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Introduction

This report addresses M&V activities for lighting retrofit energy conservation measures (ECMs) as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of 760 parking lot lighting fixtures at eight locations in [redacted], NC.

ECM-1 – Replace Probe Start MH Fixtures with Pulse Start MH Fixtures

These measures involved replacing 716 1,000-watt standard probe-start metal halide (MH) fixtures with 320-watt pulse start MH fixtures (MHPS) and 44 400-watt standard probe-start MH fixtures with 200-watt MHPS fixtures. The installed fixture quanties were expected to be equal to the existing quantities.

Table 1 summarizes the proposed fixture installations.

Table 1. Proposed Lighting Fixture Installations

ECM	Qty	Measure	Location
1	23	1000W MH to 320W MHPS	redacted
2	5	1000W MH to 320W MHPS	redacted
3	34	1000W MH to 320W MHPS	redacted
4	24	1000W MH to 320W MHPS	redacted
5	21	1000W MH to 320W MHPS	redacted
6	12	1000W MH to 320W MHPS	redacted
7	113	1000W MH to 320W MHPS	redacted
8	179	1000W MH to 320W MHPS	redacted
9	135	1000W MH to 320W MHPS	redacted
10	170	1000W MH to 320W MHPS	redacted
11	8	400W MH to 200W MHPS	redacted
12	3	400W MH to 200W MHPS	redacted
13	14	400W MH to 200W MHPS	redacted
14	13	400W MH to 200W MHPS	redacted
15	6	400W MH to 200W MHPS	redacted
Total	**760**	-	-

Goals and Objectives

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

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Table 2. Project Goals

ECM	Facility Name	Applicant		Duke Energy			
		Annual kWh Savings	Average kW Reduction*	Projected Annual kWh Savings**	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	redacted	55,861	-	-	74,597	0	1.03
2	redacted	12,144	-	-	16,217	0	0.22
3	redacted	82,578	-	-	110,274	0	1.52
4	redacted	58,290	-	-	77,840	0	1.08
5	redacted	51,004	-	-	68,110	0	0.94
6	redacted	29,145	-	-	38,920	0	0.54
7	redacted	274,450	-	-	366,499	0	5.07
8	redacted	434,748	-	-	580,560	0	8.03
9	redacted	327,882	-	-	437,853	0	6.05
10	redacted	412,889	-	-	551,370	0	7.62
11	redacted	6,433	-	-	8,591	0	0.12
12	redacted	2,412	-	-	3,221	0	0.04
13	redacted	11,258	-	-	15,033	0	0.21
14	redacted	10,454	-	-	13,960	0	0.19
15	redacted	4,825	-	-	6,443	0	0.09
Total	**-**	**1,774,372**	**N/A***	**2,516,923**	**2,369,488**	**0**	**32.76**

* The applicant's proposed demand reductions for individual measures are not clearly documented.
** Source: DSMore input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 3 granted approval to plan and to schedule the site visit for this M&V effort.

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Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	p: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	p: 303-389-2509 Christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The locations where this project was installed are shown in Table 4.

Table 4. Project Locations

Location	Address	ECM
redacted	redacted	2, 12
redacted	redacted	3, 13
redacted	redacted	4
redacted	redacted	5, 14
redacted	redacted	6
redacted	redacted	7, 15
redacted	redacted	8
redacted	redacted	9
redacted	redacted	10
redacted	redacted	10
redacted	redacted	1, 11

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. As the site contact was based in a corporate office, he contacted general managers at the individual sites to explain the evaluation plan and alert them to the upcoming visit.

This project involved lighting retrofits at 11 different dealerships in seven separate locations across [redacted]. The on-site staff at most sites were car salespeople and not familiar with lighting fixture operations. At three sites ([redacted]), Cadmus spoke with facility managers who were familiar with the lighting fixture control strategy. The manager of the four [redacted] locations ([redacted]) said photosensors, located on facility roofs, controlled the fixtures. The [redacted] and [redacted] managers said the fixtures operated on timeclock control (set for 6:00 pm–7:00 am during winter and 7:00 pm–6:00 am during summer).

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All fixtures provided parking lot lighting and did not produce interactive effects with HVAC systems.

As the sites installed the same two fixture types, Cadmus installed a power meter at a single location. Light loggers could not be installed to verify operating hours due to the fixtures' outside location; weather and sunlight would either damage the meter or provide inaccurate measurements. Pole heights prevented Cadmus from accessing the fixtures' interiors.

Christie Amero and Tom Davis of Cadmus performed the site visits on January 8, 2016. Notably, site visits were performed on a cloudy, rainy day, which could have affected the status of exterior lighting fixtures.

Field Data

Cadmus visited all [redacted] locations to count fixtures and verify fixture and control types. One power meter was installed at the [redacted] location to verify electrical demand and operating hours on one lighting circuit. Table 5 summarizes total fixture counts at each location and fixture status at the time of inspection. Fixtures were on at the [redacted] and [redacted] locations during the inspection (~1:00 pm).

Fixture counts are based on Cadmus' walkthroughs of each property. Determining counts proved challenging as most properties bordered one another. For example, it was difficult to differentiate which fixtures should be considered on the [redacted] property or the [redacted] property.

Table 5. Summary of Lighting Fixture Counts and Control Strategies

ECM	Facility Name	Installed Fixture Description	Fixture Quantity		Status During Inspection	Control Strategy
			Proposed	Installed		
1	redacted	320W MH PS	23	22	Off	Timeclock, 6PM-7AM
2	redacted	320W MH PS	5	6	Off	
3	redacted	320W MH PS	34	41	ON	
4	redacted	320W MH PS	24	22	Off	
5	redacted	320W MH PS	21	64	Off	
6	redacted	320W MH PS	12	18	Off	
7	redacted	320W MH PS	113	82	Off	Timeclock, Time N/A
8	redacted	320W MH PS	179	177	Off	Photosensor
9	redacted	320W MH PS	135	134	Off	Photosensor
10	redacted	320W MH PS	170	152	Off	Photosensor
11	redacted	200W MHPS	8	4	Off	Timeclock, 6PM-7AM
12	redacted	200W MHPS	3	6	ON	
13	redacted	200W MHPS	14	14	ON	
14	redacted	200W MHPS	13	18	Off	

ECM	Facility Name	Installed Fixture Description	Fixture Quantity		Status During Inspection	Control Strategy
			Proposed	Installed		
15	redacted	200W MHPS	6	22	Off	Timeclock, Time N/A
Total		**-**	**760**	**782**		

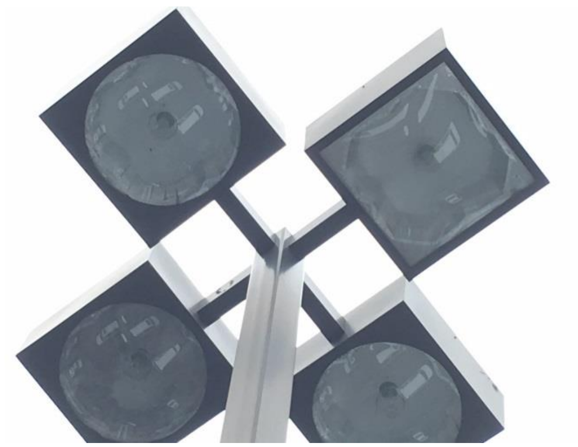
Cadmus also photographed installed parking lot fixtures at various locations. Figure 1 shows the parking lot at [redacted]. Figure 2 shows an energized lamp at [redacted] (which was forced on during the power meter installation). Figure 3 shows a two-fixture pole at the [redacted]. Figure 4 shows the four-fixture pole at [redacted].

Figure 1. [redacted] Parking Lot Fixtures

Figure 2. [redacted] Parking Lot Fixture – Lamp ON

Figure 3. [redacted] Parking Lot Fixture

Figure 4. [redacted] Parking Lot Fixture



Cadmus installed a three-phase, electric power meter on one exterior lighting circuit at [redacted], a circuit visually verified to feed five exterior lighting fixtures. Data were collected for two weeks at one-minute intervals. Table 6 summarizes the installed metering equipment;

Figure 5 shows the reading during Cadmus' verification of the circuit load.

Table 6. Summary of Installed Metering Equipment

Equipment ID	RX3000	WattNode 3D-480	Current Transducers (Qty/Size)
'OL Sect. 2' Circuit	1	1	3 / 50 A

Figure 5. [redacted] Lighting Circuit Metering – Current Reading

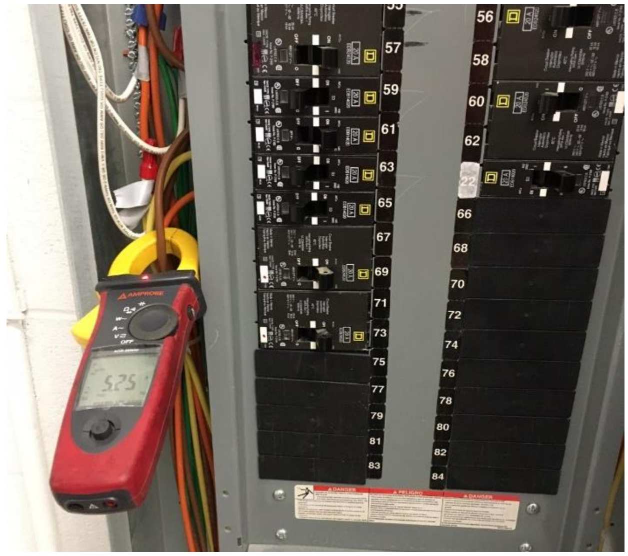
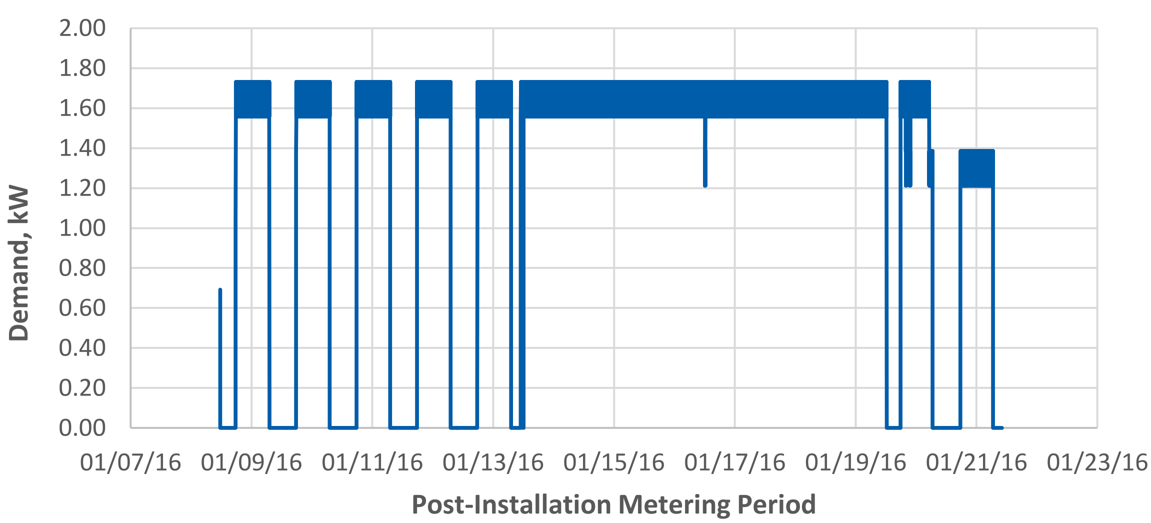


Figure 6 summarizes the two weeks of metered power data for the lighting circuit, with an average operating demand of 1.61 kW. As the panel served five fixtures, measured watts per fixture were 323 W, which falls within 5% of the input wattage submitted in the application (340 W).

Based on the power metered data, it appears a photosensor controlled the fixtures, given fixtures turned on at slightly different times every day. During most days, fixtures turned on around 5:45 pm and turned off a little after 7:00 am. However, the fixtures stayed on 24 hours per day, from January 13 at ~11:00 am to January 19 at 12:00 pm. While the additional operating hours were initially unclear, the Martin Luther King holiday fell on January 18 in 2016; this is a popular holiday for automotive marketing and sales. Cadmus assumed the lights remained on during this time for marketing purposes.

Figure 6. [redacted] Installed Fixture Power Metering Data



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Data Accuracy

Table 7. Metering Equipment Accuracy

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

Data Analysis

Cadmus used the power metered data to verify the installed fixtures' electric demand. A combination of metered data, site observations, and discussions with site personnel were used to verify operating hours. Fixture counts were used to verify quantities installed.

As the fixture input wattage for the 320-watt pulse start MH fixtures was 5% less than that submitted in the application (323-watt vs. 340-watt), this ratio also applied to the 200-watt pulse start MH fixtures.

The lighting fixture at the [redacted] and [redacted] locations remained on during the 1:00 pm inspection. Therefore, these fixtures were assumed to operate all hours of the year (i.e., 8,760 hours).

As metered data for the [redacted] fixtures showed 24-hour operation during holidays, it was assumed other dealerships followed a similar schedule. Additional hours were added for three days around seven holidays: MLK Day, Presidents' Day, Memorial Day, Fourth of July, Labor Day, Columbus Day, and Thanksgiving weekend. Total annual operating hours for timeclock and photosensor controls were 4,629 hours. Evaluated installed case energy use was 1,204,780 kWh and average demand was 137.5 kW.

As Cadmus could not measure the power usage of the pre-retrofit fixtures, input wattages were based on rated input wattages shown in Table 57 of the Massachusetts 2015 Technical Reference Manual (the rated input wattage for a 400-watt metal halide is 455-watt, and the rated wattage for a 1,000-watt metal halide is 1,075-watt).

Annual operating hours of the pre-retrofit fixtures were assumed equal to the installed fixtures as changes were not made to the control strategy. Evaluated pre-retrofit annual energy use was 3,838,663 kWh and average demand was 438.2 kW.

Evaluated total annual energy savings were 2,633,883 kWh. The average (or noncoincident) demand reduction for all sites was 300.7 kW. The summer coincident peak demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) was 0.0 kW as exterior lighting fixtures were not operated during that period.

Conclusion

Cadmus found most lighting fixtures installed as expected. Slight variations in quantities occurred, which may have been due to evaluator counting errors. Annual operating hours were higher than expected, given fixtures at [redacted] appeared to operate 24 hours per day during holiday weekends, and fixtures at [redacted] and [redacted] remained on during the middle of the day.

The fixture input wattage for the 320-watt pulse start MH fixtures was slightly lower than expected (5% less). This reduction in input wattage was applied to the 200-watt fixtures.

The overall energy savings realization rate was 111%; the summer coincident peak demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) was 100%; and the average (or noncoincident) peak demand reduction realization rate was 918%.

Table 8 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 9 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 8. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant	Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Annual kWh Savings	CP kW Reduction	Non-CP kW Reduction	Annual kWh Savings	CP kW Reduction	Non-CP kW Reduction
1	55,861	74,597	0	1.03	81,571	0.00	9.31
2	12,144	16,217	0	0.22	15,913	0.00	1.82
3	82,578	110,274	0	1.52	204,185	0.00	23.31
4	58,290	77,840	0	1.08	86,548	0.00	9.88
5	51,004	68,110	0	0.94	8,823	0.00	1.01
6	29,145	38,920	0	0.54	32,808	0.00	3.75
7	274,450	366,499	0	5.07	439,766	0.00	50.20
8	434,748	580,560	0	8.03	626,126	0.00	71.48
9	327,882	437,853	0	6.05	471,458	0.00	53.82
10	412,889	551,370	0	7.62	618,714	0.00	70.63
11	6,433	8,591	0	0.12	13,105	0.00	1.50
12	2,412	3,221	0	0.04	1,323	0.00	0.15
13	11,258	15,033	0	0.21	30,988	0.00	3.54
14	10,454	13,960	0	0.19	10,524	0.00	1.20
15	4,825	6,443	0	0.09	-7,968	0.00	-0.91
Total	**1,774,372**	**2,369,488**	**0**	**32.76**	**2,633,883**	**0.00**	**300.67**

Table 9. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW	Non-CP kW
1	109%	NA	904%
2	98%	NA	826%
3	185%	NA	1533%
4	111%	NA	915%
5	13%	NA	107%
6	84%	NA	694%
7	120%	NA	990%
8	108%	NA	890%
9	108%	NA	890%
10	112%	NA	927%
11	153%	NA	1247%
12	41%	NA	378%
13	206%	NA	1685%
14	75%	NA	632%
15	-124%	NA	-1011%
Total	**111%**	NA	**918%**

Application ID 14-1654031 Lighting Replacement: M&V Report

August 5, 2016

Duke Energy Carolina
139 East Fourth Street
Cincinnati, OH 45201

CADMUS

Prepared by:
Dave Korn
Christie Amero
Ari Jackson

Cadmus

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Introduction

This report addresses M&V activities for lighting retrofit energy conservation measures (ECMs), conducted as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of fluorescent T5 lighting fixtures with high-output T5 (T5-HO) lighting fixtures.

ECM-1—Replace Fluorescent T5 Lighting Fixtures with T5-HO Fixtures

The measure includes replacing 453 six-lamp, 351-watt T5 lighting fixtures with 453 225-watt T5-HO lighting fixtures.

Goals and Objectives

Table 1 shows projected savings goals identified in the project application.

Table 1. Project Goals

Applicant		Duke Energy		
Annual kWh Savings	Avg. Demand Reduction, kW	Claimed Annual kWh savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
354,112	57	337,186	55.8	55.8

The M&V project sought to verify actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for this M&V effort.

Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	office: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-289-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The location where this measure was installed is shown in Table 3.

Table 3. Project Location

Address	ECM
redacted	1

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Tom Davis of Cadmus performed the site visit on January 5, 2016.

Field Notes

During the site visit, Cadmus photographed fixture information, conducted a survey with facility personnel, and installed lighting loggers. The facilities operates seven days per week, and its schedule did not change after the installation. The site visit determined 432 fixtures were installed and not the originally reported 453.

Field Data

Cadmus installed 15 light loggers to meter the facility for two weeks; these data were then used to estimate annual hours of operation. Table 4 summarizes the light logger data.

Table 4. Summary of Meter Data

Meter S/N	Location	Metered Hours	Operating Hours	Percentage Operating	Projected Annual Operating Hours	Coincidence Factor
10374190	Break room	322	224	70%	6,092	100%
10374194	Back aisle - row #28	322	223	69%	6,066	100%
10374220	Receiving area - back right	322	218	68%	5,945	100%
10380395	Aisle 6	322	223	69%	6,070	100%
10380397	Showroom/aisle 99	322	225	70%	6,120	100%
10380400	Office area	322	223	69%	6,079	100%
10380405	Aisle 46 - bay #14	322	211	66%	5,746	100%
10380408	Aisle 27	322	219	68%	5,975	100%
10380409	Aisle 22	322	219	68%	5,964	100%
10380410	Aisle 14	322	173	54%	4,710	100%
10380415	Training/conference room	322	190	59%	5,184	99%
10380416	Automotive room	322	223	69%	6,080	100%
10380545	Front area aisle	322	211	66%	5,755	95%
10380612	Aisle 43	322	223	69%	6,065	100%
10380615	Aisle 8	322	211	66%	5,750	100%

Data Analysis

In the original analysis, annual operating hours for all fixtures were assumed to be approximately 6,049 hours. Cadmus averaged the projected annual hours of operation of all light loggers installed and applied the resulting estimates to calculate savings. On average, lights were projected to operate 5,840 hours annually. These values were applied to demand values and quantities confirmed on site to calculate savings, shown in Table 5. Additionally, Cadmus averaged peak coincidence factors for each space type and used these values to calculate peak demand reductions and applied waste heat factors to final numbers to account for HVAC interactive effects.

Table 5. Savings Calculations

Annual Operating Hours	Fixture Quantity	CF	Demand, kW		Energy Savings		
			Pre	Post	Average kW Reduction	CP kW Reduction	Annual kWh
5,840	432	100%	0.4	0.2	68.5	68.5	372,877

Conclusion

Cadmus found 21 fewer fixtures installed than expected. The energy savings realization rate was 111% compared to the Duke Energy claimed savings. The summer peak demand and noncoincident peak demand realization rates were calculated at 123%.

Table 6 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 7 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 6. Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
354,112	57	337,186	55.8	55.8	372,877	68.5	68.5

Table 7. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-CP kW
111%	123%	123%

Application ID 13-1594680 Lighting Replacement: M&V Report

August 5, 2016

Duke Energy Carolinas
139 East Fourth Street
Cincinnati, OH 45201

CADMUS

Prepared by:

Dave Korn

Christie Amero

Cadmus

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Introduction

This report addresses M&V activities for a lighting retrofit energy conservation measure (ECM), conducted as part of the [redacted] Smart $aver custom program application; specifically, the replacement of 157 metal halide lighting fixtures with 105 LED lighting fixtures.

Cadmus based the following facility and measure descriptions on the original project documentation.

ECM-1—Replace Metal Halide Fixtures with LED Lighting Fixtures

The measure involved replacing 157, 455-Watt, metal halide (MH) lighting fixtures with 105, six-lamp, 150-Watt LED fixtures. The customer applied for Smart $aver prescriptive incentives for motion sensors under a different application.

Goals and Objectives

Table 1 shows projected savings goals identified in the project application.

Table 1. Project Goals

Applicant		Duke Energy			
Annual kWh Savings	Avg. kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
524,990	60	490,528	490,520	56	56

* Source: DSMore input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for this M&V effort.

Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	p: 513-287-4096 frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The location where this measure was installed is shown in Table 3.

Table 3. Project Location

Address	ECM
redacted	1

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on January 7, 2016.

Field Lighting Survey

During the site visit, Cadmus met with the facility manager to review the attached lighting survey and to collect general operating information.

The facility produces prepackaged chicken products. Production runs 24 hours per day, Monday through Friday, but cleaners and maintenance personnel occupy the spaces during the weekends. The site contact estimated that lighting fixtures operate 24/7. The site observes four or five standard holidays per year.

There are a few occupancy sensors in the offices, small storage areas, and gowning areas, but the new fixtures were installed in the production areas. The facility has no photosensors.

The production area is served by an ammonia refrigeration system.

The site contact noted there has been a mix of increased and decreased light levels since the project implementation. Staff have reported that the light output seems brighter but has less range.

Field Data

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify and count the new lighting fixtures. Because the lighting fixtures are located in cooler or freezer spaces with daily spray-downs, no light loggers could be installed. Figure 1 shows installed LED lighting fixtures in the refrigerated warehouse space. Table 4 summarizes the installed lighting fixture counts.

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Figure 1. Refrigerated Warehouse LED Lighting Fixtures

Table 4. Installed Lighting Fixture Counts

#	Location Description	Installed Lighting Fixtures	
		Description	Quantity
1	Line 3 - 1st Room (Cooler)	LED MH Replacement, Wet Location	8
2	Line 3 - 2nd Room (Cooler)	LED MH Replacement, Wet Location	4
3	Line 3 - Pack Out	LED MH Replacement, Wet Location	3
4	Clean Room - #1	LED MH Replacement, Wet Location	1
5	Clean Room - Hall	LED MH Replacement, Wet Location	2
6	Clean Room - #3	LED MH Replacement, Wet Location	4
7	Line 1 - Marination	LED MH Replacement, Wet Location	15
8	Line 1 - Main	LED MH Replacement, Wet Location	7
9	Line 1 - Hall	LED MH Replacement, Wet Location	3
10	Battery Room	LED MH Replacement, Wet Location	4
11	Raw Process / Marination	LED MH Replacement, Wet Location	14
12	Shipping - 1	LED MH Replacement, Wet Location	5
13	Shipping - 2	LED MH Replacement, Wet Location	8
14	Storage Ingredients	LED MH Replacement, Wet Location	3
15	Hallway to Cooler	LED MH Replacement, Wet Location	3
16	Exterior Dock	LED MH Replacement, Wet Location	2
17	Freezer	LED MH Replacement, Wet Location	6
18	Cooler (Back)	LED MH Replacement, Wet Location	11
19	New Shipping Dock	LED MH Replacement, Wet Location	8
20	Line 1 - Clean Room	LED MH Replacement, Wet Location	4
Total	**-**	**-**	**115**

Data Analysis

Cadmus used the survey data and manufacturer's data to verify the power demand and operating hours of the controlled equipment. The installed fixture was confirmed to be the high-bay, CPS-HBL, 150-Watt LED fixture, listed on the Design Lights Consortium's (DLC) list of certified LED fixtures. The DLC lists the fixture input wattage as 152 Watts. The total number of installed fixtures, based on the walkthrough, are 115 fixtures. Based on the discussion with the facility manager, annual operating hours are 8,760 hours.

The evaluated installed lighting energy use is 153,125 kWh, with 17.5 kW annual average demand.

As Cadmus could not measure the power usage of the pre-retrofit fixtures, input wattages were based on the rated input wattages in Table 57 of the Massachusetts 2015 Technical Reference Manual. According to the TRM, the rated input wattage for a 400-Watt metal halide is 455 W.

Annual operating hours of the pre-retrofit fixtures were assumed equal to the installed fixtures as changes had not been made to the control strategy. The quantity was assumed equal to that assumed in the original study (i.e., 157 fixtures). Evaluated pre-retrofit lighting annual energy use is 625,771 kWh, and annual average demand is 71.4 kW.

The lighting fixture annual energy savings are 472,646 kWh; the average demand reduction is 54.0 kW.

Since the lighting retrofit was performed in refrigerated spaces, additional energy savings result from reduced load on the cooling system. The energy savings and demand reduction with HVAC interactions were calculated using the following equations for cooler and freezer LEDs in the Massachusetts Technical Reference Manual (TRM):

$$\text{Cooling Annual Energy Savings, kWh} = \text{Lighting Fixture Annual Energy Savings, kWh} * 0.28 * \text{Efficiency of Refrigeration System, kW/ton}$$

Where:

Lighting Fixture Annual Energy Savings, kWh = 472,646 kWh

0.28 = Conversion from kW and tons (3,412 Btuh/kW ÷ 12,000 Btuh/ton)

Efficiency of Refrigeration System, kW/ton = 0.8 kW/ton (assumption for ammonia system)

The cooling annual energy savings are 105,873 kWh and the demand reduction is 12.1 kW.

The evaluated total annual energy savings are 578,518 kWh. The annual average (or noncoincident) demand reduction is 66.0 kW. The summer coincident peak demand reduction (July, Monday–Friday, 4:00 pm–5:00 pm) is also 66.0 kW.

Conclusion

Cadmus found the LED lighting fixture type installed as expected with a slight increase in installed fixture quantity (115 fixtures versus 105 fixtures). The overall energy savings realization rate was 118%, compared to the Duke Energy claimed savings. The summer peak demand realization rate was calculated as 118% and the annual average (or noncoincident) peak demand reduction realization rate was also 118%.

While the installed fixture quantity increased, the evaluated energy savings account for reduced load on the refrigeration system, which was not accounted for in the original analysis.

Table 5 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 6 provides realization rates compared to energy savings and demand reductions claimed by Duke Energy.

Table 5. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
524,990	60	490,520	56.0	56.0	578,518	66.0	66.0

Table 6. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-CP kW
118%	118%	118%

Application ID 14-1658121
Lighting
M&V Report

November 16, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
An Employee-Owned Company • www.cadmusgroup.com

CADMUS

Prepared by:
Dave Korn
Christie Amero

Cadmus

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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for five retrofit energy conservation measures (ECMs) as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing 3,384 fluorescent T12 lighting fixtures with T8 lighting fixtures at one location in [redacted], North Carolina. Energy savings were expected to result from the reduced fixture input wattage. Descriptions of the ECMs as submitted in the application documentation are provided below.

ECMs: Replace Fluorescent T12 Fixtures with T8 Fixtures

[Redacted] is a property management company, located in [redacted], North Carolina. [Redacted] is a 281,226 square-foot, 19-story office building with an attached parking garage. Business hours are Monday through Friday, 7:00 a.m. to 7:00 p.m., and cleaning occurs on weekdays from 6:00 p.m. to 2:00 a.m. There is minimal weekend use; the original analysis estimated that 10% of the office lighting fixtures are used for a total of eight hours on weekends. The hallway, restroom, and parking garage lighting fixtures operate round the clock, all week. The annual electricity energy use is approximately 7,080,000 kWh, based on 2013 and 2014 utility data.

[Redacted] decided to replace fluorescent T12 lighting fixtures in offices, hallways, restrooms, and the parking garage with lower-wattage T8 fixtures. Table 1 summarizes pre-retrofit and installed lighting fixtures included in the five ECMs. All lighting fixtures were installed with Consortium for Energy Efficiency-qualified lamps and ballasts.

Table 1. Summary of Lighting ECMs

ECM	Location	Annual Operating Hours	Pre-Retrofit		Installed	
			Fixture Description	Quantity	Fixture Description	Quantity
1	Offices	4,680	3-lamp, 4-foot T12	2,268	2-lamp, 4-foot T8	2,268
2	Hallway	8,760	3-lamp, 4-foot T12	561	2-lamp, 4-foot T8	561
3	Restrooms	8,760	2-lamp, 4-foot T12	242	2-lamp, 4-foot T8	242
4	Parking Deck	8,760	2-lamp, 8-foot T12	198	4-lamp, 4-foot T8	198
5	Parking Deck	8,760	2-lamp, 4-foot T12	115	2-lamp, 4-foot T8	115
Total	**-**	**-**	**-**	**3,384**	**-**	**3,384**

Goals and Objectives

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

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Table 2. Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	1,114,495	N/A	705,257	686,352	150.70	65.97
2	516,008	N/A	491,436	491,427	56.10	56.07
3	116,596	N/A	116,596	116,594	13.31	13.30
4	154,369	N/A	133,555	133,553	15.25	15.24
5	53,392	N/A	48,355	48,354	5.52	5.52
Total	**1,954,860**	**N/A**	**1,495,199**	**1,476,280**	**240.87**	**156.10**

* Source: DSMore input spreadsheet.

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

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

Project Contacts

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

Table 3. Project Contacts

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

Site Location

The site location is listed in Table 4.

Table 4. Site Location

Address	ECM
redacted	1 through 5

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and schedule the site visit. Christie Amero of Cadmus performed the site visit on June 23, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager to review the lighting survey and to collect general operating information. Each floor of the 19-story building is composed of a central lobby area, hallways, and common bathrooms. Various tenant offices spaces wrap around the common areas. Five central elevators serve the 19 floors.

The facility operates Monday through Friday, from 6:00 a.m. to 12:00 a.m., year round. The building is closed on weekends and observes 10 standard holidays per year. Lighting fixtures in the common areas (lobbies, hallways, and bathrooms) are controlled by a timeclock. The current timeclock setting is 6:00 a.m. to 12:00 a.m., Monday through Friday. The cleaning crews and security staff are in change of turning fixtures in the private offices spaces on and off at the end of each day. There are no occupancy sensors in the common areas or offices.

The parking garage lighting fixtures are on both photocell and timeclock control. Each parking level has four rows of lighting fixtures: two in the center of the garage and one close to the exterior on each side. The lights in rows near the exterior are mostly off during daylight hours, based on the light level. The rows in the center are on during daylight hours since that area does not receive direct sunlight. All of the parking garage lighting is off from 12:00 a.m. to 6:00 a.m. when the building is closed.

Cooling for the building is provided by two 370-ton Trane water-cooled chillers, both of which are over 20 years old. The cooling system uses air-side economizer controls to provide free-cooling when outside air conditions allow. Conditioned air is distributed to the spaces via variable air volume boxes with electric reheat coils.

The facility manager confirmed that the site has retrofitted approximately 85% to 90% of the pre-retrofit T12 lamps with T8 lamps. They still use T12s in a few stairwells and storage rooms.

During the interview, the facility manager stated that in general, they have received positive feedback regarding the lighting retrofit and have noticed an improvement in lighting quality. However, some tenants have complained that the new T8 fixtures are too bright, so the facility staff removed some of the T8 lamps in a few offices.

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Field Data

ECMs: Replace Fluorescent T12 Fixtures with T8 Fixtures

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the installed lamp types and to install light loggers. Since the site still uses the pre-retrofit T12 lamps in a few stairwells and storage rooms, Cadmus was able to record the make and model for both the pre-retrofit and installed lamps. Figure 1 shows the make and model number of the new 4-foot T8 lamps that were installed throughout the building. The 4-foot Philips F32T8/ADV835/EW lamps have an of 28 watts.

Figure 2 shows the make and model number of the new Philips ADVANCE ICN-2P32-N electronic ballast and Figure 3 shows the ballast specifications.

Figure 4 shows an installed two-lamp, 2-foot by 4-foot T8 troffer lighting fixture, which is typical throughout the facility.

Figure 1. Installed Philips 28-Watt F32T8 Lamp

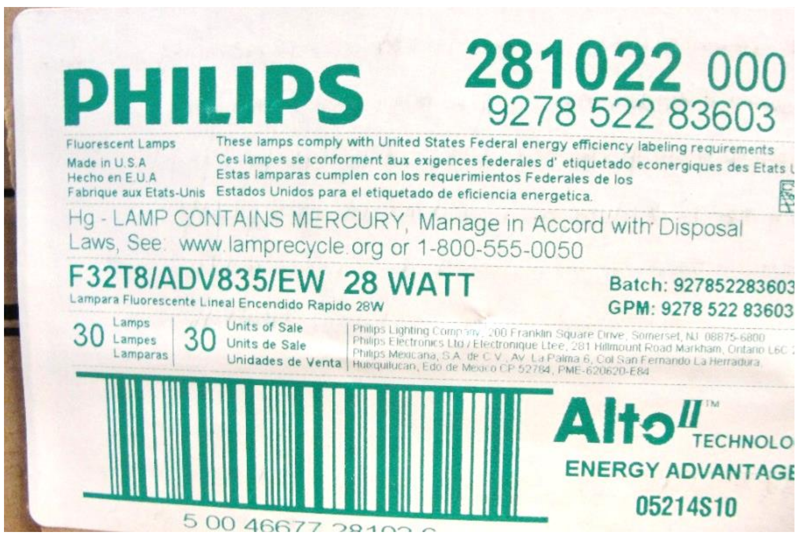


Figure 2. Installed Philips ADVANCE Electronic Ballast

Figure 3. Installed Philips Electronic Ballast Specifications

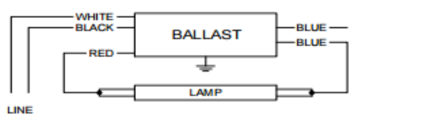
ADVANCE TRANSFORMER CO.

Electrical Specifications

ICN-2P32-N @ 120V	
Brand Name	**CENTIUM**
Ballast Type	**Electronic**
Starting Method	**Instant Start**
Lamp Connection	**Parallel**
Input Voltage	**120-277**
Input Frequency	**50/60 HZ**
Status	**Active**

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
* F17T8	1	17	0/-18	0.17	21	1.08	10	0.99	1.6	5.14
F17T8	2	17	0/-18	0.26	32	0.90	10	0.99	1.6	2.81
F25T8	1	25	0/-18	0.24	29	1.05	10	0.99	1.6	3.62
F25T8	2	25	0/-18	0.38	45	0.89	10	0.99	1.6	1.98
F32T8	1	32	0/-18	0.31	37	1.05	10	0.99	1.6	2.84
F32T8	2	32	0/-18	0.49	56	0.89	10	0.99	1.6	1.59
F32T8/ES (25W)	1	25	60/16	0.24	28	1.05	10	0.99	1.6	3.75
F32T8/ES (25W)	2	25	60/16	0.38	45	0.92	10	0.99	1.6	2.04
F32T8/ES (28W)	1	28	60/16	0.24	31	1.03	10	0.99	1.6	3.32
F32T8/ES (28W)	2	28	60/16	0.41	48	0.89	10	0.99	1.6	1.85
F32T8/ES (30W)	1	30	60/16	0.28	33	1.03	10	0.98	1.6	3.12
F32T8/ES (30W)	2	30	60/16	0.45	54	0.89	10	0.99	1.6	1.65
F40T8	1	40	32/00	0.35	42	1.00	10	0.98	1.6	2.38

Wiring Diagram



Diag. 68

Insulate unused blue lead for 1000V

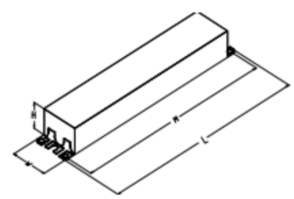
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	24	61
White	24	61
Blue	28	71.1
Red	45	114.3
Yellow		0
Gray		0
Violet		0

	in.	cm.
Yellow/Blue		0
Blue/White		0
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
9.5 "	1.3 "	1.0 "	8.9 "
9 1/2	1 3/10	1	8 9/10
24.1 cm	3.3 cm	2.5 cm	22.6 cm

Figure 4. Installed 2-Lamp 2-Foot by 4-Foot T8 Troffer

Figure 5 shows the make and model number of the pre-retrofit T12 lamp used in the common bathrooms, storage areas, and mechanical rooms. Figure 6 shows the make and model number of the pre-retrofit T12 lamp used in the offices and hallways.

Figure 5. Pre-Retrofit T12 Lamp – Bathrooms and Mechanical Rooms

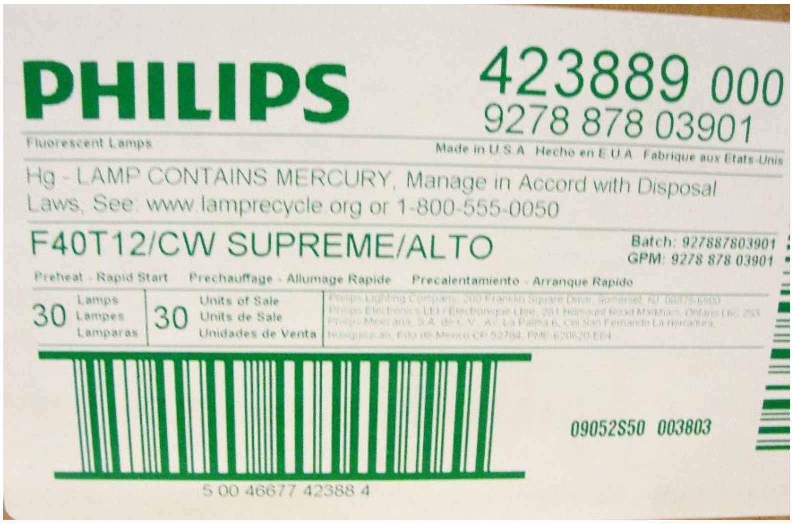
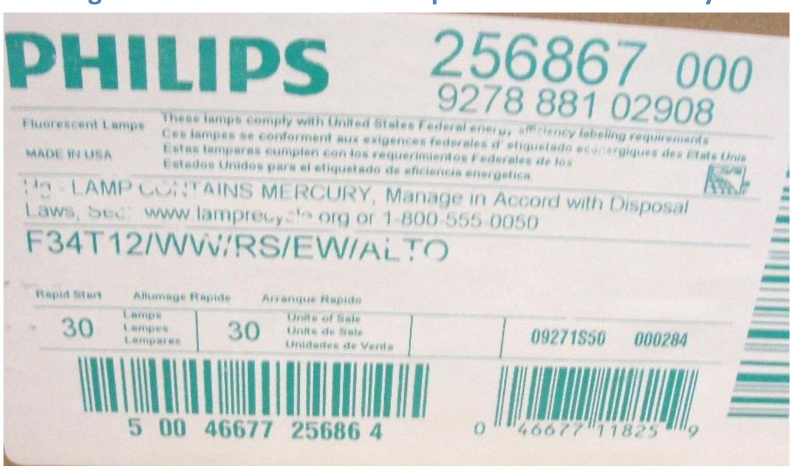


Figure 6. Pre-Retrofit T12 Lamp – Offices and Hallways



Cadmus installed eight light loggers on four floors of the facility (two per floor) and two loggers in the parking garage to collect fixture operating hours for a three-week period. Table 5 summarizes the locations of the light loggers and the monitored fixture types.

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Table 5. Summary of Fixture Counts and Installed Light Loggers

#	Floor	Location	Installed Fixture Description	Light Logger Serial Number
1	12	'United Guaranty' Office	2-lamp, 2-foot by 4-foot T8 troffer	10261581
2		Women's Restroom	3-lamp, 2-foot by 4-foot T8 troffer	10326559
3	17	Office	2-lamp, 2-foot by 4-foot T8 troffer	10272067
4		Common Area Hallway, Near Elevators	2-lamp, 2-foot by 4-foot T8 troffer	10272105
5	7	Office	2-lamp, 2-foot by 4-foot T8 troffer	10268223
6		Cubicles	2-lamp, 2-foot by 4-foot T8 troffer	10327029
7	3	Main Hallway	2-lamp, 2-foot by 4-foot T8 troffer	10326687
8		Private Office	2-lamp, 2-foot by 4-foot T8 troffer	10162076
9	Parking Garage	P2, Exterior Row, Level L	2-lamp, 4-foot T8 strip	10332054
10		P2, Interior Row, Level L	2-lamp, 4-foot T8 strip	10261597

Figure 7 through Figure 10 show the approximate locations (in red) where Cadmus installed light loggers on each floor of the building.

Figure 7. Floor 3 Light Logger Installation Locations

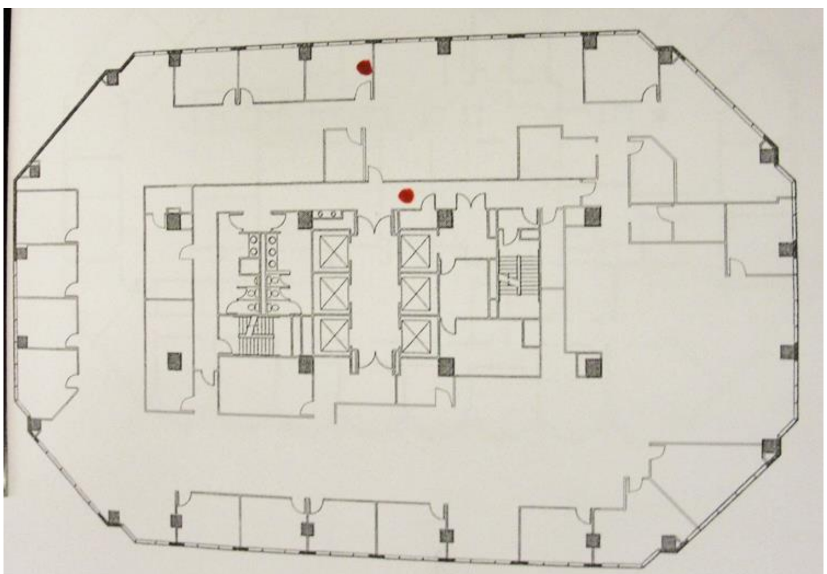

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Figure 8. Floor 7 Light Logger Installation Locations

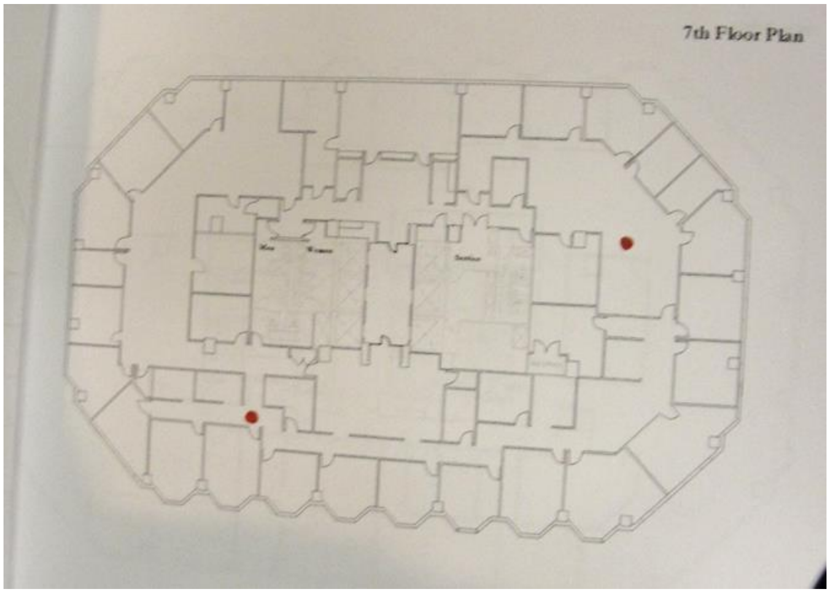

Figure 9. Floor 12 Light Logger Installation Locations

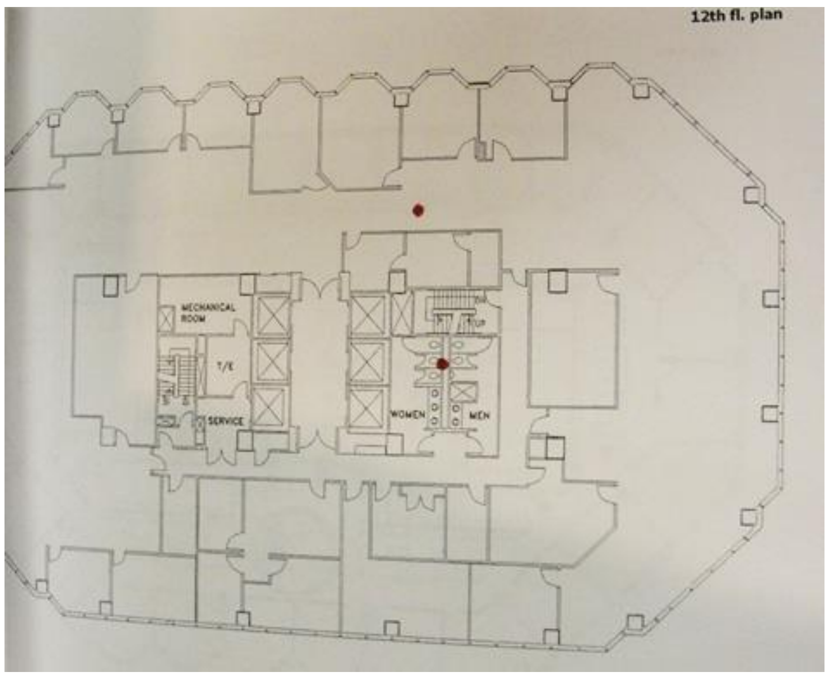

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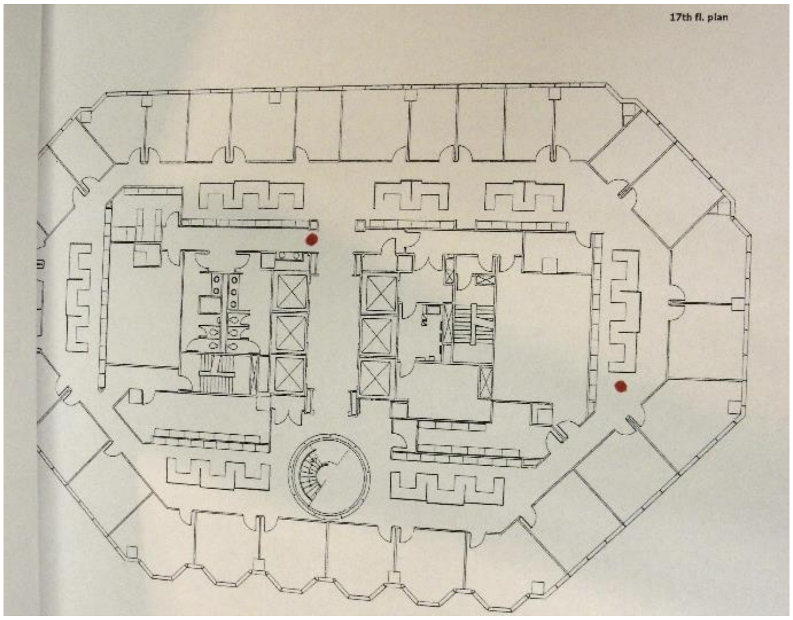
Figure 10. Floor 17 Light Logger Installation Locations



Data Analysis

ECMs: Replace Fluorescent T12 Fixtures with T8 Fixtures

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

Table 6. Summary of Light Logger Data

#	Floor	Location	Total Metered Hours	Total Operating Hours	Percentage Operating	Average Coincidence Factor
1	12	Office	614.9	321.9	52%	100%
2		Restroom	614.8	222.8	36%	100%
3	17	Office	614.6	197.5	32%	100%
4		Hallway	614.5	614.5	100%	100%
5	7	Office	614.6	208.6	34%	100%
6		Cubicles	614.6	207.7	34%	100%
7	3	Hallway	614.7	350.0	57%	100%
8		Office	614.7	96.5	16%	58%
9	Parking Garage	Exterior Row	613.3	304.8	50%	0%
10		Interior Row	614.6	614.6	100%	100%

Cadmus averaged the logger data for each space type and extrapolate to estimate annual operating hours and the peak coincidence factor:

- The five loggers in tenant office areas produced a mean projected annual runtime of 2,942 hours and a mean coincidence factor of 92%
- The two loggers in hallways produced a mean projected annual runtime of 6,874 hours and a mean coincidence factor of 100%
- The one logger in a restroom produced a projected annual runtime of 3,175 hours and a coincidence factor of 100%
- The two loggers in the parking garage produced a mean projected annual runtime of 6,557 hours and a mean coincidence factor of 50%

Based on the installed lamp and ballast model numbers collected on site, the total fixture input for the two-lamp, 2-foot by 4-foot T8 fixtures is 48 watts, and the total input for the four-lamp, 4-foot T8 fixtures is 94 watts. Cadmus adjusted the pre-retrofit T12 fixture wattages slightly based on the T12 lamp model numbers collected on site and technical reference manual rated wattages tables. We assumed that the pre-retrofit and installed case fixture quantities were equal to the original application based on sample area counts during the site visit.

The energy savings and peak demand reduction without HVAC interactive effects are 1,053,727 kWh and 236.91 kW, respectively.

Cadmus also calculated energy savings and demand reductions for interior fixtures with HVAC interactive effects, based on the heating and cooling system type collected on site. Cadmus used the waste heat factors listed in TechMarket Works' Process and Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in the Carolina System: Lighting and Occupancy Sensors report submitted in April 2013. The energy waste heat factor for a small office near Greensboro, North Carolina with air conditioner cooling, an economizer, and electric heating is -0.032 and the demand factor is 0.136. The following equation is used to calculate savings with HVAC interactions:

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

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

Where:

WHFe = Waste heat factor for energy (= -0.032)

WHFd = Waste heat factor for demand (= 0.136)

The total evaluated energy savings were 1,025,314 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 267.41 kW, and the average, or non-coincident, peak demand reduction was 117.04 kW.

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Conclusion

While on the site, Cadmus found the equipment installed as expected. The overall energy savings realization rate was 69%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 111%. The average (or non-coincident) peak demand reduction realization rate was 75%.

The most significant impact to energy savings was the reduction in annual operating hours. The evaluated annual operating hours for lighting fixtures in offices, hallways, and restrooms were 63%, 78%, and 36%, respectively, of those claimed in the original application. The evaluated average annual operating hours for the parking garage lighting fixtures were 75% of that claimed in the original application. The installed fixture wattages were also higher than that claimed in the original application, and pre-retrofit fixture wattages were lower.

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

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

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	1,114,495	N/A	686,352	150.70	65.97	529,608	193.71	60.46
2	516,008	N/A	491,427	56.10	56.07	306,101	52.26	34.94
3	116,596	N/A	116,594	13.31	13.30	23,798	8.80	2.72
4	154,369	N/A	133,553	15.25	15.24	131,121	10.00	14.97
5	53,392	N/A	48,354	5.52	5.52	34,685	2.65	3.96
Total	**1,954,860**	**N/A**	**1,476,280**	**240.87**	**156.10**	**1,025,314**	**267.41**	**117.04**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	77%	129%	92%
2	62%	93%	62%
3	20%	66%	20%
4	98%	66%	98%
5	72%	48%	72%
Total	**69%**	**111%**	**75%**

Application ID 14-1785459 Lighting M&V Report

November 15, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.

An Employee-Owned Company • www.cadmusgroup.com

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Prepared by:

Dave Korn

Christie Amero

Cadmus

CADMUS

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CADMUS

Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for three retrofit energy conservation measures (ECMs) as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing metal halide and fluorescent T12 lighting fixtures with LED high-bay lighting fixtures. Energy savings were expected to result from the reduced fixture input wattage and the reduced fixture quantity. Descriptions of the measures as submitted in the original application documentation are provided below.

ECMs: Replace Metal Halide and Fluorescent Fixtures with LED High-Bays

[Redacted] selected to replace the 943 metal halide lighting fixtures and 45 fluorescent T12 lighting fixtures in its approximately 40,000 square-foot distribution warehouse with 277 LED high-bay fixtures. The LED high-bay fixtures have a fixture input of 155 watts. All installed LED high-bay fixtures are listed on the Design Lights Consortium Qualified Products list.

The warehouse operates Mondays through Fridays, from 5:00 a.m. to 6:00 p.m., and Saturdays from 8:00 a.m. to 12:00 p.m. (3,588 hours per year). The annual electricity use for the facility remains unknown at this time due to limited billing data being available; [redacted] moved into the facility in August 2014.

Table 1 summarizes the pre-retrofit and installed lighting fixtures included in the three ECMs.

Table 1. Summary of Lighting ECMs

ECM	Pre-Retrofit		Installed	
	Fixture Description	Qty	Fixture Description	Qty
1	458 Watt Metal Halide	277	155 Watt LED High Bay	87
	2-Lamp, 8-Foot T12 (207 Watt)	45		
2	458 Watt Metal Halide	577	155 Watt LED High Bay	165
3	458 Watt Metal Halide	89	155 Watt LED High Bay	25
Total		**988**	**-**	**277**

Goals and Objectives

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

Table 2. Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	416,402	N/A	440,233	431,131	122.70	38.42
2	825,057	N/A	856,423	835,382	238.69	38.42
3	130,366	N/A	132,351	129,614	36.89	19.21
Total	**1,371,825**	**N/A**	**1,429,007**	**1,396,128**	**398.27**	**96.05**

* Source: DSMore input spreadsheet.

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

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

Project Contacts

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

Table 3. Project Contacts

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

Site Location

The site location is listed in Table 4.

Table 4. Site Location

Address	ECMs
redacted	1 through 3

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on June 23, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager and lighting contractor to review the lighting survey and to collect general operating information. The facility is a furniture distribution center with warehouse spaces, offices, and shipping and receiving areas. The facility operates Mondays through Saturdays, from 7:00 a.m. to 12:30 a.m., year round. The site observes seven holidays per year.

The areas where the lighting fixture retrofit was performed are neither heated nor cooled. There are a few emergency electric unit heaters in the warehouse, but these are only used a couple of days per year to prevent pipes from freezing.

The building was originally designed as a fabric spinning plant and required a high lighting power density. Almost 1,000 450-watt metal halides and 200-watt fluorescent T12 fixtures were used to meet the lighting requirements. There were no occupancy sensors and the fixtures were controlled manually.

After [redacted] moved into the building, the lighting system was redesigned to meet the reduced load. The fixture quantity was reduced to 277 LED high bay fixtures. Two Lithonia Lighting IBH LED fixture models were installed, identical except for their input wattage and lumen output. All of the installed LED lighting fixtures have ceiling-mounted occupancy sensors.

The facility manager confirmed that the lighting levels have decreased since the project was completed, as the site did not need the same lighting level that was used previously.

Field Data

ECMs: Replace Metal Halide and Fluorescent Fixtures with LED High-Bays

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the new lighting fixture types and to install light loggers. Figure 1 shows an installed LED high bay lighting fixture in one of the warehouse spaces (left) and the fixture make and model number (right). Figure 2 shows the ceiling-mounted occupancy sensors that were installed with the LED high bay lighting fixtures.

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Figure 1. Installed LED High Bay Lighting Fixture

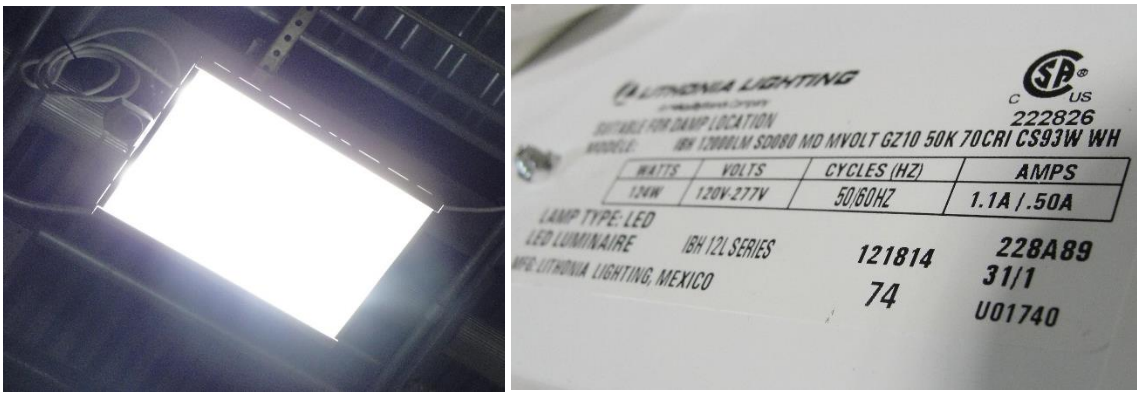

Figure 2. Installed Occupancy Sensors for LED High Bay Fixtures

Cadmus installed 10 light loggers throughout the facility to collect fixture operating hours for a three-week period. Table 5 summarizes the fixture quantities and locations of installed light loggers.

Table 5. Summary of Fixture Counts and Installed Light Loggers

#	Location	Fixture Description	Light Logger Serial Number
1	Parts Room	LED high bay (2-lamp)	10332061
2	Parts Room	LED high bay (2-lamp)	10380465
3	Parts/Rugs Room	LED high bay (2-lamp)	10162087
4	Parts/Rugs Room	LED high bay (2-lamp)	10327419
5	Rugs Room	LED high bay (2-lamp)	10171984
6	Rugs/Racks Room	LED high bay (2-lamp)	10268180
7	Warehouse/Showroom	LED high bay (2-lamp)	10374216
8	Receiving	LED high bay (2-lamp)	10380621
9	Warehouse/Garage	LED high bay (2-lamp)	10272716
10	FedEx/UPS	LED high bay (2-lamp)	10261711

Figure 3 shows one of the locations where Cadmus installed a light logger.

Figure 3. Light Logger Location #4

Data Analysis

ECMs: Replace Metal Halide and Fluorescent Fixtures with LED High-Bays

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

Table 6. Summary of Light Logger Data

#	Location	Total Metered Hours	Total Operating Hours	Percentage Operating	Average Coincidence Factor
1	Parts	537.9	450.82	84%	88%
2	Parts	532.4	37.73	7%	25%
3	Parts/Rugs	533.5	131.21	25%	79%
4	Parts/Rugs	531.2	32.24	6%	13%
5	Rugs	536.9	122.78	23%	82%
6	Rugs/Racks	537.5	107.20	20%	32%
7	Warehouse/Showroom	537.7	149.46	28%	66%
8	Receiving	538.0	223.53	42%	105%
9	Warehouse/Garage	537.8	228.46	42%	79%
10	FedEx/UPS	535.7	116.42	22%	67%
Average		**535.9**	**160.00**	**30%**	**64%**

The 10 loggers produced a mean projected annual runtime of 2,610 hours. During the three-week metering period, the site produced a mean coincidence factor of 64%. Cadmus assumed that the projected annual operating hours and coincidence factor were equal in the pre-retrofit and installed cases.

The project lighting contractor provided the specification sheets for the installed LED lighting fixtures. All of the installed fixtures are Lithonia Lighting LED high bays, model IBH. Most of the fixtures have an output of 12,000 lumens and input of 123 watts. Only the fixtures in the shipping and receiving areas are 9,000 lumens with an input of 98 watts. Figure 4 shows the lumens and wattages for the selected LED fixtures.

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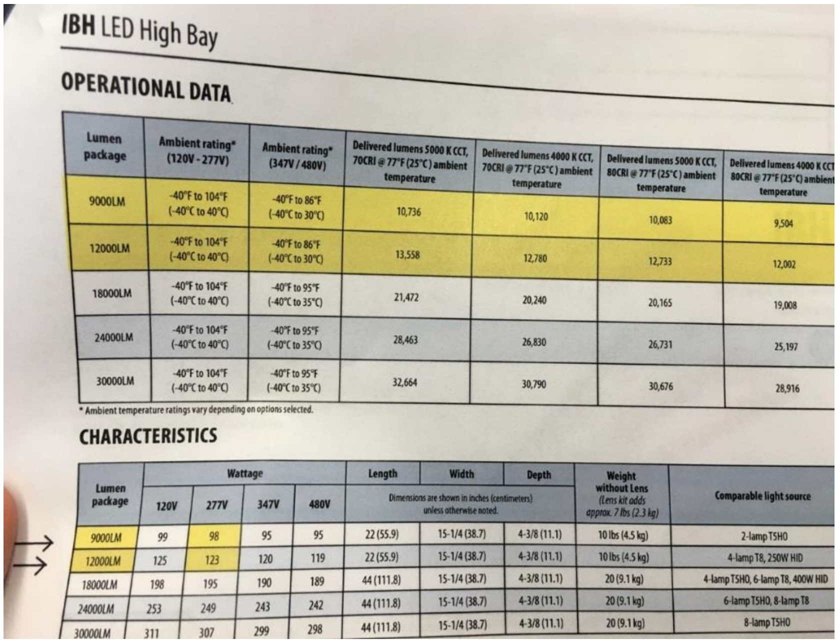
Figure 4. Specifications for Installed LED High Bay Fixtures



IBH LED High Bay

OPERATIONAL DATA

Lumen package	Ambient rating* (120V - 277V)	Ambient rating* (347V / 480V)	Delivered lumens 5000 K CCT, 70CRI @ 77°F (25°C) ambient temperature	Delivered lumens 4000 K CCT, 70CRI @ 77°F (25°C) ambient temperature	Delivered lumens 5000 K CCT, 80CRI @ 77°F (25°C) ambient temperature	Delivered lumens 4000 K CCT, 80CRI @ 77°F (25°C) ambient temperature
9000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 86°F (-40°C to 30°C)	10,736	10,120	10,083	9,504
12000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 86°F (-40°C to 30°C)	13,558	12,780	12,733	12,002
18000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 95°F (-40°C to 35°C)	21,472	20,240	20,165	19,008
24000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 95°F (-40°C to 35°C)	28,463	26,830	26,731	25,197
30000LM	-40°F to 104°F (-40°C to 40°C)	-40°F to 95°F (-40°C to 35°C)	32,664	30,790	30,676	28,916

* Ambient temperature ratings vary depending on options selected.

CHARACTERISTICS

Lumen package	Wattage				Length	Width	Depth	Weight without Lens (Lens kit adds approx. 7 lbs (2.3 kg)	Comparable light source
	120V	277V	347V	480V	Dimensions are shown in inches (centimeters) unless otherwise noted.				
9000LM	99	98	95	95	22 (55.9)	15-1/4 (38.7)	4-3/8 (11.1)	10 lbs (4.5 kg)	2-lamp T5HO
12000LM	125	123	120	119	22 (55.9)	15-1/4 (38.7)	4-3/8 (11.1)	10 lbs (4.5 kg)	4-lamp T8, 250W HID
18000LM	198	195	190	189	44 (111.8)	15-1/4 (38.7)	4-3/8 (11.1)	20 (9.1 kg)	4-lamp T5HO, 6-lamp T8, 400W HID
24000LM	253	249	243	242	44 (111.8)	15-1/4 (38.7)	4-3/8 (11.1)	20 (9.1 kg)	6-lamp T5HO, 8-lamp T8
30000LM	311	307	299	298	44 (111.8)	15-1/4 (38.7)	4-3/8 (11.1)	20 (9.1 kg)	8-lamp T5HO

This project involved a change in space use (manufacturing to warehouse) and in the required light levels. For this reason, Cadmus could not compare the energy use of the installed, low power density lighting system to the pre-retrofit, high power density lighting system. In order to evaluate the savings, we determined a 'baseline' lighting system design with the same number of lighting fixtures to the installed system. If the site did not choose to install LEDs, we assumed they would have removed or de-lamped a percentage of the pre-retrofit 400-watt metal halide and fluorescent T12 lighting fixtures. Since Cadmus could not verify the power usage of the pre-retrofit fixtures, we confirmed their specific power using technical reference manuals.

The adjusted total pre-retrofit quantity was 277 fixtures, compared to 988 fixtures in the original application (72% reduction).

The evaluated installed case annual energy use was 87,288 kWh. The coincident peak demand was 21.30 kW, and the average annual demand was 9.96 kW.

The evaluated pre-retrofit annual energy use was 323,133 kWh; coincident peak demand was 78.87 kW; and average annual demand was 36.89 kW.

The total evaluated energy savings were 235,845 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00p.m. to 5:00 p.m.) was 57.56 kW, and the average, or non-coincident, peak demand reduction was 26.92 kW.

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Conclusion

While on the site, Cadmus found the equipment installed as expected. The overall energy savings realization ratio was 16.9%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 14.5%. The average (or non-coincident) peak demand reduction realization ratio was 28.0%.

The evaluated energy savings and demand reduction for this project are significantly lower than the claimed values because the original analysis did not account for the change in space use and load. The original analysis calculated savings as a retrofit project (comparing proposed equipment to existing equipment), but should have been analyzed as a new construction project (comparing proposed equipment to a comparable baseline design that would meet the same load requirements).

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

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

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	416,402	N/A	431,131	122.70	38.42	68,099	16.62	7.77
2	825,057	N/A	835,382	238.69	38.42	144,258	35.21	16.47
3	130,366	N/A	129,614	36.89	19.21	23,488	5.73	2.68
Total	**1,371,825**	**N/A**	**1,396,128**	**398.27**	**96.05**	**235,845**	**57.56**	**26.92**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	15.8%	13.5%	20.2%
2	17.3%	14.8%	42.9%
3	18.1%	15.5%	14.0%
Total	**16.9%**	**14.5%**	**28.0%**

Application ID 14-1772467 LED Lighting: M&V Report

August 5, 2016

Duke Energy Carolina
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.
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CADMUS

Prepared by:
Dave Korn
Christie Amero
Ari Jackson

Cadmus

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Introduction

This report addresses M&V activities for lighting retrofit energy conservation measures (ECMs), conducted as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of fluorescent lighting fixtures with LEDs at three [redacted] locations in South Carolina.

ECMs—Replace Fluorescent Lighting Fixtures with LEDs

The customer replaced 39 four-lamp, 2'x4', 160-Watt T12 lighting fixtures with 39 two-lamp, 4-foot 44-watt LED lighting fixtures.

Goals and Objectives

Table 1 summarizes projected savings goals identified in the project application.

Table 1. Project Goals

ECM	Applicant		Duke Energy		
	Annual kWh Savings	Avg. kW Reduction	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	7,849	1.7	8,353	1.8	1.8
2	5,756	1.3	6,126	1.3	1.3
3	6,803	1.5	7,240	1.6	1.6
Total	**20,408**	**4.5**	**21,719**	**4.7**	**4.7**

The M&V project sought to verify the actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for this M&V effort.

Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	office: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 Christie.amero@cadmusgroup.com
Customer	redacted	

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Site Location

The locations where these measures were installed are shown in Table 4.

Table 3. Project Locations

Address	ECM
redacted	1
redacted	2
redacted	3

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visits for the three locations. Tom Davis of Cadmus performed the site visits on January 4, 2016.

Field Notes

As the three locations were retail stores, store clerks made much of the on-site personnel. Facility descriptions are based only on Cadmus' observations. While on site, Cadmus installed lighting loggers to monitor the ECMs' hours of use.

Field Data

Cadmus performed a walkthrough of each location to verify and count the new lighting fixtures and to install light loggers.

In each facility, Cadmus installed light loggers to collect fixture operating hours over two weeks. Table 4 summarizes the fixture quantities and locations of installed light loggers.

Table 4. Summary of Light Logger Metered Data

Site	Meter S/N	Location	Metered Hours	Operating Hours	Percentage Operating	Projected Annual Operating Hours	CF
redacted	10380404	Main store	322	119	37%	3,229	86%
	10380529	Bathroom	322	1	0%	15	0%
	10380569	Main store	322	119	37%	3,231	86%
	10380600	Back storage	322	17	5%	449	6%
redacted	10268288	Cigar room	322	322	100%	8,760	100%
	10380396	Main store	322	129	40%	3,518	86%
	10380414	Bathroom	322	35	11%	941	12%
	10380607	Main store	322	128	40%	3,497	86%

Site	Meter S/N	Location	Metered Hours	Operating Hours	Percentage Operating	Projected Annual Operating Hours	CF
redacted	10380406	Main store	322	0	0%	12	0%
	10380394	Back room	322	27	8%	743	70%
	10380407	Cigar room	322	120	37%	3,281	86%
	10380411	Main store	322	120	37%	3,281	86%
	10380412	Main store	322	121	38%	3,295	86%

Data Analysis

Cadmus used the survey and light logger data to verify the demand and operating hours of the installed lighting fixtures and applied waste heat factors to final numbers to account for HVAC interactive effects. Table 5 summarizes the energy savings calculations.

Table 5. Energy Savings Calculations

Actual Operating Hours	CF	Quantity	Demand, kW		Energy Savings		
			Pre	Post	Average kW Reduction	CP kW Reduction	Annual kWh
2,635	61%	15	0.16	0.04	1.8	1.1	4,743
		13	0.16	0.04	1.6	1.0	4,111
		11	0.16	0.04	1.3	0.8	3,478
Total*					**5.3**	**3.2**	**13,602**

* Includes HVAC interactive effects.

Conclusion

Cadmus found the equipment installed as expected. The overall energy savings realization ratio was 68% compared to Duke Energy's claimed savings. The summer peak demand realization rates were calculated as 63%. The average (or noncoincident) peak demand reduction realization ratio was 113%.

Energy savings were reduced due to the original analysis assuming a greater number of operating hours than the facility actually operates.

Table 6 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction.

Table 7 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

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Table 6. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	7,849	1.7	8,353	1.8	1.8	4,743	1.1	1.8
2	5,756	1.3	6,126	1.3	1.3	4,111	1.0	1.6
3	6,803	1.5	7,240	1.6	1.6	3,478	0.8	1.3
Total*	**20,408**	**4.5**	**21,696**	**4.7**	**4.7**	**13,602**	**3.2**	**5.3**

* Includes HVAC interactive effects.

Table 7. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-Coincident Peak kW
63%	68%	113%

Application ID 13-1358865
Lighting
M&V Report

August 26, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.

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Dave Korn
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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for three retrofit energy conservation measures (ECMs) included as part of the [redacted], Smart $aver custom incentive program application. Specifically, [redacted], a property management company, performed a lighting retrofit at its [redacted] building in North Carolina, and expected to save energy as a result of reduced fixture operating hours.

The three-story office building is occupied mainly from Monday through Friday during normal business hours. The building's annual electric energy use is 6,639,000 kWh, based on utility data for 2012 and 2013. Descriptions of the three ECMs as submitted in the application documentation are provided below.

ECM-1: Relocate 8,760-Hour Lighting Circuits to New Panels with Scheduling

Pre-Retrofit: The site previously used 222 non-emergency lighting fixtures on emergency lighting panels, which caused the lights to operate 24 hours per day, seven days per week, even though the spaces were occupied only during normal business hours.

The original analysis assumed that all 222 fixtures were two-lamp, 4-foot fluorescent fixtures with 32-watt T8 lamps. The fixture input was assumed to be 59 watts.

Installed: This measure involved relocating the 222 lighting fixture circuits to new relay panels. This allowed the facility to schedule the fixtures to turn off during unoccupied periods. The original analysis claimed updated lighting fixture operating hours as follows:

- First floor (24 fixtures): 13 hours per day, Monday through Friday, or 3,380 hours per year
- Second floor (127 fixtures): 13 hours per day, Monday through Friday, or 3,380 hours per year
- Third floor (71 fixtures): 13.6 hours per day, Monday through Friday, or 3,536 hours per year

Energy savings were expected to result from reduced lighting fixture operating hours, being turned off overnight and on weekends. This measure did not produce peak demand reduction, as fixtures were operated during the peak period.

ECM-2: Replace Parking Lot Photocells with Timeclock Controls

Pre-Retrofit: The site's exterior parking lot lighting fixtures were controlled by photocells, which automatically enabled lighting fixtures when ambient light levels decreased. Twelve of the fixtures were located in a remote parking lot, with no overnight use and minimal weekend use, as additional parking is located closer to the building.

The original analysis assumed that all 12 fixtures had an input of 1,150 watts.

Installed: This measure involved replacing photocells for the 12 fixtures with timeclock controls, which the facility programmed to turn the fixtures off overnight and on weekends. Programmed fixture operating hours were six hours per evening, weekdays only.

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Energy savings were expected to result from reduced fixture operating hours, used only for a limited time overnight and not on weekends. This measure did not produce peak demand reduction, as the exterior lighting was not operated during the peak period (both pre-retrofit and installed).

ECM-3: Install New Lighting Control System with Zone Control

Pre-Retrofit: The site's pre-retrofit, single-zone, lighting control system was based on each building wing. This control strategy forced most lighting fixtures to stay on longer than necessary, when some zones were occupied longer than others. Table 1 shows pre-retrofit operating hour assumptions.

The original analysis assumed that all controlled 3,525 lighting fixtures were two-lamp, 32-watt T8 fixtures with a total input of 59 watts.

Installed: The measure involved installing a new, multi-zone lighting control system, which allowed the facility to program different schedules for each zone in each wing and to reduce lighting fixture operating hours. Table 1 summarizes the assumed, installed fixture operating hours for each zone.

Table 1. Zone Controls—Pre-Retrofit and Installed Fixture Operating Hours

Floor	Wing	Zone	Operating Hours Per Week		Percentage Reduction
			Pre-Retrofit	Installed	
1	Purple	1	99.8	55.0	45%
		2		65.0	35%
		3		55.0	45%
	Blue	1	76.4	55.0	28%
	Red	1	168.0	55.0	67%
		2		65.0	61%
		3		75.5	55%
	Teal	1	113.9	65.0	43%
2	Purple	1	168.0	84.0	50%
	Blue	1	93.8	65.0	31%
		2		70.0	25%
		3		79.0	16%
	Red	1	92.3	55.0	40%
		2		55.0	40%
		3		65.0	30%
		4		85.0	8%
		5		64.0	31%
		6		60.0	35%
		7		70.0	24%
	Teal	1	65.8	55.0	16%
		2		52.5	20%
		3		62.5	5%
3	Purple	1	81.0	69.0	15%
	Blue	1	93.0	93.0	0%

Floor	Wing	Zone	Operating Hours Per Week		Percentage Reduction
			Pre-Retrofit	Installed	
		2		60.0	35%
		3		73.0	22%
	Middle	1	96.5	79.0	18%
	Red	1	96.5	55.0	43%
		2		69.0	28%
		3		52.5	46%
	Teal	1	80.0	60.0	25%
		2		66.0	18%

Goals and Objectives

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

Table 2. Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	75,730	N/A	69,786	69,451	0	7.96
2	38,916	N/A	38,916	39,533	0	0.32
3	385,638	N/A	355,511	360,080	0	30.83
Total	**500,284**	**N/A**	**464,213**	**469,065**	**0**	**39.11**

* Source: DSMore input spreadsheet.

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

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

Project Contacts

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

Table 3. Project Contacts

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

Site Location

The site location is listed in Table 4.

Table 4. Site Location

Address	ECM
redacted	1, 2, & 3

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on June 24, 2016.

Field Survey

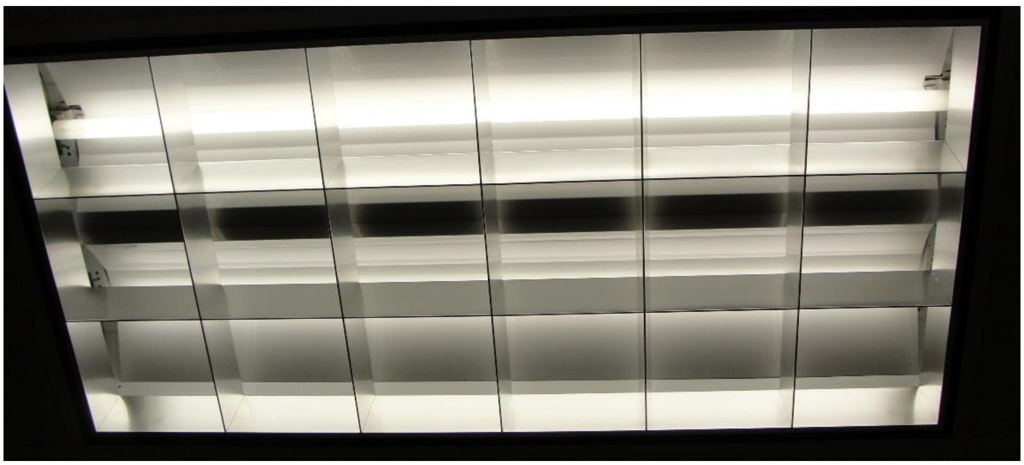
During the site visit, Cadmus met with the facility manager to review the lighting survey and to collect general operating information. The three-story building is laid out in an “X” shape with four separate wings: red, blue, purple, and teal. There is currently one tenant leasing the red, blue, and purple wings. The teal wing is completely unoccupied and there are no new tenants to fill the space. The third floor of the red wing is also unoccupied.

Most of the areas in the building are occupied during typical office hours (Monday through Friday, 7:00 a.m. to 6:00 p.m.). The building is closed on all federal holidays. The interior lighting fixtures are controlled by a central EMS and most lighting zones are programmed to be in “occupied” mode from 6:00 a.m. to 11:00 p.m., Monday through Sunday. There are 12 electrical panels controlling the lighting fixtures in the building (one on each floor of each wing). The exterior parking lot pole and wall pack lighting fixtures are also controlled by the central EMS.

Cooling for the building is provided by two 450-ton variable speed chillers. According to the facility manager, the chillers were installed less than three years ago. The cooling system uses economizer control to provide free cooling when outside air conditions allow. Heating is provided by electric perimeter reheat coils only. Conditioned air is distributed to the zones by variable air volume (VAV) boxes. There are approximately 14 VAV boxes per building floor, and only half are equipped with electric heating coils.

Most of the existing lighting fixtures in the offices and hallways are two-lamp, 2-foot by 4-foot parabolic troffers with fluorescent T8 lamps (see Figure 1). The lamps are EiKO model F32T8/841K and the ballasts are GE232MAXP-N/ULTRA. The total fixture input is 54 watts. Many of the downlights in the central lobbies and elevators were recently converted to LED.

Figure 1. Existing Parabolic Troffer with T8 Lamps



Field Data

After completing the lighting survey, Cadmus reviewed the central lighting control system and recorded current schedules, performed a walkthrough of the facility to verify the existing interior and exterior lighting fixture types, and installed light loggers on a sample of interior fixtures. A summary of the field data we collected for each ECM is provided below.

ECM-1: Relocate 8,760-Hour Lighting Circuits to New Panels with Scheduling

In order to estimate the number of lighting fixtures currently on emergency circuits, Cadmus counted the lighting fixtures that were on in the teal wing, since only the emergency fixtures were energized. There were 31 fixtures on in the first floor and 25 fixtures on in the third floor. There was construction on the second floor and some of the non-emergency fixtures were on, so we did not count the second floor. According to the facility manager, the number of emergency fixtures should be approximately the same in each wing.

ECM-2: Replace Parking Lot Photocells with Timeclock Controls

There are seven two-lamp high pressure sodium (HPS) pole fixtures and two one-lamp HPS pole fixtures in the overflow lot. Figure 2 shows one of the HPS pole fixtures in the remote lot.

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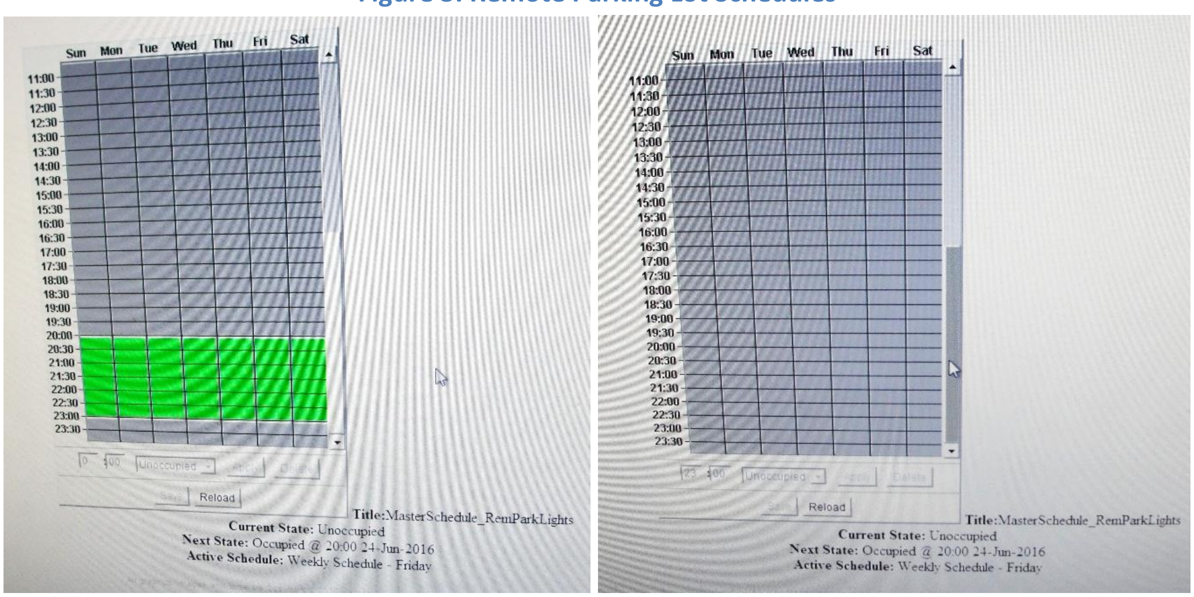
Figure 2. Remote Parking Lot

While reviewing the lighting control schedules during the site visit, Cadmus identified that the exterior lighting fixtures in the overflow parking lot were on timeclock control from 8:00 p.m. to 11:00 p.m. during the summer months and from 5:00 p.m. to 11:00 p.m. during the winter months. However, the facility manager pointed out that this parking lot has been closed due to reduced occupancy in the building and the lights are not required. The facility manager adjusted the timeclock schedule to keep the exterior fixtures in the overflow lot off at all times. Figure 3 shows the original and adjusted timeclock schedules.

Figure 3. Remote Parking Lot Schedules



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ECM-3: Install New Lighting Control System with Zone Control

Cadmus reviewed the central lighting control schedule and installed five light loggers to evaluate the energy savings from this measure. Figure 4 shows the red and blue wings' first floor layouts and current schedules. According to the central controls, the lighting fixtures in all zones of the blue wing are scheduled to be on from 6:00 a.m. to 11:00 p.m., Monday through Sunday. Figure 5 shows the purple and teal wings' first floor layouts and current schedules. The teal wing is currently unoccupied.

Figure 4. Red (left) and Blue (right) Wings' Lighting Schedules

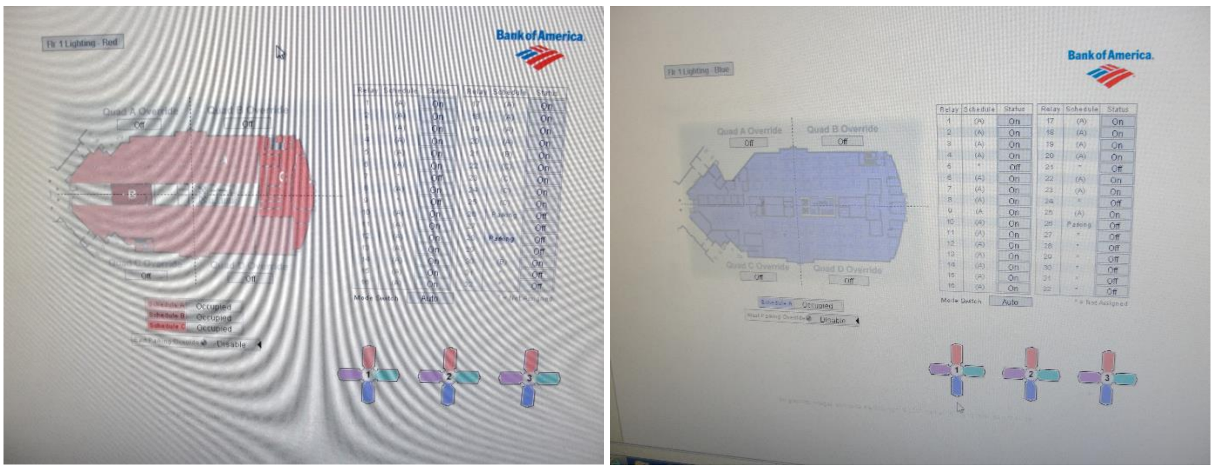

Figure 5. Purple (left) and Teal (right) Wings' Lighting Schedules

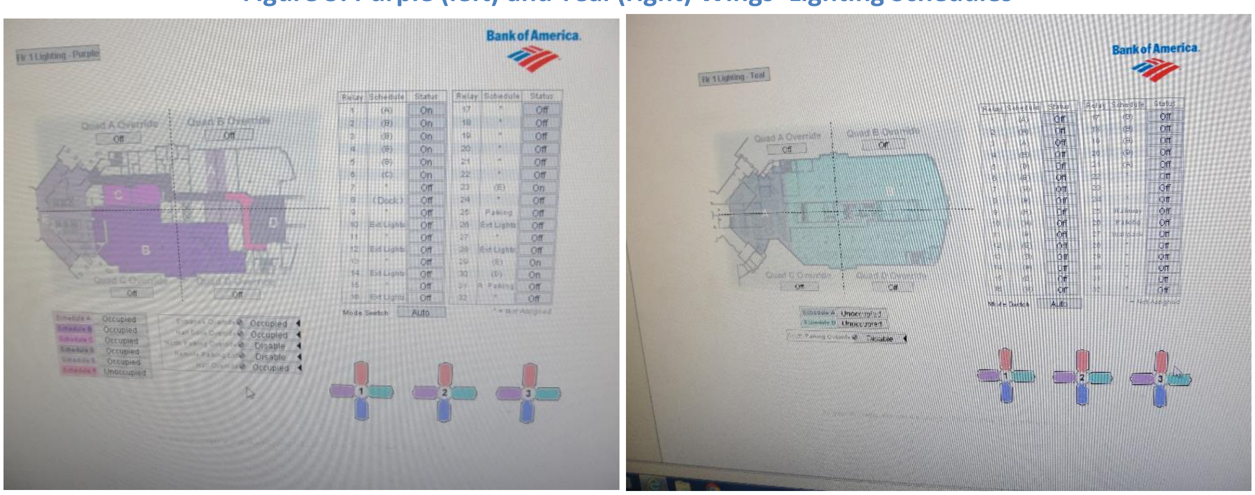

Figure 6 shows the hourly breakdown of the lighting schedule for a zone of the red wing (zone 1A).

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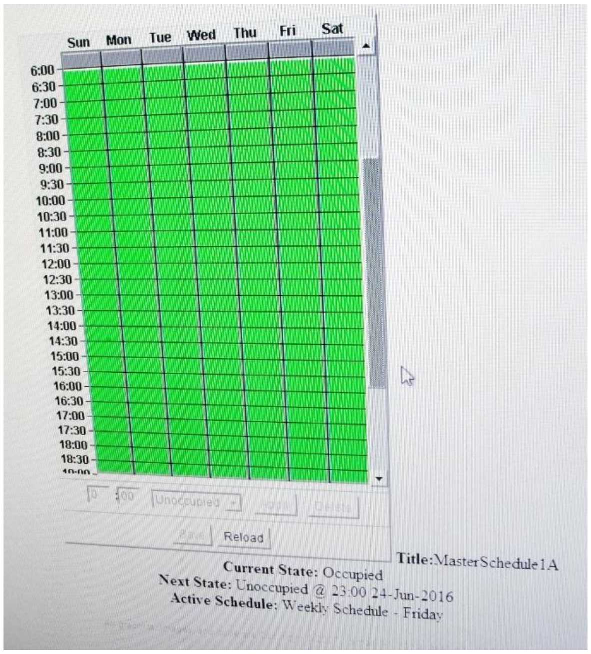
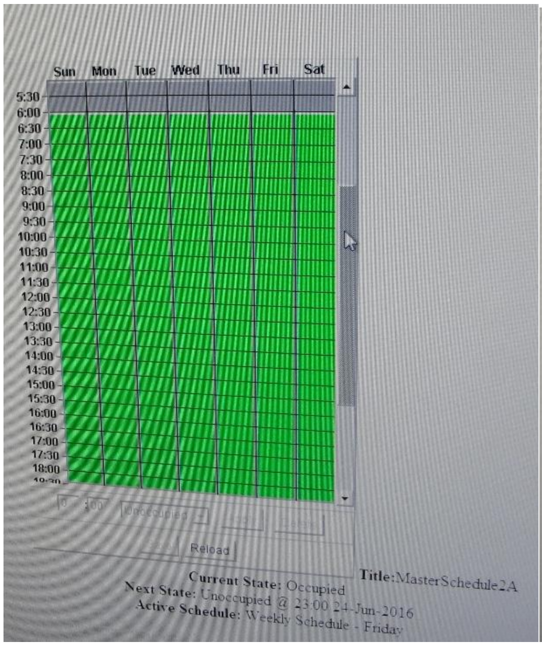
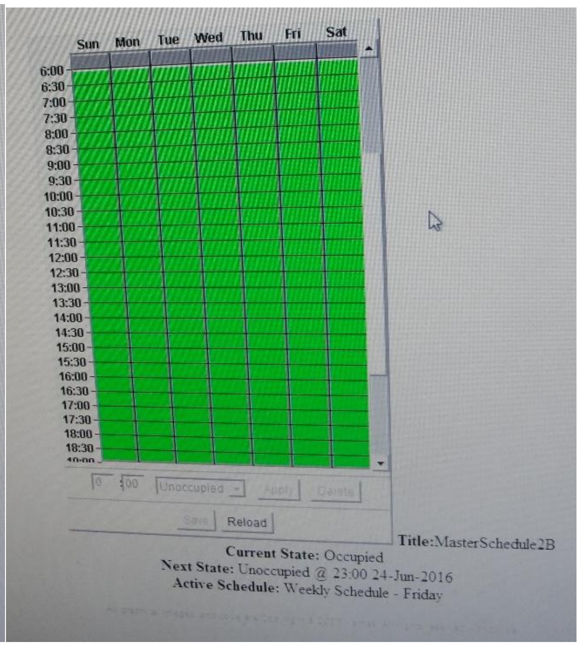
Figure 6. Red Wing Zone 1A Installed Lighting Schedule







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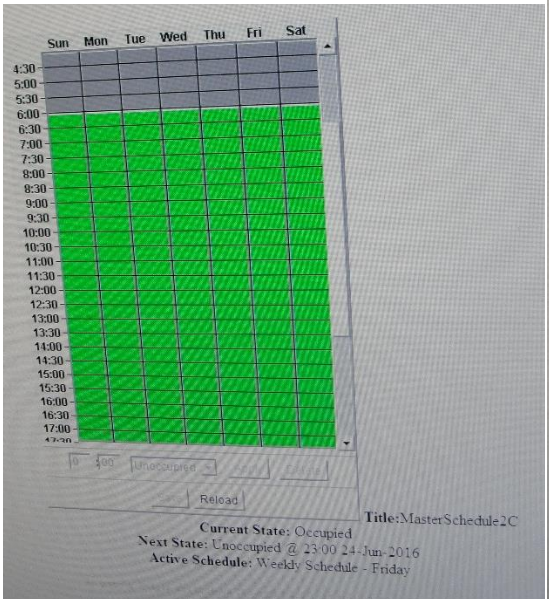

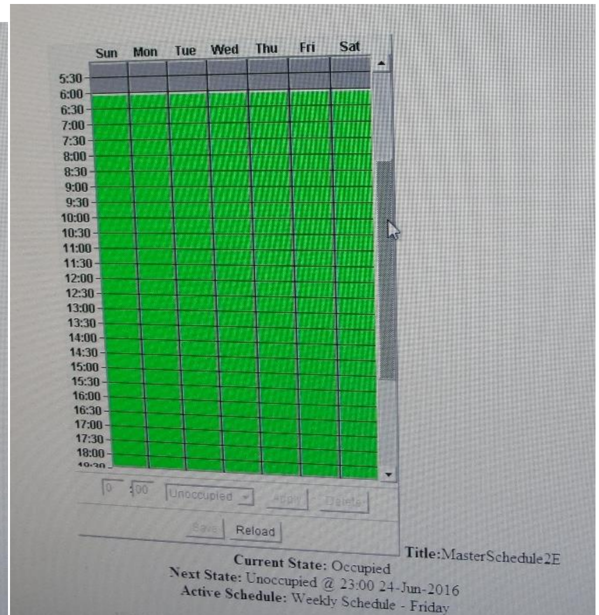

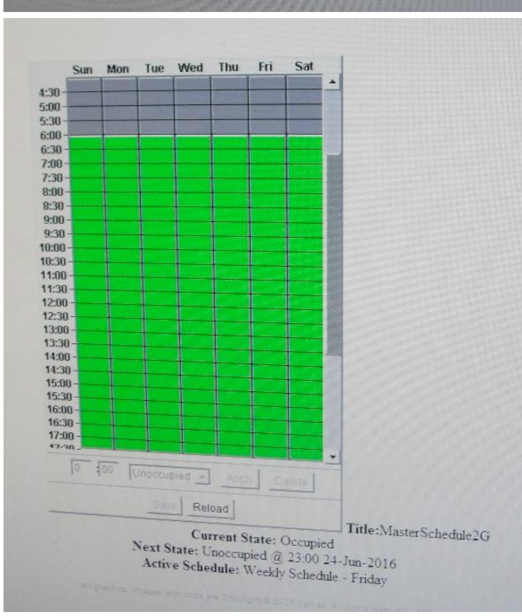

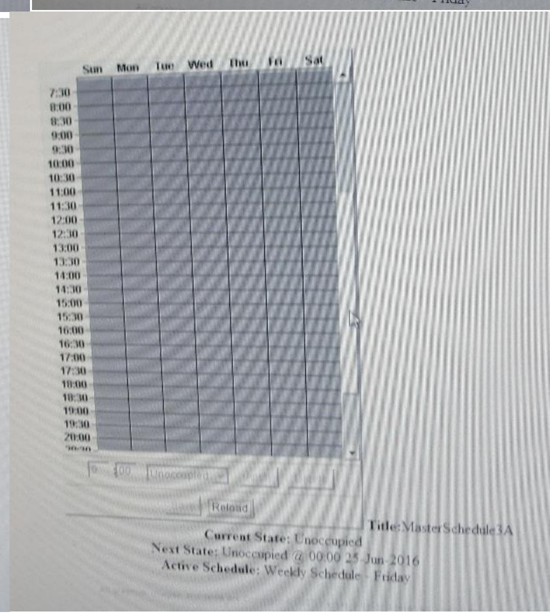

Since the building occupants can override the lighting schedules, Cadmus installed light loggers throughout the facility to collect actual fixture operating hours for a three-week period. Table 5 summarizes fixture quantities and locations of installed light loggers.

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Table 5. Summary of Fixture Counts and Installed Light Loggers

#	Wing	Location	Fixture Description	Light Logger Serial Number
1	Blue	Floor 1 - Outside electrical room	2-lamp, 2'x4' T8	10266124
2		Floor 2 - Outside electrical room	2-lamp, 2'x4' T8	10171838
3		Floor 3 - Outside electrical room	2-lamp, 2'x4' T8	10187474
4	Purple	Floor 3 - Outside electrical room	2-lamp, 2'x4' T8	10261681
5		Floor 2 - Outside electrical room	2-lamp, 2'x4' T8	10346084
6		Floor 1 - Outside electrical room, in corridor to loading dock	2-lamp, 2'x4' T8	10327340

Data Analysis

ECM-1: Relocate 8,760-Hour Lighting Circuits to New Panels with Scheduling

Cadmus extrapolated the emergency lighting fixture counts from the teal wing to the remaining three wings. Based on the teal wing counts, the total installed case emergency fixture count is estimated to be 336, versus 228 fixtures in the original application.

Since Cadmus could not confirm the number of pre-retrofit fixtures on emergency circuits, we assumed that the total pre-retrofit count of 450 in the original application was correct. We assumed that the remaining 114 lighting fixtures were operated 65% of the year (5,709 hours per year) based on the metered data collected for ECM-3 (see Table 6 below). In contrast, the original analysis assumed that the fixtures removed from emergency circuits would operate approximately 3,400 hours per year.

The energy savings and peak demand reduction for this measure (without HVAC interactive effects) are 18,782 kWh and 0.0 kW, respectively.

ECM-2: Replace Parking Lot Photocells with Timeclock Controls

Since it is unclear how long the remote lot will be unused, Cadmus evaluated this measure assuming the timeclock controls were still active. In the pre-retrofit case, the fixtures were on photocell control and operated approximately 4,380 hours per year. In the installed case, the fixtures operated approximately 1,638 hours per year.

The HPS fixture input is 460 watts based on technical reference manual lookup tables. The total connected load is 7.36 kW. The energy savings and peak demand reduction for this measure are 20,181 kWh and 0.0 kW, respectively.

ECM-3: Install New Lighting Control System with Zone Control

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

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Table 6. Summary of Light Logger Data

Logger #	Wing	Floor	Total Metered Hours	Total Operating Hours	Percentage Operating	Average Coincidence Factor
1	Blue	Floor 2	435.0	220.9	51%	100%
2	Blue	Floor 3	435.0	311.7	72%	100%
3	Purple	Floor 3	434.9	315.4	73%	100%
4	Purple	Floor 2	434.8	311.5	72%	100%
5	Purple	Floor 1	434.7	257.6	59%	100%
Average			**434.9**	**283.4**	**65%**	**100%**

The five loggers produced a mean projected annual runtime of 5,709 hours. During the three-week metering period, the site produced a mean coincidence factor of 100%. Since the occupants can override the programmed schedules, Cadmus used the metered operating hours to evaluate the measure.

The lighting fixtures in the teal wing and third floor of the red wing were also assumed to operate 5,709 hours per year to account for expected future growth.

The fixture input for the two-lamp, 2-foot by 4-foot T8 troffer is 54 watts. The fixture counts in each wing were assumed to equal that submitted in the original application. The evaluated total connected lighting load in the pre-retrofit and installed case was estimated to be 190.4 kW.

Cadmus assumed that the pre-retrofit lighting schedules submitted in the original application were accurate. The pre-retrofit fixtures averaged 5,222 annual operating hours.

The energy savings and peak demand reduction for this measure (without HVAC interactive) effects are -92,689 kWh and 0.0 kW, respectively.

Cadmus also calculated energy savings and demand reductions for interior spaces with HVAC interactive effects, based on the heating and cooling system type we observed on site. Cadmus used the waste heat factors listed in TechMarket Works' Process and Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in the Carolina System: Lighting and Occupancy Sensors report submitted in April 2013. The energy waste heat factor for a small office near [redacted], North Carolina with air conditioner cooling, an economizer, and electric heating is -0.032 and the demand factor is 0.136. The following equation is used to calculate savings with HVAC interactions:

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

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

Where:

WHFe = Waste heat factor for energy (= -0.032)

WHFd = Waste heat factor for demand (= 0.136)

The total evaluated energy savings for the three measures with HVAC effects were -51,361 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 0.00 kW, and the average, or non-coincident, peak demand reduction was -5.86 kW.

Conclusion

The overall energy savings realization ratio was -11%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 100%. The average (or non-coincident) peak demand reduction realization rate was -15%.

Cadmus identified the following differences from the original application that impacted the evaluated energy savings:

- There are more lighting fixtures on emergency circuits than expected in the original application
- The fixtures that were taken off emergency circuits operate for longer than expected in the original study
- There are fewer HPS fixtures in the remote parking lot than expected in the original application
- The timeclock controls for the remote lot HPS fixtures were scheduled to be on from Monday through Sunday, versus Monday through Friday in the original application
- The installed zone controls have less aggressive schedules than the site's pre-retrofit, single-zone lighting control system (the new controls do not appear to be programmed as expected in the original study)

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

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

ECM	Applicant		Duke Energy Claimed			Evaluation		
	Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	75,730	N/A	69,451	0.00	7.96	18,181	0.00	2.08
2	38,916	N/A	39,533	0.00	0.32	20,181	0.00	2.30
3	385,638	N/A	360,080	0.00	30.83	-89,723	0.00	-10.24
Total	**500,284**	**N/A**	**469,065**	**0.00**	**39.11**	**-51,361**	**0.00**	**-5.86**

Table 8. Energy Savings and Demand Reduction Realization Rates

ECM	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
1	26%	NA	26%
2	51%	NA	719%
3	-25%	NA	-33%
Total	**-11%**	**NA**	**-15%**

Application ID 15-1806905
Lighting
M&V Report

November 16, 2016

Duke Energy
139 East Fourth Street
Cincinnati, OH 45201

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Prepared by:
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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for one retrofit energy conservation measure (ECM) as part of the [redacted], Smart $aver custom incentive program application—specifically for replacing 1,467 fluorescent T12 lighting fixtures with 452 reduced-wattage T8 fixtures. Energy savings were expected to result from the reduced fixture input wattage and the reduced fixture quantity. A description of the measure as submitted in the original application documentation is provided below.

ECM-1: Replace Fluorescent T12 Fixtures with Reduced Wattage T8s

[Redacted] is a manufacturer and distributor of windows treatments and operates a warehouse in [redacted], North Carolina, for 3,120 hours per year, according to the original application.

This retrofit project replaced 797 one-lamp, 8-foot T12 high-bay fixtures and 670 four-lamp, 4-foot T12 fixtures with 204 two-lamp, 4-foot, reduced-wattage T8 troffers and 248 four-lamp, 4-foot, reduced-wattage T8 strip fixtures, respectively. The installed lamps and ballasts were listed on the Consortium for Energy Efficiency's approved equipment list.

The decreased fixture quantity was supported by a lumen-level study performed by the original project engineer; this indicated that an adequate light level would be maintained despite a large reduction in the number of installed fixtures.

Goals and Objectives

Table 1 shows the projected savings goals identified in the project application.

Table 1. Project Goals

Application		Duke Energy			
Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
501,971	N/A	501,971	488,514	160.89	38.38

* Source: DSMore input spreadsheet.

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

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

Project Contacts

Table 2 lists the Duke Energy contact who granted Cadmus approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

Table 2. Project Contacts

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

Site Location

The site location is listed in Table 3.

Table 3. Site Location

Address	ECM
Redacted	1

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. Christie Amero of Cadmus performed the site visit on June 20, 2016.

Field Survey

During the site visit, Cadmus met with the facility manager and site electrician to review the lighting survey and to collect general operating information. The [redacted] facility is a furniture distribution center composed of administrative offices, a warehouse, and a bulk storage room. According to the facility manager, the warehouse is approximately 124,000 square feet.

The operating hours are Mondays through Thursdays, from 6:00 a.m. to 4:30 p.m., year round. However, the site contact said the lighting fixtures may be turned on as early as 5:15 a.m. The site observes approximately 10 holidays per year.

Conditioning for the administrative offices is provided by Carrier heat pumps. Conditioning for the warehouse is provided by four 40-ton Lennox direct expansion units with electric heating coils. There are two small Trane air conditioning units for the data room. The bulk storage space is heated only by electric unit heaters to 50°F in the winter months.

The facility manager confirmed that all pre-retrofit spaces had T12 fluorescent lamps. No occupancy sensors or daylighting controls were installed as part of the project: all the fixtures are controlled manually. The facility manager said the staff has noticed an improvement in the lighting quality and estimated that the project has reduced their electricity bill by approximately $500 per month.

Field Data

ECM-1: Replace Fluorescent T12 Fixtures with Reduced Wattage T8s

After completing the lighting survey, Cadmus performed a walkthrough of the facility to verify the new lighting fixture types and to install light loggers. Figure 1 and Figure 2 show the four-lamp, 4-foot T8 lighting strip fixtures in the bulk storage space. Figure 3 shows the 32-watt T8 lamp that was installed in the bulk storage fixtures. Cadmus was not able to inspect the ballast for the bulk storage fixtures due to the height of the fixtures. The site contact did not have any extra ballasts for the bulk storage fixtures.

Figure 1. Fluorescent Lighting Fixtures in Bulk Storage Space

Figure 2. 4-Lamp, 4-Foot T8 Fixture in Bulk Storage Space

Figure 3. 32-Watt T8 Lamp Installed in Bulk Storage Space

Figure 4 shows the two-lamp, 2-foot by 4-foot T8 troffer fixture installed in the warehouse and offices. Figure 5 shows the make and model number of the installed, 28-watt T8 lamp. Figure 6 shows the installed ballast for the warehouse and office fixtures.

Figure 4. 2-Lamp, 2-Foot by 4-Foot T8 Lighting Fixture in Warehouse Space

Figure 5. Reduced Wattage Fluorescent 4-Foot 28-Watt T8 Lamp

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Figure 6. GE Ballast for 4-Foot, 2-Lamp T8 Fixtures

Cadmus installed light loggers throughout the facility to collect fixture operating hours for a three-week period. Table 4 summarizes the locations of installed light loggers and monitored fixture types.

Table 4. Summary of Fixture Counts and Installed Light Loggers

#	Section	Location	Fixture Description	Light Logger Serial Number
1	Office	Corner fixture near door	2-lamp, 4-foot T8s	10221844
2	Entryway	2nd fixture in from main door	2-lamp, 4-foot T8s	10270023
3	Warehouse	Between section A49 and A48	2-lamp, 4-foot T8s	10268265
4	Bulk Storage	Pole C, row 5	4-lamp, 4-foot T8s	10187339
5	Warehouse Bathroom	Ladies bathroom	2-lamp, 4-foot T8s	10187397

Data Analysis

ECM-1: Replace Fluorescent T12 Fixtures with Reduced Wattage T8s

Cadmus used the survey and light logger data to verify demand and operating hours for the installed lighting fixtures. Table 5 summarizes the light logger data.

Table 5. Summary of Light Logger Data

#	Section	Total Metered Hours	Total Operating Hours	Percentage Operating	Average Coincidence Factor
1	Office	551.1	137.2	25%	50%
2	Entryway	550.8	550.8	100%	100%
3	Warehouse	550.6	147.0	27%	57%
4	Bulk Storage	550.5	144.7	26%	30%
5	Warehouse Bathroom	550.4	550.4	100%	100%

The projected annual operating hours are 2,180 hours for office fixtures, 8,760 hours for the entryway fixtures, 2,339 hours for the warehouse fixtures, and 2,303 hours for the bulk storage fixtures. Cadmus assumed that the operating hours and coincidence factors were equal in the pre-retrofit and installed cases.

Cadmus used the survey data and lamp and ballast model numbers we collected on the site to calculate the actual installed fixture demand (kW). The two-lamp, 2-foot by 4-foot troffer fixtures in the office and warehouse spaces were installed with 28-watt lamps and the overall fixture input is 64 watts according to the GE ballast specifications. Based on the MassSave 2013 rated wattage tables, the four-lamp, 4-foot strip fixtures in the bulk storage spaces were installed with 32-watt T8 lamps and the overall fixture input is 107 watts. Cadmus confirmed the fixture quantities submitted in the original application via an invoice provided by the site contact. The connected lighting load for the installed system is 39.59 kW.

Cadmus confirmed the power usage of pre-retrofit fixtures using technical reference manual lookup tables. A four-lamp, 2-foot by 4-foot troffer fixture with F40 T12 lamps is rated at 160 watts, and a one-lamp, 8-foot strip fixture with F40 T12HO lamps is rated at 125 watts. We confirmed the pre-retrofit fixture quantities using the same invoice described above, which included demolition costs.

The energy savings and peak demand reduction without HVAC interactive effects are 386,361 kWh and 73.70 kW, respectively.

Cadmus also calculated energy savings and demand reductions with HVAC interactive effects for the office and warehouse fixtures, based on the heating and cooling system type we observed on site. Cadmus used the waste heat factors listed in TechMarket Works' Process and Impact Evaluation of the Non-Residential Smart $aver® Prescriptive Program in the Carolina System: Lighting and Occupancy Sensors report submitted in April 2013. The energy waste heat factor for a small office near Charlotte, North Carolina with heat pump cooling and heating and no economizer is 0.047, and the demand factor is 0.152. The energy waste heat factor for a warehouse near Charlotte, North Carolina with air conditioner cooling, electric heating, and no economizer is -0.183, and the demand factor is 0.127. The following equations are used to calculate savings with HVAC interactions:

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

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

Where:

WHFe = Waste heat factor for energy

WHFd = Waste heat factor for demand

The total evaluated energy savings were 359,800 kWh. The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 80.6 kW, and the average, or non-coincident, peak demand reduction was 41.1 kW.

Conclusion

The overall energy savings realization rate was 74%, compared to Duke Energy claimed savings. The summer peak demand realization rate was calculated as 50%. The average (or non-coincident) peak demand reduction realization rate was 107%.

Cadmus found a slight variation in the installed lighting fixture wattage compared to the original application. The T8 lamps installed in the bulk storage areas are 32 watt, versus 28 watts as outlined the original study. The T8 lamps installed in the offices and warehouse are 28 watts, as expected.

The most significant impact on the evaluated energy savings and peak demand reduction was that the evaluated annual operating hours were 26% less than that claimed in the original application. The evaluated average peak coincidence factor was 43%, versus 100% claimed in the original application.

Table 6 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 7 provides realization rates comparing energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 6. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
501,971	N/A	488,514	160.89	38.38	359,800	80.6	41.1

Table 7. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
74%	50%	107%

Application ID 13-1464614
Lighting Replacement
M&V Report

August 5, 2016

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Introduction

This report addresses M&V activities for lighting retrofit energy conservation measures (ECMs), conducted as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of fluorescent lighting fixtures with LED fixtures.

ECMs—Replace Fluorescent Lighting Fixtures with LED Lighting Fixtures

These measures involve replacing 3,268 fluorescent T8 and T12 fixtures with LED fixtures. Table 1 summarizes pre-retrofit and installed lighting fixtures.

Table 1. Summary of Pre-Retrofit and Installed Lighting Fixtures

ECM	Fixture Quantity	Area Served	Pre-Retrofit		Installed	
			Fixture Description	W / Fixture	Fixture Description	W / Fixture
1	64	Manufacturing	2LT12 troffer	631	LED	280
2	90	Manufacturing	2LT12 strip	631	LED	350
3	245	Manufacturing	2LT8 strip	508	LED	350
4	50	Manufacturing	3LT8 troffer	710	LED	499
5	1,569	Manufacturing	4LT12 troffer	1,261	LED	499
6	542	Offices	4LT12 troffer	374	LED	148
7	85	Manufacturing	4LT8 troffer	937	LED	499
8	61	Manufacturing	1LT12 strip	604	LED	350
9	1	Manufacturing	2LT12 strip	1,077	LED	701
10	12	Manufacturing	2LT8 strip	508	LED	350
11	1	Manufacturing	4LT12 strip	2,155	LED	701
12	1	Manufacturing	4LT8 strip	937	LED	701
13	516	Manufacturing	8' 1LT12	981	LED	350
14	1	Manufacturing	8' 2LT12	1,989	LED	701
15	30	Manufacturing	4' 2LT12	631	LED	350
Total	**3,268**					

Goals and Objectives

Table 2 shows the projected savings goals identified in the project application. Duke Energy did not provide a breakdown of claimed savings by measure.

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Table 2. Project Goals

ECM	Applicant		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1	15,768	1.8	22,426	N/A	N/A	N/A
2	25,229	2.9	24,645	N/A	N/A	N/A
3	38,632	4.4	37,043	N/A	N/A	N/A
4	10,512	1.2	18,243	N/A	N/A	N/A
5	1,166,044	133.1	1,438,356	N/A	N/A	N/A
6	122,600	47.2	147,473	N/A	N/A	N/A
7	37,230	4.3	50,372	N/A	N/A	N/A
8	12,448	1.4	15,496	N/A	N/A	N/A
9	84,376	9.6	108,387	N/A	N/A	N/A
10	1,892	0.2	1,814	N/A	N/A	N/A
11	82,887	9.5	82,148	N/A	N/A	N/A
12	12,299	1.4	11,625	N/A	N/A	N/A
13	293,916	33.6	322,107	N/A	N/A	N/A
14	504,786	57.6	550,694	N/A	N/A	N/A
15	2,803	0.3	8,215	N/A	N/A	N/A
Total	**2,411,422**	**308.4**	**2,839,044**	**2,812,619**	**361.4**	**361.3**

* Source: DSMore input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 3 granted approval to plan and to schedule the site visit for this M&V effort.

Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	office: 513-287-4096 frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The location where these measures were installed is shown in Table 5.

Table 4. Project Location

Address	ECMs
redacted	1-15

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit, which Tom Davis of Cadmus performed on January 5, 2016.

Field Notes

During the site visit, Cadmus photographed fixture information, conducted a survey with facility personnel, and installed lighting loggers. The facilities operates seven days per week, without controls, and its schedule did not change after installation.

Field Data

Cadmus installed 15 light loggers to meter the facility for two weeks, and then used these data to estimate annual hours of operation. Table 5 summarizes the light logger data.

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Table 5. Summary of Meter Data

Meter S/N	Location	Metered Hours	Operating Hours	Percentage Operating	Projected Annual Operating Hours	Coincidence Factor
10380417	Supply	322	93	29%	2,539	17%
10380535	Warehouse walkway	322	322	100%	8,760	100%
10380565	Office #1181	322	85	27%	2,325	11%
10380571	Lunch/break	322	322	100%	8,760	100%
10380601	Inspection #1703	322	322	100%	8,760	100%
10380602	Office #1183	322	87	27%	2,355	12%
10380608	Office #1101	322	111	35%	3,031	28%
10380618	Front office hallway	322	169	52%	4,595	71%
10380619	Hallway, warehouse	322	322	100%	8,760	100%
10374182	Blending/discharge #1510	322	322	100%	8,760	100%
10374185	Staging - main warehouse floor	322	322	100%	8,760	100%
10374187	Facility maintenance	322	162	50%	4,407	60%
10374188	Kitchen - front offices #2100	322	91	28%	2,472	28%
10380393	Conference #1163	322	37	11%	995	7%
10380402	HR lobby	322	322	100%	8,760	100%

Data Analysis

In its application, [redacted] claimed 8,760 annual hours of operation for ECMs in its warehouse and 2,600 hours for ECMs in its offices. Cadmus averaged the projected annual hours of operation, determined by light loggers installed in these spaces, and applied the resulting estimates to calculate savings. On average, lights in the warehouse were projected to operate 8,760 hours annually and lights in offices were projected to operate 4,024 annually. These values were applied to demand values and quantities confirmed on site to calculate savings, as shown in Table 6. Additionally, Cadmus averaged peak coincidence factors for each space type and used these values to calculate peak demand reductions and applied waste heat factors to final numbers to account for HVAC interactive effects.

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Table 6. Savings Calculations

ECM	Qty	Annual Operating Hours	CF	Pre-Retrofit kW	Installed kW	Energy Savings		
						Avg. kW Reduction	CP kW Reduction	Annual kWh
1	64	8,760	100%	0.07	0.03	2.56	2.56	22,426
2	90	8,760	100%	0.07	0.04	2.81	2.81	24,645
3	245	8,760	100%	0.06	0.04	4.23	4.23	37,043
4	50	8,760	100%	0.08	0.04	2.08	2.08	18,243
5	1,569	8,760	100%	0.14	0.04	164.20	164.20	1,438,356
6	542	4,024	43%	0.14	0.04	56.72	24.39	228,242
7	85	8,760	100%	0.11	0.04	5.75	5.75	50,372
8	61	8,760	100%	0.07	0.04	1.77	1.77	15,496
9	1	8,760	100%	36.65	24.28	12.37	12.37	108,387
10	12	8,760	100%	0.06	0.04	0.21	0.21	1,814
11	1	8,760	100%	14.02	4.64	9.38	9.38	82,148
12	1	8,760	100%	5.56	4.24	1.33	1.33	11,625
13	516	8,760	100%	0.11	0.04	36.77	36.77	322,107
14	1	8,760	100%	98.06	35.20	62.86	62.86	550,694
15	30	8,760	100%	0.07	0.04	0.94	0.94	8,215
Total			**-**	**155.3**	**68.8**	**437.9**	**399.0**	**3,188,437**

Conclusion

Cadmus found the measures and quantities installed as expected. The energy savings realization rate is 113%, compared to Duke Energy claimed savings, due to of greater usage in office spaces than initially reported. The summer coincident peak demand realization rate is calculated at 110%, given 43% peak coincidence factor measures installed in office spaces. The noncoincident peak demand reduction realization rate is 121%.

Table 7 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 8 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

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Table 7. Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
2,411,422	308.4	2,812,619	361.4	361.3	3,188,437	399.0	437.9

Table 8. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW	Non-CP kW
113%	110%	121%

Application ID 12-296
Injection Molding Machine Retrofit
M&V Report

Prepared for
Duke Energy South Carolina

February 2015, Version 3.0
(revised August 19, 2016)

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 program

Submitted by:

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NORESCO

Stuart Waterbury
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United Technologies

On August 19, 2016 the Duke Energy projected savings in this report were corrected by Cadmus to correspond to Duke Energy expected savings as found in the Duke Energy program tracking database.

Introduction

This document addresses M&V activities for the injection molding machine retrofit for [redacted] that was rebated under Duke Energy's Smart $aver Custom Incentive program.

ECM-1 – Injection Molding Machine Replacement

[Redacted] is engaged in the manufacture of injection molding products. Injection molding machines – also known as presses – are used to mold polypropylene resin into various exterior building products. These presses range in size from 44-ton to 3000-ton. This project targeted a 1970s vintage 700-ton press that was fully utilized. The old press was replaced with a 2012 model Milacron press that is more energy efficient and was expected to increase productivity.

The old machine had an estimated cycle time of 60 seconds and power usage of 83 kWh/h. The new equipment was estimated to have a cycle time of 32 seconds, power usage of 36 kWh/h and an expected runtime from 7:00am to 7:48pm, 52 weeks per year. Analysis of these metrics is detailed in this report.

Goals and Objectives

A post-retrofit survey of the injection molding machine was conducted to determine the power reduction from the upgrade.

The projected savings goals were:

Application Proposed Annual savings (kWh)	Application Proposed Peak Savings (kW)	Duke Expected Savings (kWh)	Duke Expected Peak Savings (kW)
398,112	47	402,674	48

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

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

Project Contacts

Duke Energy M&V Admin.	Frankie Diersing	513-287-4096	
Site Contact	redacted		
NORESCO Contact	Rob Slowinski	303-459-7409	rslowinski@noresco.com

Site Locations/ECMs

Address	ECMs Implemented
redacted	1

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

Field Data Points

Post-Installation

Survey data

- Verified that the injection molding machine nameplate data was consistent with the application
- Verified that the old injection molding machine was removed
- The site contact said that the injection molding machine runs 24/7, and produces 1,743 pieces per day.

Field Data Logging

Dual ElitePro data loggers (with 3 Magnelab CTs each) were used to measure the kW of the injection molding machine. One logger was used to gather kW at 1-second increments for 3 days, while the other was used to gather 5-minute data for a period of 3 weeks. Both of these data streams were used to create an accurate characterization of the injection molding machine's load profile.

Data Analysis

Energy savings for this retrofit measure depend upon three major components: the cycle time for the machine, the operational kW of the machine and its use profile throughout the year. To determine the use profile, three weeks of 5-minute interval kW data was logged on the injection molding machine, seen in Figure 1:

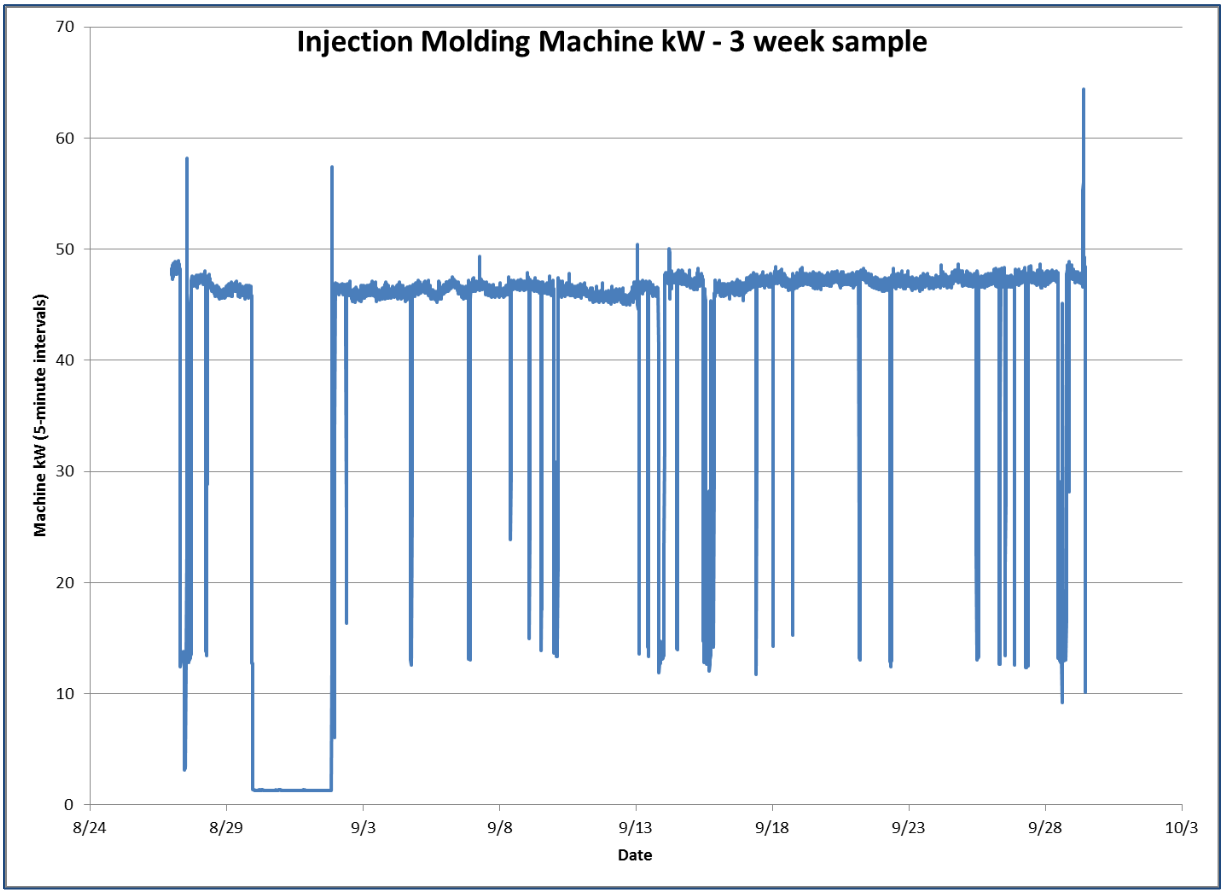

Figure 1: Injection molding machine 3-week usage profile.

The building operator claimed that the machine runs 24/7, save for outages or changeovers, and this is believable, according to the graphed 5-minute interval data. The calculated annual equivalent full load run hours (EFLH)—based on the 3 week data sample—was determined to be 7,684 hours per year.

To determine cycle time, additional data loggers were deployed to capture machine kW at 1-second intervals. This data can be seen in Figure 2.

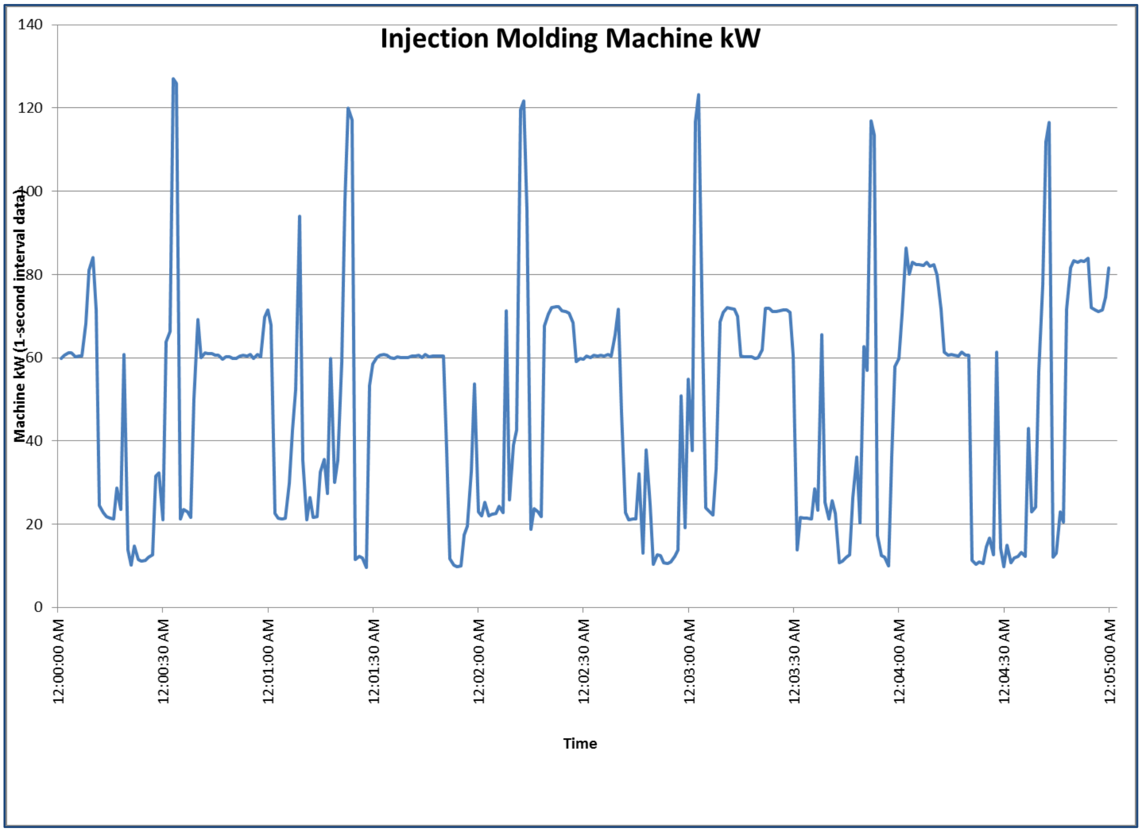

Figure 2: 1-second interval data of machine kW.

Taking a consistent subset of the 1-second interval data, a sample of 25 cycles revealed a cycle time of 49.8 seconds, which amounts to 1,735 cycles per day. The building operator survey revealed a production rate of 1,743 cycles per day (49.6 seconds per cycle), which is very similar. These calculations will use the operator-provided numbers for cycles per day and seconds per cycle.

Finally, calculations revealed that the average operating kW for the injection molding machine (discounting the short downtime seen in the 5-minute data) was 46.7kW.

The energy usage of the machine was then estimated according to the following equation:

$$kWh = \#Cycles \times CycleTime \times \frac{1\ hour}{3600\ seconds} \times OperatingkW$$

where:
Cycles is the annual count of cycles, in this case 558,056 for one year of post-retrofit production
CycleTime is listed in seconds per cycle
OperatingkW is the average kW of the machine during production only.

Rather than using different pre- and post-retrofit throughput levels, the savings calculations normalize the annual throughput. This reflects the reality of the situation, where [redacted] is using the new machine to provide more throughput for the year, rather than simply yield the same amount of throughput in a shorter amount of time. The annual cycles (units produced) per year with the post-retrofit equipment is estimated to be 558,056. In the post-retrofit case, this takes 7,684 hours at full load, while in the pre-retrofit case the production of this many units would theoretically take 9,301 hours.

Verification and Quality Control

1. Visually inspected logger data for consistent operation.
2. Verified the post retrofit machine was consistent with the application.
3. Verified that pre-retrofit machine was removed from the project.

Recording and Data Exchange Format

1. Post-installation Survey Form and Notes.
2. ElitePro logger files
3. Excel spreadsheets

Results Summary

The following tables summarize the total estimated savings for the [redacted] injection molding machine retrofit, both in annual totals and on a per-unit basis.

Table 1. Pre- and Post-Retrofit Energy and Demand Summary.

	Pre-retrofit	Post-retrofit	Savings
Operating Hours	9,301*	7,684	-
Averaged Demand (kW)	83	46.7	36.3
Annual Energy (kWh/year)	771,977	359,156	412,822
Energy per unit produced (kWh/unit)	1.38	0.64	0.74

*Note: The pre-retrofit case involves the hypothetical production of 558,056 units, which would take longer than one year at full load.

Table 2. Annual Energy Savings and Realization Rates.

	Duke Savings	Verified Savings	Realization Rates
Energy (kWh)	402,674	412,822	103%
Peak Demand (kW)	36	36.3	101%
CP Demand (kW)	48	36.3	76%

The energy savings verified by this M&V project are very close to the Duke estimated savings, while peak coincident demand savings fall short of the estimate. This is due to the fact that the machine's operating kW was originally estimated to be 36kW, but logger data shows it to be 46.7kW.

Application ID 14-1785194 Air Compressor Retrofit: M&V Report

August 5, 2016

Duke Energy Carolina
139 East Fourth Street
Cincinnati, OH 45201

The Cadmus Group, Inc.

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CADMUS

Prepared by:

Dave Korn

Christie Amero

Cadmus

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Introduction

This report addresses M&V activities for one retrofit energy conservation measure (ECM), conducted as part of the [redacted] Smart $aver custom incentive program application; specifically, the replacement of fixed-speed air compressors with one VFD-driven air compressor.

The following facility and equipment descriptions have based on original project documentation.

ECM-1—VFD Air Compressor

Pre-retrofit: The pre-retrofit case was two 50-hp fixed-speed air compressors and one 25-hp fixed-speed air compressor. The two 50-hp compressors were estimated to operate 7,664 hours per year. The 25-hp compressor served as a trim machine. The site's compressed airflow demand ranged from ~130 cfm to 300 cfm.

Installed: The installed case is one Ingersoll Rand R75N-A115, 100-hp variable-speed, rotary air compressor. Operating hours and compressed airflow demand were assumed to equal the pre-retrofit case.

Goals and Objectives

Table 1 shows projected savings goals identified in the project application.

Table 1. Project Goals

Applicant		Duke Energy			
Annual kWh Savings	Avg. Demand Reduction, kW	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
130,982	15	143,875	142,073	21	21

* Source: DSMore Input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 2 granted approval to plan and to schedule the site visit for this M&V effort.

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Table 2. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	office: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Location

The location where this measure was installed is shown in Table 4.

Table 3. Project Location

Address	ECM
redacted	1

M&V Option

To assess this project, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. The site contact confirmed that the equipment was served by 480V and metering could be performed de-energized. The contact confirmed that the site did not have trend points set up on the compressed air system. Christie Amero and Tom Davis of Cadmus performed the site visit on January 7, 2016.

Field Notes

During the site visit, Cadmus met with the site contact to review the metering plan and to collect general operating information.

The site's compressed air system serves paper corrugators on the manufacturing floor. The compressed air system typically operates 24 hours per day, Monday through Friday, and occasionally on Saturdays (depending on production schedules). Separate shifts do not operate during the day, but compressed air demand peaks during cleanup hours.

Production remains fairly consistent throughout the year, and major changes have not occurred to production levels since the project implementation. The contact said the site has added eight stations to the floor, but the compressed air used by the new stations requires a very small percentage of overall use. The compressed air discharge pressure is maintained at 110 psi.

The new VFD air compressor was installed on May 4, 2015, and has run ~5,900 hours since then. No issues have arisen with the new machine. The two existing, single-stage, 50-hp air compressors remain on site (though are used only as backups).

The new compressor installation included a heat recovery duct to use waste heat for warehouse space heating when outside air conditions permit. During the site visit, the discharge temperature of the compressor ranged between 183°F and 192°F.

Field Data

Table 4 shows data Cadmus collected for the installed VFD air compressor.

Table 4. Equipment Nameplate Data

Equipment ID	Make	Model Number	Serial Number	hp	Control Strategy
VFD Compressor	Ingersoll Rand	R75N-A	NK2265U15043	100	Variable speed

During the site visit, Cadmus photographed the installed and existing air compressors and the associated nameplates. Figure 1 shows the installed VFD compressor. **Error! Reference source not found.** shows the compressor nameplate. Figure 3 shows the compressor's control panel output with the current discharge pressure setpoint and compressor percent capacity. Figure 4 shows the compressor's heat recovery ductwork.

Figure 1. Installed VFD Air Compressor

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Figure 2. VFD Air Compressor Nameplate

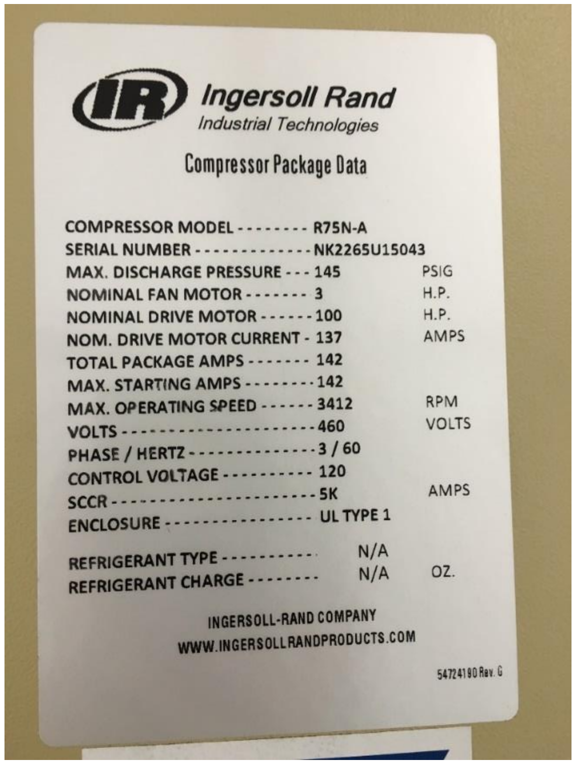


Figure 3. VFD Air Compressor Control Panel—Pressure and % Capacity

Figure 4. Installed Air Compressor Heat Recovery Duct

Figure 5 documents the old Ingersoll Rand air compressors, which serve only as backups.

Figure 5. Old Ingersoll Rand Single-Speed Compressors—Backups Only

Cadmus installed a three-phase electric power meter on the new VFD air compressor. Data were collected for two weeks at one-minute intervals. Table 5 summarizes the installed metering equipment.

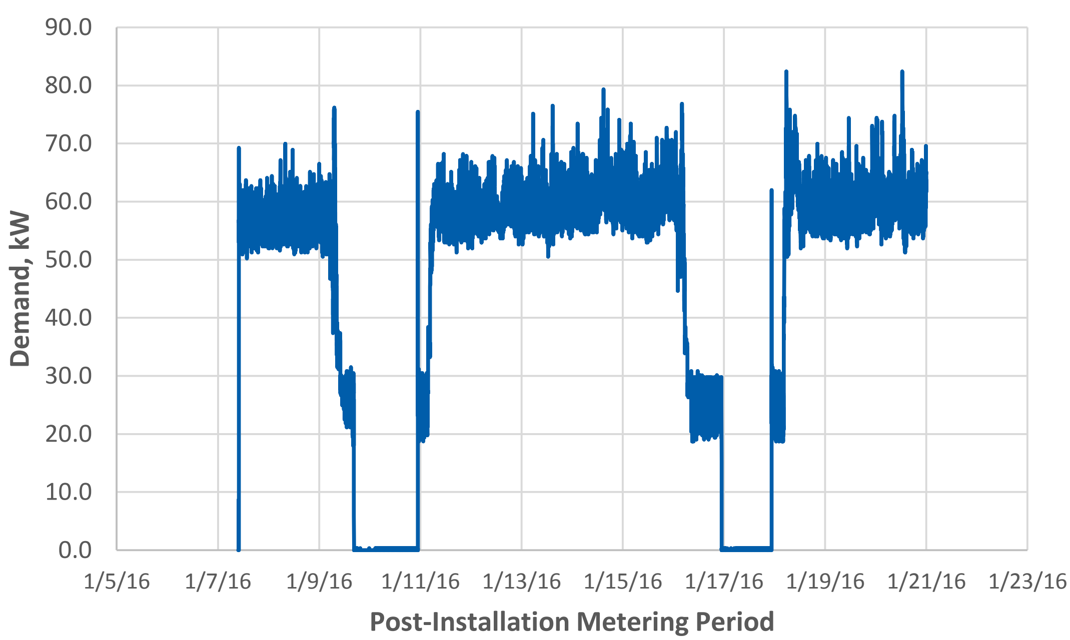
Table 5. Summary of Installed Metering Equipment

Equipment ID	RX3000	WattNode 3D-480	Current Transducers (Qty/Size)
VFD Comp	1	1	3 / 100 A

Figure 6 shows the power meter installation, and Figure 7 summarizes the metered demand data for the VFD air compressor during the metering period.

Figure 6. VFD Air Compressor Power Disconnect

Figure 7. VFD Air Compressor Power Metered Data



Data Accuracy

Table 6. Metering Equipment Accuracy

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

Data Analysis

Cadmus used the post-installation metered data to verify the power demand and operating hours of the controlled equipment. Daily average operating demand and operating hours were averaged per week. The average weekly ratio of operating hours to total hours (including weekends) was 84%, and the average operating demand was 49.9 kW. Based on discussions with site personnel, it was assumed the compressor operates 51 weeks per year (including shutdowns and maintenance).

Evaluated installed case energy use was calculated as 358,527 kWh, with average demand of 40.9 kW, and summer peak coincident demand of 57.3 kW.

As trends could not be obtained for pressure and airflow, Cadmus used airflow data collected in the original study and the assumed compressor performance to calculate pre-retrofit energy use. Average pre-retrofit compressor performance was 0.27 kW/cfm, and average annual airflow demand was 250 cfm. Peak period airflow demand was 286 cfm. Operating hours were assumed equal to the installed case.

Evaluated pre-retrofit energy use is 481,779 kWh, with average demand of 55.0 kW, and summer peak coincident demand of 76.6 kW.

Total evaluated annual energy savings are 123,252 kWh. Evaluated total summer coincident peak demand reduction (July, Monday–Friday, 4:00–5:00 p.m.) is 19.4 kW, and the average (or noncoincident) peak demand reduction is 14.1 kW.

Conclusion

Cadmus found the new VFD air compressor installed as expected. Installation of the heat recovery duct provides additional energy savings, not accounted for in the original analysis.

The overall energy savings realization rate was 87%, compared to the Duke Energy claimed savings. The summer peak demand realization rate was calculated at be 93%. The average demand reduction realization rate was 67%.

Average metered demand data for the compressor fell within 1% of the average demand estimated in the original study. Based on metered data and discussions with site personnel, however, operating hours were projected at 6.3% less (479 hours) than originally expected.

Table 7 provides a comparison of the applicant, Duke Energy claimed, and evaluation energy savings and demand reduction. Table 8 provides the realization rates compared to energy savings and demand reductions claimed by Duke Energy.

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

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Avg. kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
130,982	15	142,073	21	21	123,252	19.4	14.1

Table 8. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
87%	93%	67%

Application ID 13-1624545
HVAC
M&V Report

January 25, 2017

Duke Energy
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Introduction

This report outlines Cadmus' measurement and verification (M&V) activities for one new construction energy conservation measure (ECM) as part of the [redacted], Smart $aver custom incentive program application—specifically for the installation of a new, high-performance HVAC system for a new data center in [redacted], North Carolina. Energy savings were expected to result from the improved cooling performance and reduced pump and fan demand. A description of the measure as submitted in the original application documentation is provided below.

ECM-1: High-Performance HVAC System

[redacted] Data Centers offers mission-critical data storage and has a campus in [redacted], North Carolina. In 2014, it constructed a new 75,700 square-foot data center, referred to as Project Hawk. The data centers operate 24 hours per day, year round, and require year-round cooling to maintain space conditions for data storage equipment.

Baseline: This project's baseline was determined using the Pacific Gas & Electric Energy Efficiency Baseline for Data Centers document (dated November 30, 2011). In 2011, variable-speed motors and water-side economizers were not considered baseline designs for data centers.

Installed: This project entailed installing an energy-efficient HVAC system for the new data center, which included variable-speed centrifugal chillers, variable-speed pumps and cooling tower fans, and a waterside economizer to provide free-cooling for the data center when outside air conditions allowed. A summary of the installed equipment follows:

- Four York YKC3CRQ4-EGGS, 280-ton, variable-speed centrifugal chillers
- Four BAC PG-S3000/3436C, cross-flow cooling towers, each with a 30-hp variable-speed fan motor
- One Alfa Laval MX25M-FGS, 840-ton, plate and frame heat exchanger
- Four 25-hp variable-speed chilled water pumps
- Four 25-hp variable-speed condenser water pumps

In the original analysis, energy savings were calculated using an eQuest software energy model, employing typical meteorological year (TMY) data for Charlotte, North Carolina. Envelope, lighting, and other interior parameters were added, based on facility design documents. The eQuest total design cooling load was 746 tons.

Goals and Objectives

Table 1 shows the projected savings goals identified in the project application.

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Table 1. Project Goals

Application		Duke Energy			
Annual kWh Savings	Average kW Reduction	Projected Annual kWh Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
2,914,790	N/A	2,914,790	2,914,790	233.67	253.20

* Source: DSMore input spreadsheet.

The objectives of this M&V project were to verify the following actual data:

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

Project Contacts

Table 2 lists the Duke Energy contact who granted Cadmus approval to plan and schedule the site visit for this M&V effort, along with the Cadmus contact and the customer contact.

Table 2. Project Contacts

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

Site Location

The site location is listed in Table 3.

Table 3. Site Location

Address	ECM
redacted	1

M&V Option

To assess this site, Cadmus followed IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy, seeking to review the evaluation plan and schedule the site visit. During the initial discussion with the site contact, Cadmus was informed that the EMS for the chilled water system currently trends power and energy use on all controlled equipment, and therefore that additional on-site power metering would not be necessary. Cadmus sent a list of required trends to the site contact ahead of the site visit. Christie Amero of Cadmus performed the site visit on June 21, 2016, to physically verify the installed equipment and collect the trend data.

Field Survey

During the site visit, Cadmus met with the facility manager to review the lighting survey and to collect general operating information. The Project Hawk site provides redundant customer data storage for emergency situations. The data center equipment is mission critical and operates 24 hours per day, year round. The data center uses cold aisle containment for the racks.

The site is still in the process of building out the data racks and increasing the cooling load. According to the facility manager, the site does not expect to reach capacity for five to seven years. The load had remained fairly constant over the past year and the facility manager did not expect the load to increase significantly over the coming year.

Field Data

ECM-1: High-Performance HVAC System

Cadmus collected the data shown in Table 4 for all installed equipment included in the application.

Table 4. Installed Equipment Nameplate Data

Equipment Type	ID	Make	Model Number	S/N	Size
Chillers	CH-1A	York	YKC3CRQ4/VSD351	KVM-060	280 tons
	CH-1B	York	YKC3CRQ4/VSD351	KVM-049	280 tons
	CH-2A	York	YKC3CRQ4/VSD351	KVM-027	280 tons
	CH-2B	York	YKC3CRQ4/VSD351	KVM-047	280 tons
Condenser Water Pumps	CWP-1A	Baldor	EM2531T-C	40E246/793C1	25 hp
	CWP-1B	Baldor	EM2531T-C	40E246/793C1	25 hp
	CWP-2A	Baldor	EM2531T-C	40E246/793C1	25 hp
	CWP-2B	Baldor	EM2531T-C	40E246/793C1	25 hp
Chilled Water Pumps	CHWP-1A	Baldor	EM2515T-G	39E366W915G1	20 hp
	CHWP-1B	Baldor	EM2515T-G	39E366W915G1	20 hp
	CHWP-2A	Baldor	EM2515T-G	39E366W915G1	20 hp
	CHWP-2B	Baldor	EM2515T-G	39E366W915G1	20 hp
Cooling Towers	CT-1A	BAC	PG S3000/3436C-4	N/A	30 hp
	CT-1B	BAC	PG S3000/3436C-4	N/A	30 hp
	CT-2A	BAC	PG S3000/3436C-4	N/A	30 hp
	CT-2B	BAC	PG S3000/3436C-4	N/A	30 hp
Heat Exchanger	PFHX-1	Alfa Laval	MX25M-FG	N/A	840 tons

During the site visit, Cadmus photographed the chilled water plant equipment and nameplates: Figure 1 shows one of the York variable speed chillers and the variable speed drive (VFD) nameplate; Figure 2 shows a chiller control panel; and Figure 3 shows one of the Baltimore Aircoil cooling towers and the VFD panel for CT-2B.

Figure 1. Variable Speed Chiller and VFD Nameplate

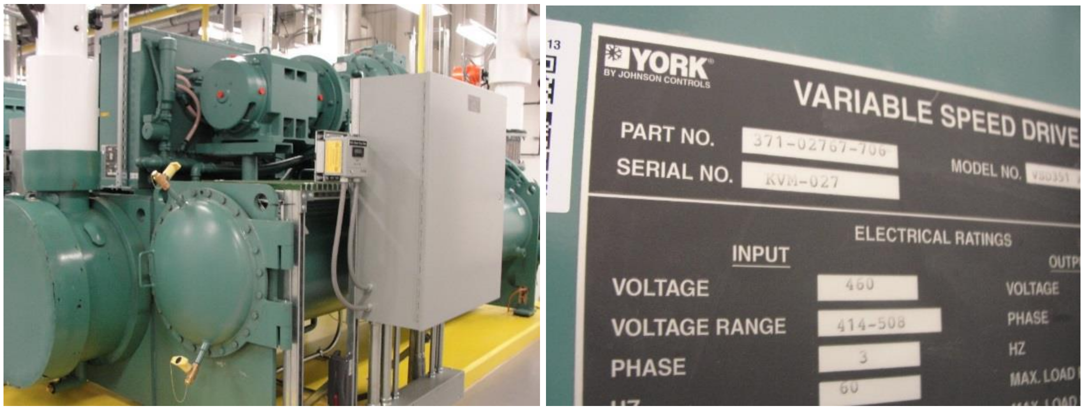

Figure 2. Variable Speed Chiller Control Panel

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Figure 3. Cooling Tower and Drive for CT-2B

Figure 4 shows one of the chilled water pump VFDs and the motor nameplate. Figure 5 shows one of the VFDs for a condenser water pump and the pump motor nameplate.

Figure 4. Chilled Water Pump VFD and Motor Nameplate

Figure 5. Condenser Water Pump (CWP-1B) VFD and Motor Nameplate

Figure 6 shows the plate and frame heat exchanger used to provide free-cooling.

Figure 6. Plate and Frame Heat Exchanger

Cadmus also collected trended power demand data for all equipment submitted in the application. Table 5 summarizes the trend points that were collected.

Table 5. Trend Points Collected from Site

Equipment ID	Trend Point	Interval	Duration
Chillers (CH-1, 2, 3, & 4)	Flow rate, GPM	1 minute	1 year
	Supply temperature, °F	5 minutes	1 year
	Return temperature, °F	5 minutes	1 year
	Total, kW	5 minutes	1 year
Chilled Water Pumps (CHWP-1, 2, 3, & 4)	Pump motor VFD speed, Hz	5 minutes	1 year
	Pump output, kW	5 minutes	1 year
Condenser Water Pumps (CWP-1, 2, 3, & 4)	Pump motor VFD speed, Hz	5 minutes	1 year
	Pump output, kW	5 minutes	1 year
Cooling Towers (CT-1, 2, 3, & 4)	Fan motor VFD speed, Hz	5 minutes	1 year
	Fan output, kW	5 minutes	1 year
Outside Air Conditions	Wet bulb temperature, °F	1 minute	6 months
	Dry bulb temperature, °F	1 minute	6 months

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Data Analysis

ECM-1: High-Performance HVAC System

Cadmus used the trend data for the installed equipment to verify the chilled water plant equipment demand and operating hours. Table 6 summarizes the average monthly outside air conditions, total chiller load, and equipment end-use demand from the trend data collection. We calculated the average chiller load using the individual chiller flow rates and supply and return water temperatures.

Table 6. Monthly Average Outside Air Conditions, Chiller Load, and Component Demand from Trend Data

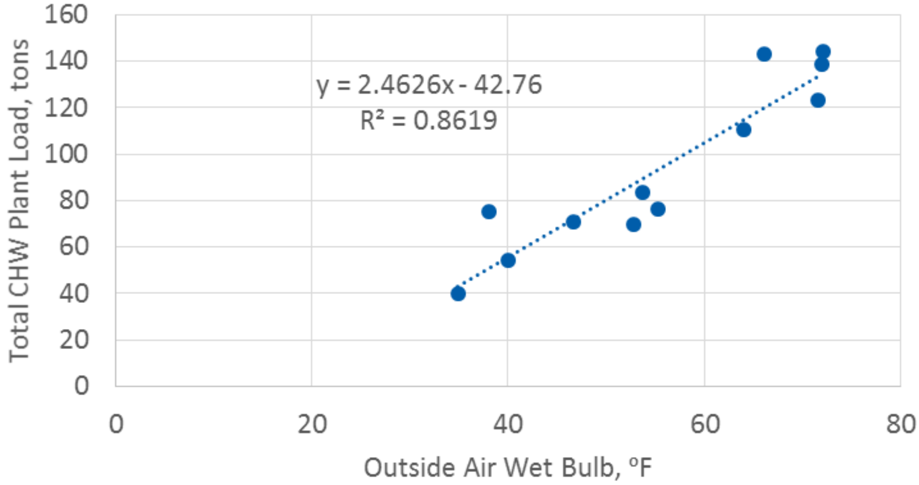
Month and Year	Outside Air Wet Bulb Temp, °F	Average Total Chiller Load, tons	Average Total Chiller Demand, kW	Average Total CHWP Demand, kW*	Average Total CT Fan Demand, kW*	Average Total CWP Demand, kW*
7/2015	N/A	123.1	90.6	4.33	6.21	12.6
8/2015	N/A	144.3	88.9	4.23	5.32	12.2
9/2015	N/A	142.9	72.3	4.22	5.49	17.0
10/2015	N/A	83.4	46.5	4.27	5.31	30.5
11/2015	N/A	70.6	32.0	3.68	7.00	21.1
12/2015	N/A	75.4	39.0	3.71	7.15	23.3
1/2016	34.9	40.1	9.1	3.04	4.30	7.3
2/2016	40.0	54.1	16.6	3.37	5.25	14.5
3/2016	52.8	69.8	36.4	3.82	6.72	26.0
4/2016	55.2	76.3	43.5	3.75	7.02	21.5
5/2016	64.0	110.4	73.5	4.10	7.94	22.2
6/2016	72.0	138.6	101.3	4.43	8.94	14.5

* Chilled water pump (CHWP), cooling tower (CT) fan, and condenser water pump (CWP) output demand provided in trends (does not include VFD penalty).

Cadmus created an 8,760 hour model with TMY data for Charlotte, North Carolina. We plotted the trended installed case chiller load against outside air wet bulb temperature (see Figure 7), then used the linear trend fit from this plot to extrapolate the installed chiller load to the 8,760 hour model. The installed system uses a plate and frame heat exchanger as a water-side economizer to provide free-cooling when outside air conditions allow, so the total space load is greater than the installed case chiller load.

Since the load for a data center is fairly consistent throughout the year, we assumed that the minimum space cooling load is approximately 85% of the maximum load in the summer, or 125 tons. Using this assumption, the average annual cooling load is 127 tons, or 17% of the design load of 746 tons used in the application's eQuest model.

Figure 7. Trended Total Chiller Load vs. Outside Air Wet Bulb Temperature



We used the average monthly equipment trended demand from Table 6 (adding in the VFD penalty of 3% of the motor nameplate horsepower for the pumps and fans) in the installed system model. We estimated the air-side system demand for the computer room air handling unit (CRAH) fans using the following equations, with the assumed installed case air-side delta-T of 20°F and the calculated total cooling load:

Total Required Airflow, CFM = Total Cooling Load, Btu/hr / (1.08 * Delta-T, °F)

Total CRAH Fan BHP = Airflow, CFM * Total Pressure, inches WC / 6,356 * Fan Efficiency, %

Total CRAH Fan kW = CRAH Fan BHP * 0.746 kW / BHP / Motor Efficiency, %

Where:

Delta-T, °F	=	20.0°F
Total Pressure, inches water column (WC)	=	1.0 inches WC
Fan Efficiency, %	=	72%
Motor Efficiency, %	=	92%

The evaluated installed case annual energy use was 864,708 kWh. The coincident peak demand was 130.4 kW, and the average annual demand was 98.7 kW.

Cadmus based the baseline chiller performance curve on the same California Data Center Baseline document that was used in the original analysis. We then calculated the baseline chiller demand using the performance curve and the calculated total cooling load. The baseline chilled water pumps, cooling tower fans, and condenser water pumps are the same size as the installed case but are constant speed. Cadmus calculated the air-side system demand using the same methodology described in the installed case, but with an air-side system delta-T of 10°F as recommended in the California Data Center Baseline document. The evaluated baseline annual energy use was 1,378,940 kWh; coincident peak demand was 165.7 kW; and average annual demand was 157.4 kW.

Table 7 provides a breakdown of the evaluated baseline and installed annual energy use by equipment end use.

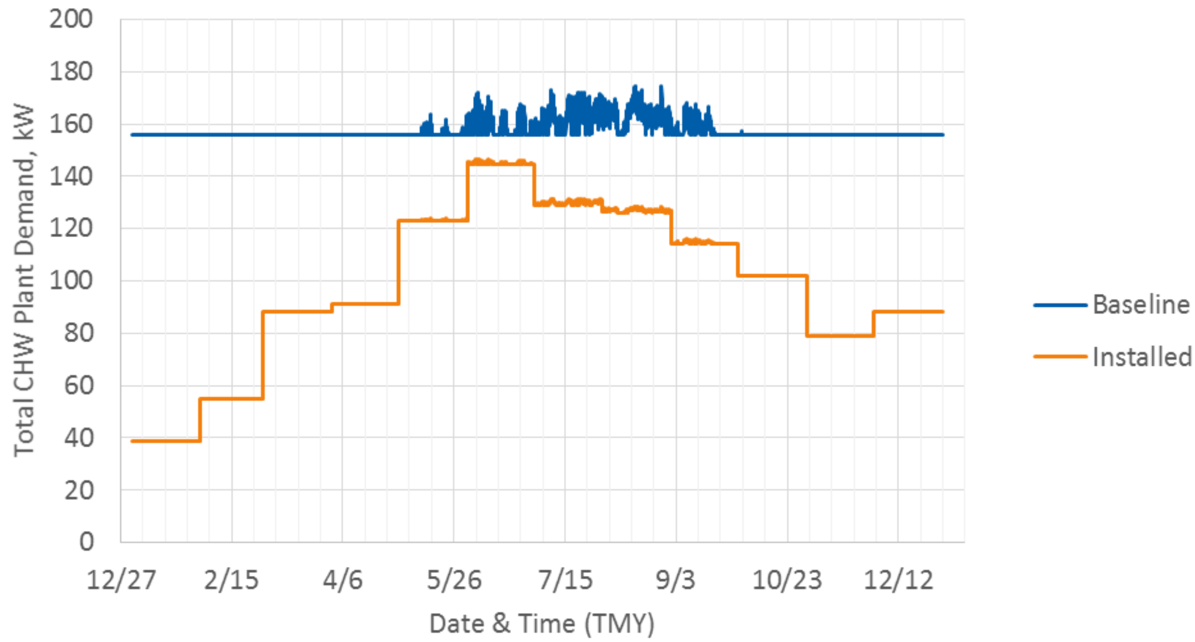
Table 7. Breakdown of Evaluated Baseline and Installed Equipment Annual Energy Use

Equipment End-User	Baseline Annual Energy Use, kWh	Installed Annual Energy Use, kWh
Chillers	718,305	476,121
Chilled Water Pumps	120,848	38,215
Condenser Water Pumps	143,110	172,832
Cooling Tower Fans	177,070	67,736
Airside System (CRAHs)	219,607	109,804
Total	**1,378,940**	**864,708**

Total evaluated energy savings based on the current load were 514,232 kWh (37% savings). The evaluated total summer coincident peak demand reduction (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 35.3 kW, and the average, or non-coincident, peak demand reduction was 58.7 kW. The greatest impact on the evaluated energy savings and demand reduction was that the evaluated average annual cooling load was only 17% of the system design load used in the original application's eQuest model. The site is still building out the data racks and has not come close to reaching capacity.

Figure 8 shows a comparison of the evaluated total system hourly demand of the baseline and installed HVAC systems.

Figure 8. Comparison of Evaluated Total Baseline and Installed System Demand



Conclusion

While on the site, Cadmus found the equipment and controls installed as expected. Since the current load is only 17% of the design load and the site expects to increase the load over time, Cadmus calculated projected energy savings and demand reduction at an assumed load growth period of seven years. Seven years was used as a conservative estimate, since the facility manager estimated a five to seven year growth period.

Table 8 summarizes the projected and present value energy savings and demand reduction over the assumed seven-year load growth period. To calculate the projected savings and demand reduction, we assumed the load would increase linearly from 17% at Year 1 (current load) to 100% at Year 7 and that savings are directly related to load. We calculated the present value savings and demand reduction using an annual discount rate of 7.09% for North Carolina. This discount rate was provided to Cadmus by Duke Energy.

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Table 8. Projected and Present Value Energy Savings and Demand Reductions Over Assumed 7-Year Growth Period

Year	Assumed Average % Capacity	Annual Energy Savings, kWh		Peak Demand Reduction, kW		Average Demand Reduction, kW	
		Projected	Present Value	Projected	Present Value	Projected	Present Value
1	17.0%	514,232	514,232	35.31	35.31	58.71	58.71
2	30.9%	930,493	868,888	63.89	59.66	106.23	99.20
3	44.7%	1,346,753	1,174,330	92.46	80.63	153.76	134.07
4	58.5%	1,763,013	1,435,519	121.04	98.56	201.28	163.89
5	72.3%	2,179,273	1,656,975	149.62	113.76	248.80	189.17
6	86.2%	2,595,534	1,842,816	178.20	126.52	296.33	210.39
7	**100.0%**	**3,011,794**	**1,996,787**	**206.78**	**137.09**	**343.85**	**227.97**

* Evaluated energy savings and demand reductions based on data collected during M&V.

Based on these assumptions, the total projected energy savings at Year 7 were 1,996,787 kWh. The total summer coincident peak demand reduction at Year 7 (for the month of July, Monday through Friday from 4:00 p.m. to 5:00 p.m.) was 137.09 kW, and the average, or non-coincident, peak demand reduction was 227.97 kW.

The overall projected Year 7 energy savings realization rate was 69%, compared to the Duke Energy claimed savings. The summer peak demand realization rate was calculated as 59%. The average (or non-coincident) peak demand reduction realization rate was 90%.

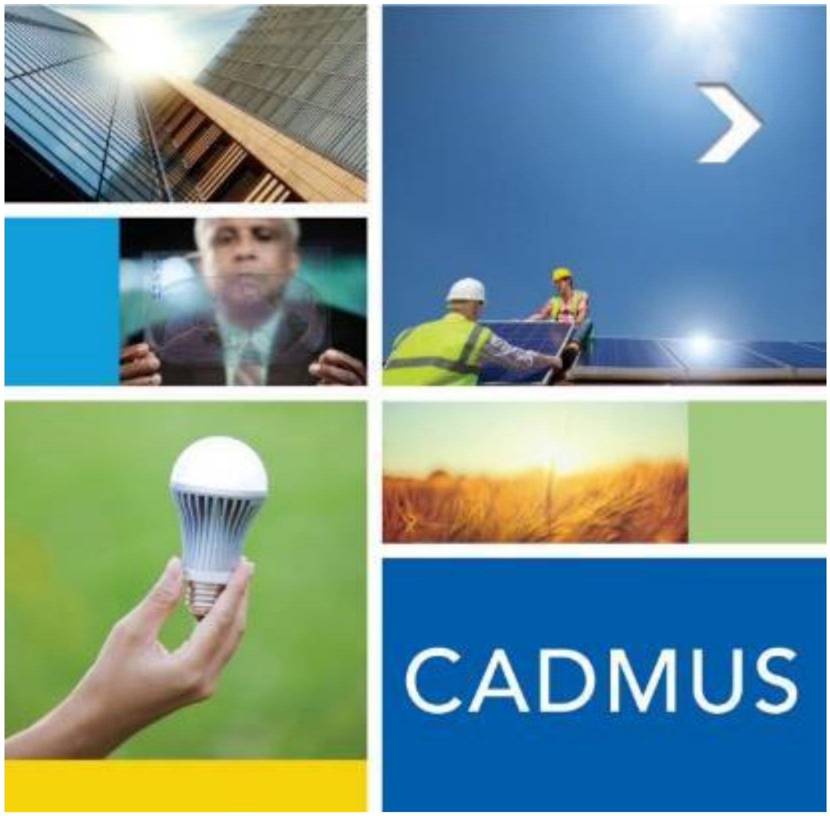
Table 9 provides a comparison of the applicant, Duke Energy claimed, and Cadmus evaluated energy savings and demand reduction. Table 10 provides realization rates comparing the energy savings and demand reductions claimed by Duke Energy to those calculated by Cadmus.

Table 9. Comparison of Applicant, Duke Energy Claimed, and Evaluation Energy Savings and Demand Reduction

Applicant		Duke Energy Claimed			Evaluation		
Annual kWh Savings	Average kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction	Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
2,914,790	N/A	2,914,790	233.67	253.20	1,996,787	137.09	227.97

Table 10. Energy Savings and Demand Reduction Realization Rates

Annual kWh Savings	Coincident Peak kW Reduction	Non-CP kW Reduction
69%	59%	90%



Application IDs 14-1706227 and 13-1547987 Compressed Air: M&V Report

August 5, 2016

Duke Energy Carolina
139 East Fourth Street
Cincinnati, OH 45201

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An Employee-Owned Company • www.cadmusgroup.com

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Table of Contents

Introduction

This report addresses M&V activities for five energy conservation measures (ECMs), submitted in two [redacted], Smart $aver custom incentive program applications: 14-1706227 and 13-1547987. Descriptions follow of the measures included in each application (descriptions are based on the original project documentation).

14-1706227

Application CSN14-1706227 covers the three compressed air retrofit measures at the customer's location in [redeacted], NC. The [redacted] production facility has two separate compressed air networks: one to supply low-pressure compressed air requirements; and one to supply all other facility compressed air requirements. ECM-1 and ECM-2 apply to the low-pressure system and ECM-3 applies to the high-pressure system.

ECM-1—Low-Pressure Air Compressor Replacement

Pre-Retrofit: The pre-retrofit system consisted of seven 350-hp, Atlas Copco, load/unload, oil-flooded, rotary screw compressors, running the low-pressure system at 95 psi. The operation ran at a fairly consistent load 24 hours per day, seven days per week. One Sullair 300-hp VFD compressor on the low system operated as a trim machine. According to the technical assistance study, the pre-retrofit compressed air system operated at an average efficiency of 4.25 cfm/Bhp.

Installed: The installed case uses two FS Elliott P500-800, 800-hp, three-stage, water-cooled centrifugal compressors, rated for 4,485 cfm each at 95 psig compressed air. According to the technical assistance study, the installed system operates at an efficiency of 5.34 cfm/Bhp.

The existing Sullair VFD compressor continues to operate as a trim machine, and the seven existing Atlas Copco compressors have been kept as back-up compressors.

As the new compressors are water-cooled, an electric penalty exists for heat rejection. According to the original documentation, one new 20-hp pump was installed to operate with the existing process-load cooling tower to reject heat from the compressors.

ECM-2—Low-Pressure Air Dryer Replacement

Pre-Retrofit: Based on the technical assistance study, the nine pre-retrofit air dryers (with a combined rating of 100-hp) proved too small for the 300-hp air compressors. The dryers were manifolded together to allow enough flow to dry the air sufficiently. All dryers were required to operate, regardless of the number of compressors running.

Installed: The installed case uses two Zeks 4800NCFM, 4,800-acfm, refrigerated air dryers for the new compressors, with combined rating of 63-hp.

ECM-3—High Pressure Dryer Replacement

Pre-Retrofit: The pre-retrofit system consisted of four, 250-hp, Atlas Copco, oil-flooded, rotary screw compressors, serving the high-pressure system at 188 psi. The operation served a fairly consistent load of ~1,000 cfm, 24 hours per day, seven days per week. One regenerative air dryer served the compressors.

The system, regulated from 188 psi in a 2½" pipe down to 125 psi in a 1½" pipe (prior to the dryer), fed a 370-cfm rated regenerative dryer. The pre-retrofit discharge pressure to the plant also was 105 psi, but this setting was found higher than necessary. The following issues arose with the pre-retrofit system:

1. The final discharge pressure to the plant should have been set at 95 psi, not 105 psi.
2. The 370 cfm dryer was not sized correctly to dry 1,000 cfm of compressed air.
3. The piping was too small to allow adequate flow.

Installed: By replacing the pre-retrofit dryer with a 1,000-cfm regenerative dryer and increasing the pipe size, pressure at the dryer inlet could be reduced from 125 psi to 95 psi. The flow would be reduced from 1,000 cfm to 760 cfm, according to the calculation below:

New Pressure (95 psi) / Existing Pressure (125 psi) * Existing Flow (1,000 cfm) = New Flow (760 cfm)

13-1547987

Application CSN13-1547987 involves two compressed retrofit measures at the customer's facility on [redacted] Street in [redacted].

ECM-1—New VFD Air Compressor

This measure involved the removal of three, existing, two-stage, Sullair, 300-hp air compressors and the installation of one, Sullair Tandem TS320-250LAC, 250-hp, VFD air compressor. Only one of the pre-retrofit compressors would operate during normal production periods; the second compressor would briefly turn on only for high demand periods.

This measure originally involved replacement of existing manual condensate drain valves with 10 zero-loss demand drains for condensate removal. As discussed below, this part of the measure was not installed, and updated energy savings calculations were submitted.

ECM-2—Compressed Air System Heat Recovery

This measure involved the installation of a heat recovery unit on the compressed air system, designed to reduce the need for electric resistance space heating during the winter months. The existing 440 kW electric resistance heating coils heated the entire [redacted] T2 building prior to the retrofit.

Goals and Objectives

Table 1 and Table 2 show the projected savings goals identified in the project applications.

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Table 1. 14-1706227 Project Goals

ECM	Application		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual Energy Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Reduction
1 & 2	6,085,893	N/A	6,955,726	N/A	N/A	N/A
3	1,002,105	N/A	132,273	N/A	N/A	N/A
Total	**7,087,999**	**N/A**	**7,087,999**	**7,087,680**	**775.5**	**809.1**

* Source: DSMore input spreadsheet.

Table 2. 13-1547987 Project Goals

ECM	Applicant		Duke Energy			
	Annual kWh Savings	Average kW Reduction	Projected Annual Energy Savings*	Claimed Annual kWh Savings	Claimed Coincident Peak kW Reduction	Claimed Non-CP kW Savings
1	478,767	N/A	379,523	372,144	55.7	N/A
2	134,572	0	127,148	121,208	0.0	N/A
Total	**613,339**	**N/A**	**506,671**	**494,115**	**55.7**	**69.7**

* Source: DSMore input spreadsheet.

The M&V project sought to verify the actual numbers for the following:

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

Project Contacts

The Duke Energy contact listed in Table 3 granted approval to plan and to schedule the site visit for this M&V effort.

Table 3. Project Contacts

Organization	Contact	Contact Information
Duke Energy	Frankie Diersing	office: 513-287-4096 Frankie.diersing@duke-energy.com
Cadmus	Christie Amero	office: 303-389-2509 christie.amero@cadmusgroup.com
Customer	redacted	

Site Locations

The locations where the measures were installed are shown in Table 4.

Table 4. Project Locations

Address	ECM
redacted	1, 2, & 3 (CSN14-1706227)
redacted	1 & 2 (CSN13-1547987)

M&V Option

To assess these projects, Cadmus utilized IPMVP Option A.

Implementation

Cadmus reached out to the site contact provided by Duke Energy to review the evaluation plan and to schedule the site visit. The site contact confirmed that trend data were available and the metering could be performed while de-energized. Christie Amero and Tom Davis of Cadmus performed the site visit on January 6, 2016.

Field Notes

Upon arriving on site, Cadmus first met to discuss the metering plan with the facility management team for both buildings. At both sites, the compressed air discharge pressure has remained constant since before project implementation. Depending on the season, production has increased slightly, and minor changes have occurred in the production schedule. Site and measure-specific notes follow.

14-1706227

The [redacted] facility operates 24 hours per day, seven day per week, year-round. During the inspection, the facility operated in its busy season.

ECM-1 & 2—Low-Pressure Air Compressor and Dryer Replacements

Rather than installing 800-hp air compressors as expected, the site installed two 900-hp air compressors. This selection change was due to a last-minute decision based on production forecasting. According to the equipment vendor, the installed units are considered to be the same model that was submitted in the application (P500-800) even though they were installed with 900 hp motors.

The site also replaced the 480 V feed for the 900-hp compressors with a 4,160 V feed. As Cadmus cannot meter above 480 V, we revised the plan to collect power demand and pressure trend data for the two 900-hp compressors.

The pre-retrofit Atlas Copco compressors remained on-site, but they were off and only used as back-ups. The existing Atlas Copco, 300-hp, VFD compressor also was off during the site visit and is rarely used, according to the site contact.

As expected, the site installed two Zeks air dryers for the low-pressure system.

A change also occurred to the cooling tower pumps: rather than two 20-hp pumps, the site installed two 40-hp cooling tower pumps. The pumps operate lead/lag. The cooling tower served by the pumps has two fans, both with VFDs. One fan ran at 15 Hz during the inspection.

ECM-3—High-Pressure Dryer Replacement

Cadmus verified the 1,000 CFM air dryer had been installed, but could not meter it as it is served by a 120 V feed. The operating current during the inspection was only 4 amps; it was determined that manufacturer's data would serve to identify its energy use. During the walkthrough the pressure was 103 psi.

Cadmus did not meter the four existing Atlas Copco air compressors.

13-1547987

The [redacted] facility typically operates 24 hours per day, Monday through Friday, but the schedule varies slightly, based on demand.

ECM-1—New VFD Air Compressor

Cadmus verified the installation of the new 250-hp, VFD air compressor.

The zero-loss condensate drains expected from the project documentation were not installed. The site contact stated that they did not plan to install the drains and did not receive an incentive for that portion of the project.

ECM-2—Compressed Air System Heat Recovery

Cadmus verified the installation of the compressed air heat recovery duct. The heated air is ducted directly from the 250-hp air compressor into a mixing room, where outside air is drawn in for humidification. The mixed air is then fed through electric duct heaters into the warehouse space.

Field Data

Cadmus collected the following: equipment nameplate data, power metered data, and photographs for each application.

14-1706227

Table 5 summarizes equipment nameplate data collected at the [redacted] location. Photographs of equipment and nameplates follow.

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Table 5. 14-1706227 Equipment Nameplate Data

Equipment ID	Make	Model Number	Serial Number	Size/Rating
900-hp Comp-1 (LP)	FS Elliot	P500-800	N/A	900 hp
900-hp Comp-2 (LP)	FS Elliot	P500-800	N/A	900 hp
300-hp VFD Comp (LP)	Atlas Copco	GA 315 VSD	APF.143057	300 hp
Dryer-1 (LP)	Zeks	4800NCFMA40NV	554076-1	4,800
Dryer-2 (LP)	Zeks	4800NCFMA40NV	554076-2	4,800
1000 CFM Dryer (HP)	Zeks	1000ZPA1HE000	554060	1,000 CFM
CT Pump-1 (LP)	Armstrong	6x6xB.5 4300TC	762750	40 hp
CT Pump-2 (LP)	Armstrong	6x6xB.5 4300TC	762751	40 hp

Figure 1 shows a screenshot of the EMS for the low-pressure compressed air system. Figure 2 shows installed air dryers for the low-pressure system. Figure 3 shows the dryer nameplates.

Figure 1. Screenshot of EMS for Low-Pressure System

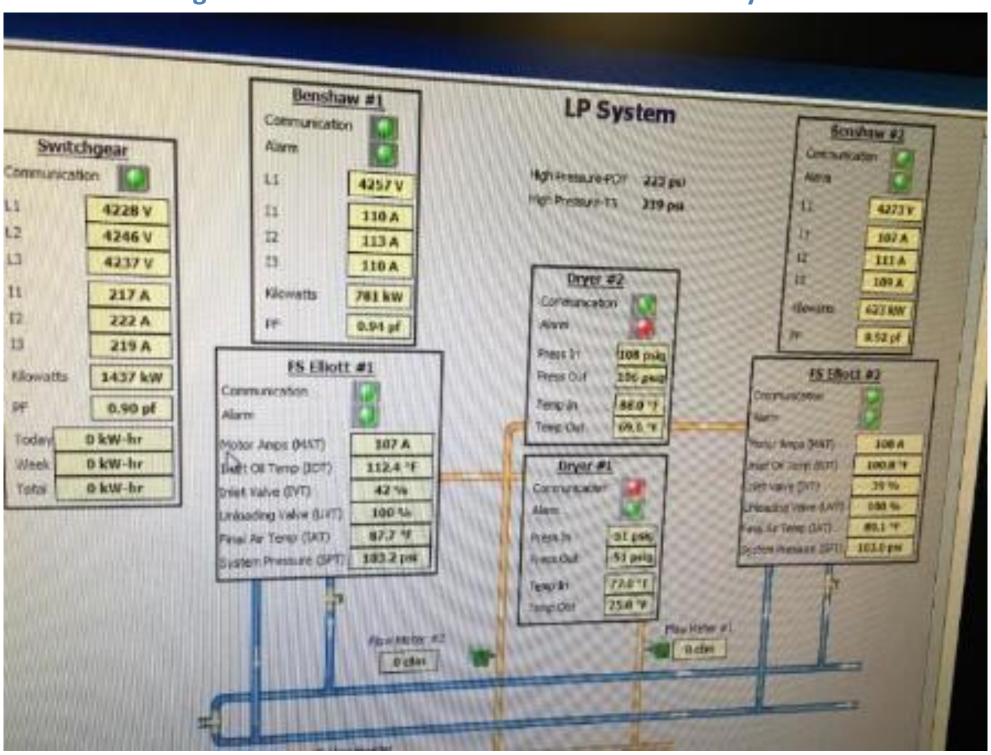

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Figure 2. Installed 4,800 CFM Air Dryers for Low-Pressure System

Figure 3. Installed 4,800 CFM Air Nameplates

Figure 4 shows the nameplate for the existing 300-hp, VFD air compressor. Figure 5 shows the two cooling tower pumps for the water-cooled air compressors. Figure 6 shows a nameplate for one pump.

Figure 4. Existing 300-hp VFD Air Compressor

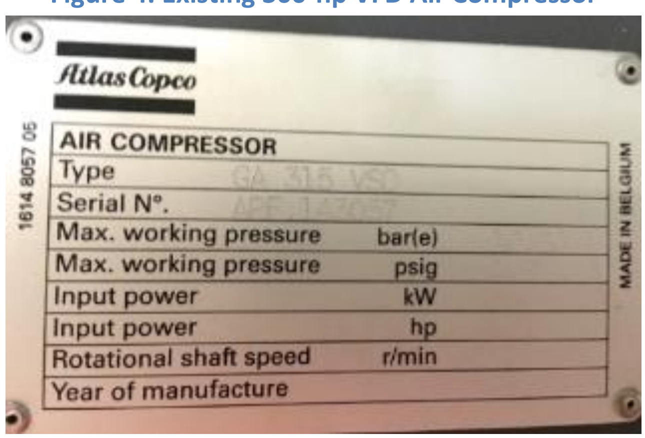

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Figure 5. 40-hp Cooling Tower Pumps for Water-Cooled Air Compressors

Figure 6. 40-hp Cooling Tower Pump Nameplate

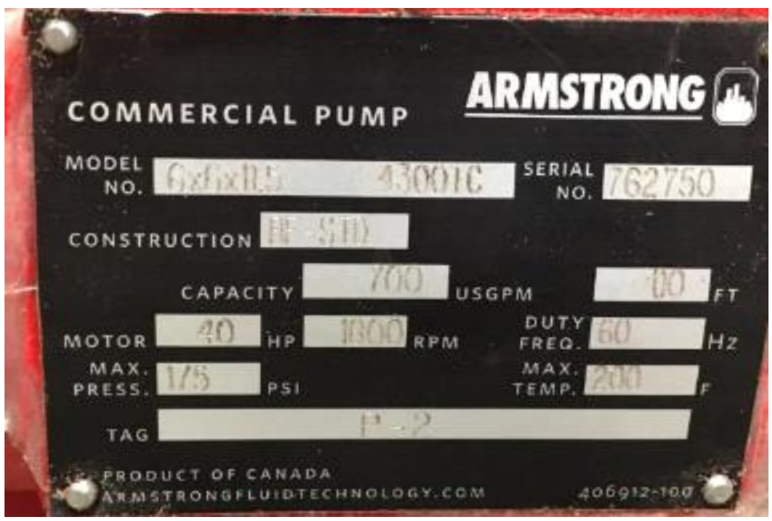


Figure 7 shows the nameplate for the installed 1,000 cfm air dryer for the high-pressure compressed air system.

Figure 7. Installed 1,000 CFM Air Dryer for High-Pressure System

As the installed 900-hp air compressors are served by ~4,200 V, Cadmus collected compressor demand and pressure trend data from the site for a two-week period. Figure 8 shows the combined power demand for the two 900-hp air compressors from the trend data. Average operating demand was 1,299.8 kW. Figure 9 shows the trended system discharge pressure. The average pressure during the trend period was 104.2 psi.

Figure 8. Trended Demand Data for Installed 900-hp Air Compressors

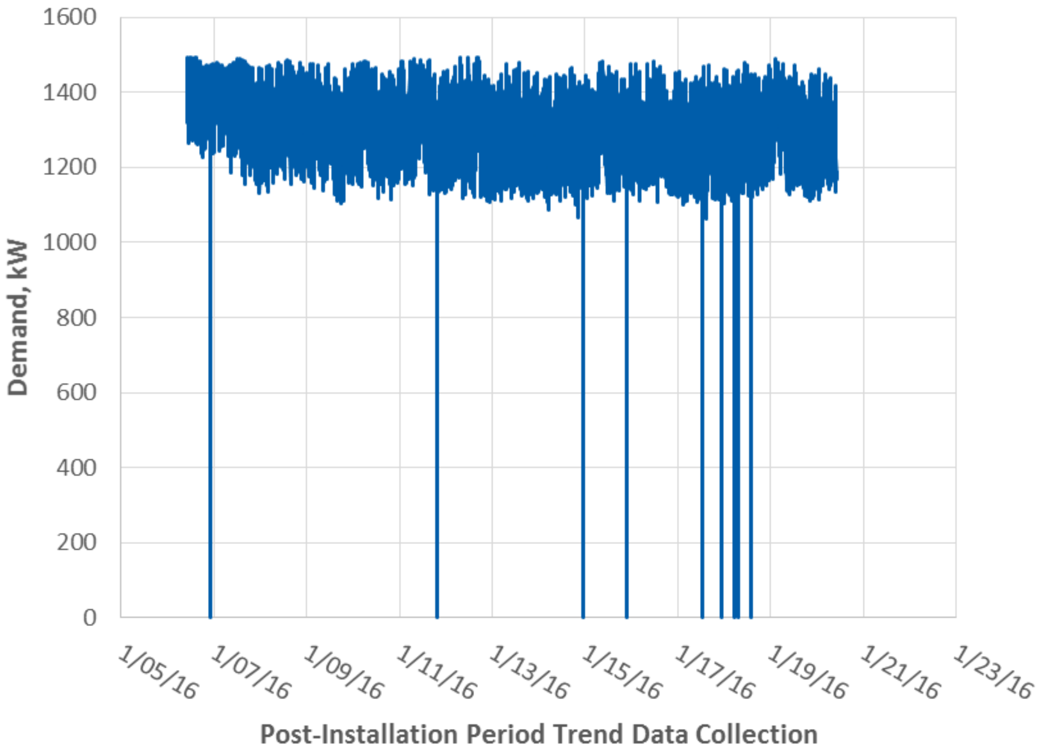
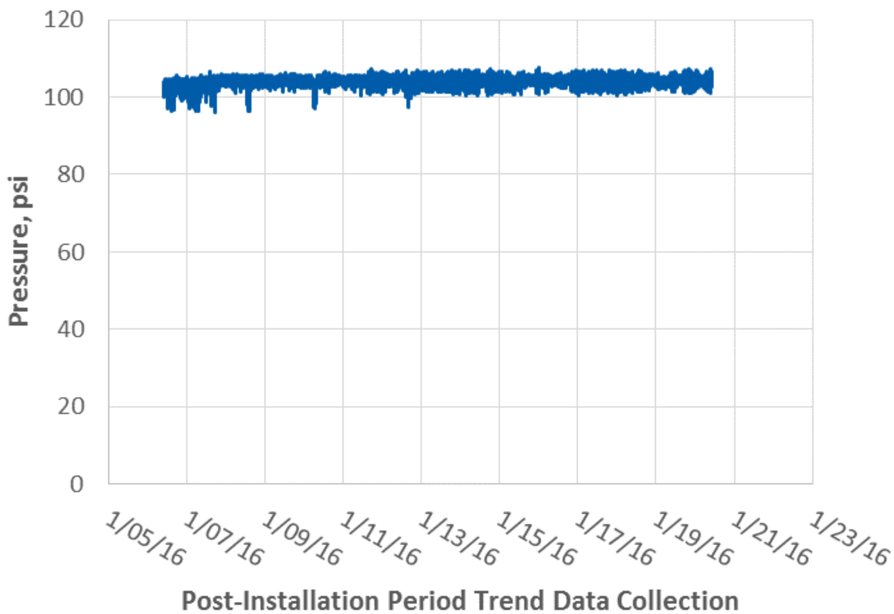


Figure 9. Trended System Discharge Pressure for Low-Pressure System



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Cadmus installed three-phase power meters on the remaining 300-hp, VFD air compressor, two air dryers, and cooling tower pumps for the low-pressure system. Data were collected for two weeks at one-minute intervals. Table 6 summarizes the installed metering equipment.

Table 6. 14-1706227 Summary of Installed Metering Equipment

Equipment ID	RX3000	WattNode 3D-480	Current Transducers (Qty/Size)
VFD Air Comp	1	1	3 / 1200 A
Dryer-1 (LP)	1	1	3 / 100 A
Dryer-2 (LP)		1	3 / 100 A
CT Pump-1	1	1	3 / 100 A
CT Pump-2		1	3 / 100 A
Total	**3**	**5**	**15**

As expected, the 300-hp VFD air compressor never ran during the metering period. Figure 10 shows metered demand data for the two, 4,800 cfm air dryers for the low-pressure system. Figure 11 shows metered demand for the two cooling pumps. Only one pump ran during the metering period.

Figure 10. Metered Demand Data for Low-Pressure Air Dryers