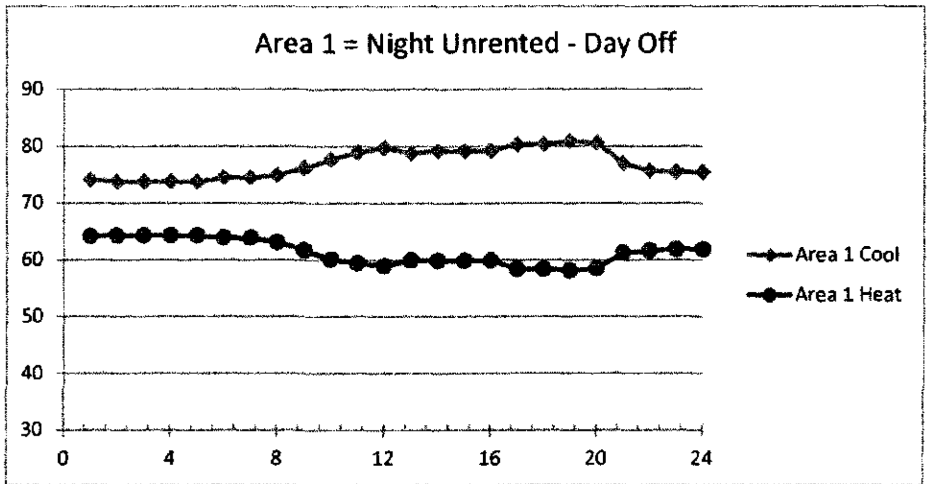
- **Rented but Unoccupied**. – If the guest room door is opened and subsequently the occupancy sensor does not detect motion, the thermostat enters this state. The temperature setpoint remains where the guest set it, but the room temperature is allowed to vary +/- 1 degree in this mode.

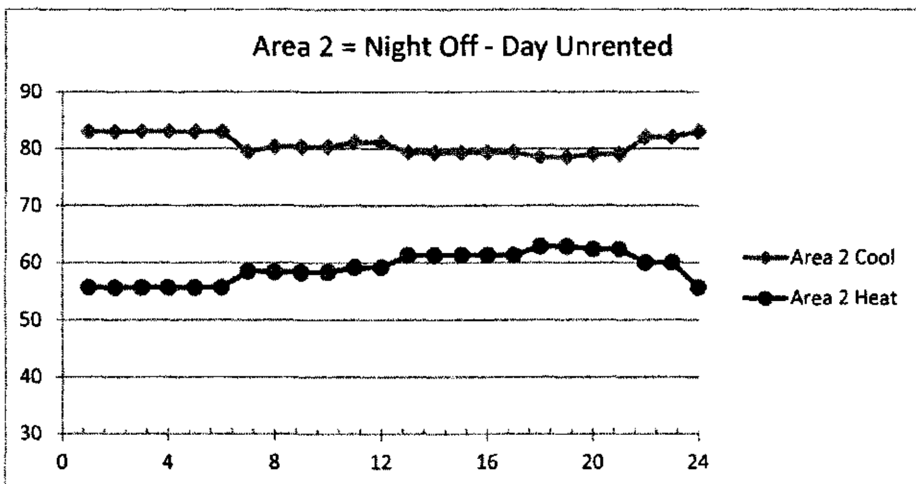
- **Unrented**. – When a guest checks out, the EMS puts the room in the Unrented state. The allowed temperature setpoint range is set to 62 to 78 °F.

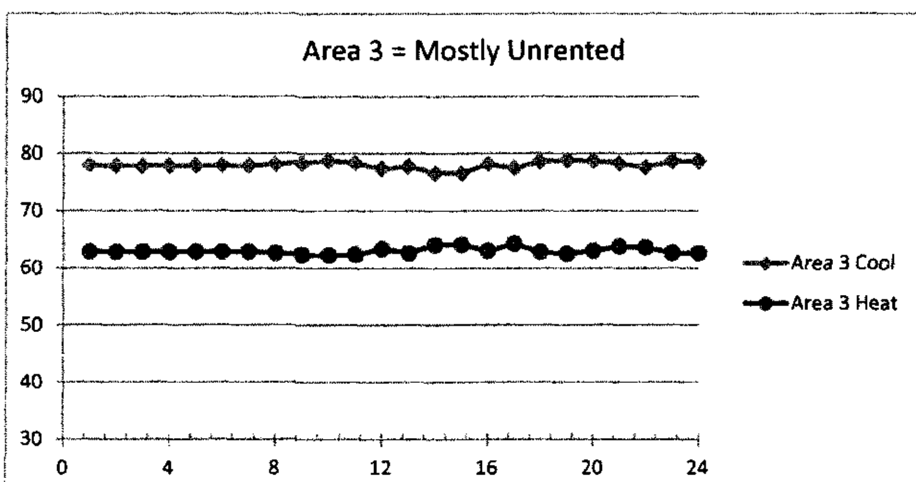
- **Off**. – If the room is unrented and is not anticipated to be rented for a period of time, the room may be placed in the Off state. In this state, the allowed temperature setpoint range is set to 50 to 90 °F.

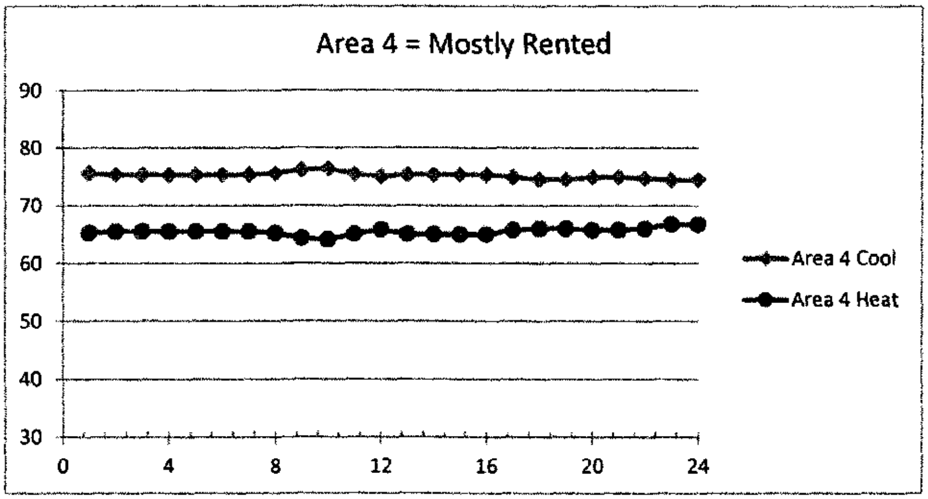
Energy savings occur with the INNCOM system because the room temperatures are allowed to set up or back automatically when the room is not in use. In the baseline case the room heating and cooling temperature setpoints remain essentially constant, as previously described.

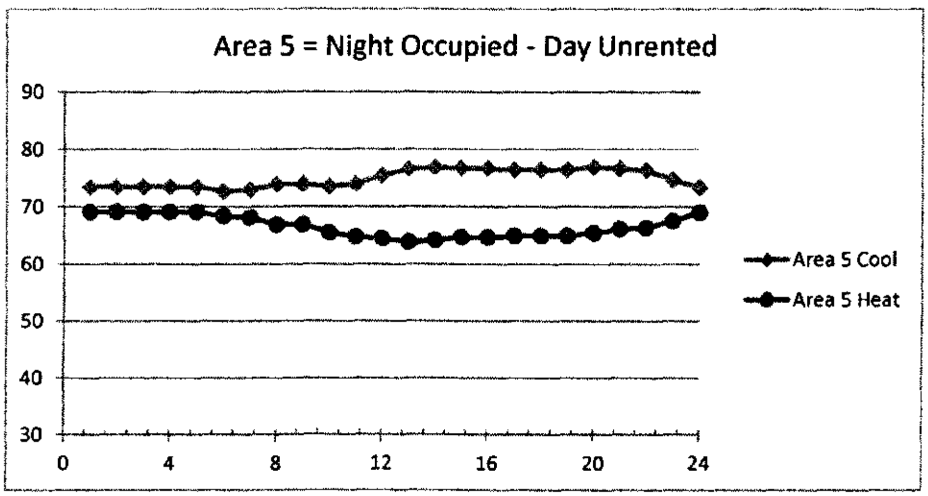
The one-week histories of the sampled thermostats were examined for average daily settings. These histories can be summarized in five "typical" daily profiles (note the hotel operates every day, and weekend days are no different from weekdays as far as thermostat settings are concerned). These daily profiles are presented below. In the simulation model, the guest rooms are zoned into "Areas," where each Area uses one of these profiles. Approximately 70% of the rooms are in Areas 1 and 2, reflecting the reported average occupancy rate of the hotel.


Area 1 = Night Unrented - Day Off
90
80
70
60
50
40
30
0
4
8
12
16
20
24
Area 1 Cool
Area 1 Heat


Area 2 = Night Off - Day Unrented
90
80
70
60
50
40
30
0
4
8
12
16
20
24
Area 2 Cool
Area 2 Heat


Area 3 = Mostly Unrented
90
80
70
60
50
40
30
0
4
8
12
16
20
24
Area 3 Cool
Area 3 Heat





After constructing the model, the verified electric energy and demand savings, as determined by this M&V project, are as follows:

Application Proposed Annual savings (kWh)	**507,265**
Duke Projected savings (kWh)	**507,265**
M&V Results	**657,570**
Realization Rate	**1.30**

Application Proposed Peak Savings (kW)	**None noted**
Duke Projected Peak savings (kW)	**202**
M&V Results	**118**
Realization Rate	**0.58**

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
657,570	507,265	1.30	118	271	0.44	69	202	0.34

Electricity savings are due primarily to reductions in fan power, since the room fan coil units were running a full speed 24/7 prior to the implementation of the control system. Minimal cooling savings were obtained since the chilled water plant at the hotel utilizes a water-side economizer, which reduces the electricity required to produce chilled water. The impacts of the room temperature controls on electricity consumption are within 30% of the program expectations due to fan energy savings rather than chilled water savings.

Site 26

[redacted]

- Injection Molding Machine Retrofit

M&V Report

PREPARED FOR:
Duke Energy
Ohio

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

PREPARED IN:
January 2012

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

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

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

Introduction

This report addresses M&V activities for the [redacted] custom program application. The application covers installation of one PLC-controlled AC inverter drive system to vary the pump speed on one injection molding machine at [redacted] location in Cincinnati, Ohio. The measure included:

ECM-1 – New speed controller on injection molding machine motor

- *As is the case in many injection molding machines, the 60hp motor for the particular machine in the application was drastically oversized for its use, as the machine typically operates at the low end of its throughput capacity.*

  Installation of a PLC-controlled AC inverter drive system on the 60hp motor allows the motor to operate in its most efficient range, reducing the pressure drop across valves. In addition, the hydraulic system can be reduced to near zero power requirements during periods of inactivity within the molding cycle. The M&V plan was written for post-retrofit only.

Goals and Objectives

The projected savings goals identified in the application are:

Facility	Projected Annual kWh savings
[redacted]	48,017
Total	**48,017**

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

- Load shape, on/off schedule and duty cycle of the injection molding machine with the new VFD drive.
- Annual energy (kWh) savings

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	[redacted]
Duke Energy BRM		
Customer Contact	[redacted]	[redacted]

Site Locations/ECM's

Site	Address
[redacted]	[redacted]

DATA PRODUCTS AND PROJECT OUTPUT

- Load shape, on/off schedule and duty cycle of the injection molding machine with the new VFD drive.
- Annual energy (kWh) savings
- kWh Realization Rates

M&V OPTION

IPMVP Option A

M&V IMPLEMENTATION SCHEDULE

- The post-retrofit survey was conducted after the customer performed the motor drive retrofit.
    - The post-retrofit sequence of operations for the injection molding machine includes operation before 7am on Saturdays, no operation on Sundays, and no operation during the 9 holidays throughout the year.
    - Post-retrofit loggers and computer trend logs were used to record kW on the entire injection molding machine and to determine on/off hours and duty cycle.
    - Logger data was collected during normal operating hours, and overlapped with the Thanksgiving Holiday.
    - Computer trend data was collected during a day when the machine was in operation.

DATA ACCURACY

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

FIELD DATA POINTS

Post – installation

Survey data

- The injection molding machine runs weekdays only, with a Friday 3rd shift running until Saturday at 7am. The machine does not run on any of the 9 holidays throughout the year.

Time series data on controlled equipment

- Injection molding machine kW (with 1 low sampling rate data logger, AND 1 high sampling rate computer trend)

The data logger was setup for 15 minute instantaneous readings and deployed for 1 month. Computer trend data with high frequency sampling (< 1 second) was deployed for 2 consecutive shot cycles while the machine was running.

FIELD DATA LOGGING

- **Data Loggers**

  Post-retrofit, one logger was installed to measure the kW of the entire injection molding machine, at the breaker box. Each leg of the power cable was monitored with separate current transducers. Logging was at intervals of 15 minutes for 3 weeks, post-measure installation.

- **Computer trend data**

  Using the existing data trending system, the injection molding machine kW was monitored with a very high rate of sampling (<1 second) for two consecutive cycles during machine operation.

VERIFICATION AND QUALITY CONTROL

60. Logger and trend data was visually inspected for consistent operation. No data was removed.

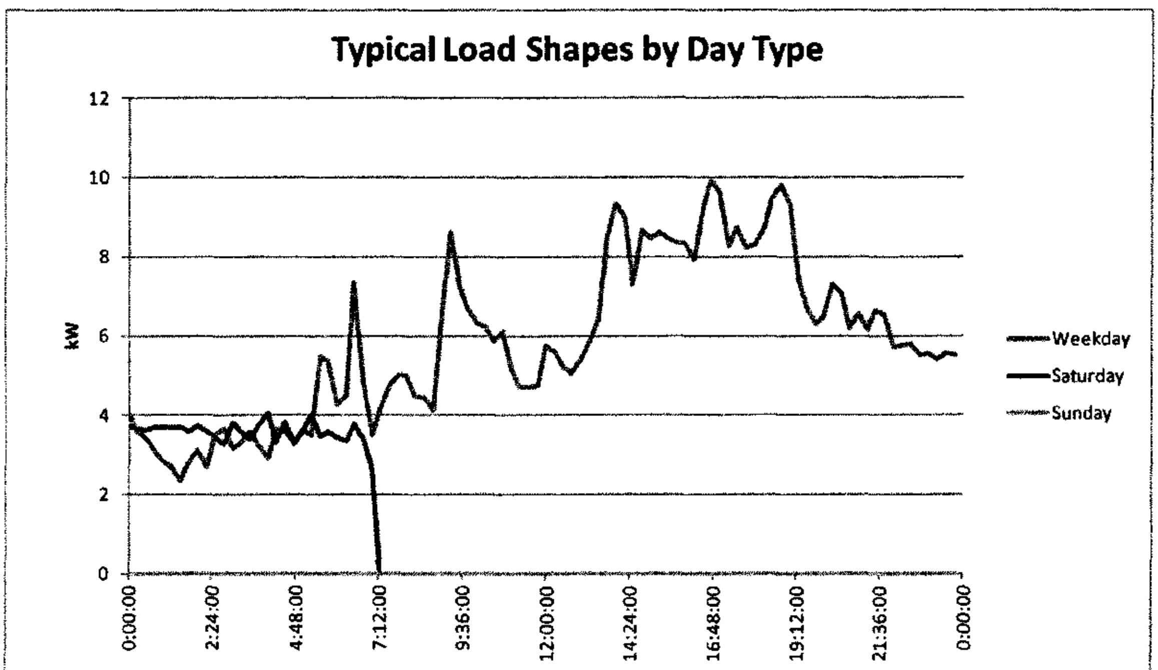
RECORDING AND DATA EXCHANGE FORMAT

50. Elite Pro logger binary files
51. Computer trend data files
52. Excel spreadsheets

DATA ANALYSIS

Logger data was used to determine the machine's ON/IDLE/OFF schedule, and used to estimate the total ON and IDLE hours for the machine throughout the year. Computer trend data was used to analyze load shape and duty cycle for when the machine was actually running. This data was compared to previously-analyzed data on the machine with a constant speed motor in order to determine the energy savings from switching to the VFD motor drive. Overall annual energy savings depends heavily upon the determined runtime, duty cycle, and load shape of the machine during production.

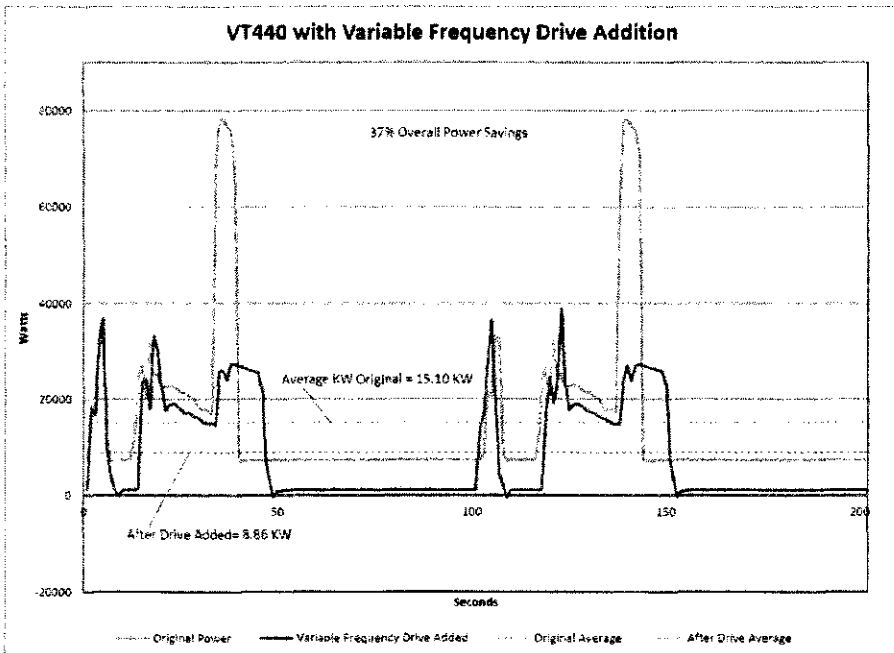
Average load shapes by day type can be seen in the graph below:



However, it was also observed that the machine experienced several long periods of time in idle mode, without manufacturing parts. These periods often lasted several hours, with an energy use of approximately 250W or 500W. A summary of ON/IDLE/OFF time can be seen in the following table:

Operation	On	Idling	Off
Weekdays	50%	39%	10%
Saturdays	10%	18%	72%
Sundays	0%	0%	100%
Holidays	0%	0%	100%

Pre- and post-retrofit energy consumption for the injection molding machine was largely dependent upon the energy consumption while idling between runs. The average energy consumption after VFD retrofit decreased from 15.1kW to 8.86kW. This is mainly due to the decrease in idling energy from 8.0kW to roughly 0.37kW. A detailed look at energy consumption during runs can be seen in the following figure:



Given the observed power consumption while ON or in IDLE (see table below), as well as the annual schedule (below) the annual energy consumption for the injection molding machine can be estimated.

Old Machine	On	Idling	Off
kW	15.1	8.0	0
New Machine	On	Idling	Off
kW	8.86	0.378	0

Days Per Year	
Weekdays	252
Saturdays	52
Sundays	52
Holidays	9
Total	365

The total expected energy savings from the VFD retrofit is 39,340 kWh, for a realization rate of 82%. Details can be seen below:

Energy Consumption [kWh]	On	Idling
Weekdays - OLD	45,662	18,870
Saturdays - OLD	1,884	1,797
Weekdays - NEW	26,793	890
Saturdays - NEW	1,106	85

Pre-Retrofit Consumption [kWh]	68,214
Post-Retrofit Consumption [kWh]	28,874
Evaluated Energy Savings [kWh]	**39,340**
Expected Savings [kWh]	48017
Realization Rate	**82%**

Cursory analysis reveals that even more energy can be saved by eliminating the long periods of time where the motor is in the IDLE, rather than in OFF position.

Final Project Savings Summary

The evaluated savings were compared to the final savings estimates from the DSMore runs. This comparison is shown in the Table below:

Final Project Savings and Realization Rate

Evaluated kWh Savings	Expected kWh Savings	kWh RR	Evaluated NCP kW Savings	Expected NCP kW Savings	NCP kW RR	Evaluated CP kW Savings	Expected CP kW Savings	CP kW RR
39,340	43,578	0.90	6	7	0.83	6	7	0.83