Opinion Dynamics

Boston | Headquarters

617 492 1400 tel
617 497 7944 fax
800 966 1254 toll free

1000 Winter St
Waltham, MA 02451

Ameren Illinois Company Transition Period Impact Evaluation Report

Volume II – Detailed Methodology and Supplemental Information
Revised Final

December 11, 2018

Contributors

Hannah Howard
Managing Director, Opinion Dynamics

Zach Ross
Principal Consultant, Opinion Dynamics

Tami Buhr
Vice President, Opinion Dynamics

Olivia Patterson
Senior Director, Opinion Dynamics

Ann Collier
Principal Consultant, Opinion Dynamics

Alan Elliott
Principal Consultant, Opinion Dynamics

Aaiysha Khursheed
Principal Consultant, Opinion Dynamics

Matt Drury
Senior Director, Opinion Dynamics

Mike Frischmann
Director - Evaluation Engineering, Michaels Energy

Kyle McKenna
Evaluation Engineer, Michaels Energy

Table of Contents

Table of Tables

Opinion Dynamics

Table of Figures

1. Introduction

This second volume of the AIC Transition Period Impact Evaluation Report presents detailed methodology and supplemental information for the following programs:

- Retail Products
- Behavior Modification
- Home Efficiency Income Qualified
- Public Sector CAC
- C&I Custom

2. Retail Products

In this section, we provide details on the savings assumptions used to estimate ex post gross energy, demand, and therm savings for lighting products and smart thermostats distributed through the Retail Products Program during the Transition Period.

2.1 Lighting Gross Impacts Overview

The evaluation team calculated gross electric and demand savings for the Transition Period using the program tracking database and applying algorithms and savings assumptions based on the Illinois Statewide Technical Reference Manual Version 5.0 (IL-TRM V5.0). Gross impact savings analysis included the calculation of carryover savings from the previous program years. Those are savings from the products purchased in the previous years but assumed to be installed in Transition Period.

The IL-TRM V5.0 outlines a carryover savings method to account for bulbs that are purchased and stored for later use. The method assumes that 2% of program bulbs will never be installed, but the remaining 98% will be installed within 3 years. As a result, Transition Period savings come from bulbs *installed* in the Transition Period but that could have been *purchased* in PY8, PY9, or the Transition Period. Because the Transition Period only accounts for seven of the twelve months of a calendar year, the quantity of bulb sales from PY8 and PY9, which each spanned a full year, had to be further adjusted. To this end, sales from PY8 that will be installed the third year after purchase and sales from PY9 that will be installed in the second year after purchase were each multiplied by 7/12th to represent the portion of bulbs installed during the Transition Period. The remaining 5/12th from each of these years will be installed in 2018 and claimed as part of 2018 savings.

Equation 1. Carryover Savings Formula – Energy Savings

$$\begin{gathered}\text{Realized Transition Period Energy Savings } = \Delta\,\text{kWh } \times \\ (\text{Units Purchased and Installed in Transition Period} + \\ (\text{Units Purchased in PY9 and Installed in Transition Period } \times {}^{7}/_{12}) + \\ (\text{Units Purchased in PY8 and Installed in Transition Period} \times {}^{7}/_{12}))\end{gathered}$$

Equation 2. Carryover Savings Formula – Demand Savings

$$\begin{aligned}&\text{Realized Transition Period Demand Savings}\\ &\quad = \Delta\,\text{kW } \times (\text{Units Purchased and Installed in Transition Period}\\ &\quad + (\text{Units Purchased in PY9 and Installed in Transition Period } \times 7\ /\ 12)\\ &\quad + (\text{Units Purchased in PY8 and Installed in Transition Period} \times 7\ /\ 12))\end{aligned}$$

Per the IL-TRM V5.0, first-year in-service rate (ISR) varies by bulb type. We took those varying first-year ISRs into account when estimating carryover savings. Table 1 below provides an installation trajectory by bulb type

Table 1. Installation Rate Trajectory for LEDs

First Year (YR1)	Second Year (YR2)	Third Year (YR3)	Final
95.0%	1.6%	1.4%	98.0%

Source: IL-TRM V5.0.

Equation 3 and Equation 4 detail the algorithms used to calculate per bulb energy and demand savings from the program-discounted bulbs. We estimated energy savings for each of the three years during which

Transition Period program bulbs are estimated to be installed. We applied the installation rate of the respective year as presented in Table 1 above.

The savings assumptions in the IL-TRM V5.0 vary depending on the customer and bulb type purchased. Based on the in-store customer intercept interviews completed as part of the PY8 evaluation, the evaluation team determined that 3% of program-discounted LEDs are installed in commercial spaces, which have greater HOU and different waste heat factors. The remaining 97% of program-discounted bulbs are installed in residential settings. To estimate energy savings, the evaluation team weighted the savings by the number of bulbs installed in residential homes and commercial spaces.

Due to the upstream nature of the program, AIC cannot limit the sales of program-discounted bulbs to AIC customers. At the same time, AIC customers can go to retailers in neighboring jurisdictions and purchase utility-discounted bulbs. Through our in-store customer research conducted in PY8, the evaluation team estimated that 13% of AIC-discounted bulbs were sold to non-AIC customers. Through secondary research that we conducted in PY7, the evaluation team estimated that AIC customers purchased and installed the equivalent 5% of AIC PY7 sales from other utility programs in Illinois, Indiana, and Missouri. Based on our estimates of both factors, we applied an overall leakage rate of 8% to gross.

Equation 3. First-Year Per Bulb Energy and Demand Savings Algorithm

$$Year\ 1\ \Delta\ kWh = \mathrm{LA} \times\ 0.97 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr1} \times HOU_{res} \times WHFe_{res}\right] + \mathrm{LA} \times 0.03 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr1} \times HOU_{com} \times WHFe_{com}\right]$$

$$Year\ 1\ \Delta\ kW = LA \times 0.97 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr1} \times WHFd_{res} \times CF_{res}\right] + LA \times 0.03 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr1} \times WHFd_{com} \times CF_{com}\right]$$

Where:

$Year\ 1\ \Delta\ kWh$=Per-bulb energy savings from program bulbs installed in the first year

$Year\ 1\ \Delta\ kW$=Per-bulb summer peak demand savings from program bulbs installed in the first year

LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)

0.97 = Residential install rate

0.03 = Commercial install rate

$Base\ Watt$ = EISA-compliant base wattage

$Bulb\ Watt$ = Actual wattage of installed bulb

ISR = First year in-service rate

HOU = Hours of use

$WHFe$ = Waste heat factor for energy savings

$WHFd$ = Waste heat factor for demand savings

CF = Summer peak coincidence factor

Res = Residential values

Com = Commercial values

We provide more detail on the savings assumptions for each quantity in Appendix A.

Similarly, to calculate savings for Transition Period purchases that will be installed during the next 2 years, we simply apply the in-service rate (ISR) for year 2 and year 3.

Equation 4. Future Years Per Bulb Energy and Demand Savings Algorithm

$$Year\ 2\ \Delta\ kWh = LA \times 0.97 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr2} \times HOU_{res} \times WHFe_{res}\right] +$$

$$LA \times 0.03 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr2} \times HOU_{com} \times WHFe_{com}\right]$$

$$Year\ 2\ \Delta\ kW = LA \times 0.97 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr2} \times WHFd_{res} \times CF_{res}\right] +$$

$$LA \times 0.03 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr2} \times WHFd_{com} \times CF_{com}\right]$$

$$Year\ 3\ \Delta\ kWh = LA \times 0.97 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr3} \times HOU_{res} \times WHFe_{res}\right] +$$

$$LA \times 0.03 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr3} \times HOU_{com} \times WHFe_{com}\right]$$

$$Year\ 3\ \Delta\ kW = LA \times 0.97 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{res,yr3} \times WHFd_{res} \times CF_{res}\right] +$$

$$LA \times 0.03 \times \left[\frac{(Base\ Watt - Bulb\ Watt)}{1000} \times ISR_{com,yr3} \times WHFd_{com} \times CF_{com}\right]$$

Where:

$Year\ 2\ \Delta\ kWh$=Per-bulb energy savings from Transition Period program bulbs installed in the second year
$Year\ 2\ \Delta\ kW$=Per-bulb summer peak demand savings from Transition Period program bulbs installed in the second year
$Year\ 3\ \Delta\ kWh$=Per-bulb energy savings from Transition Period program bulbs installed in the third year
$Year\ 3\ \Delta\ kW$=Per-bulb summer peak demand savings from Transition Period program bulbs installed in the third year
LA = Leakage adjustment equal to (1 − leakage rate) or (1 − %Leakage)
0.93 = Residential install rate
0.03 = Commercial install rate
$Base\ Watt$ = EISA-compliant base wattage
$Bulb\ Watt$ = Actual wattage of installed bulb
ISR = First year in-service rate
HOU = Hours of use

$WHFe$ = Waste heat factor for energy savings
$WHFd$ = Waste heat factor for demand savings
CF = Summer peak coincidence factor
Res = Residential values
Com = Commercial values

2.2 Lighting Net Impacts Overview

The evaluation team applied net-to-gross ratios (NTGRs) approved by the Illinois SAG to Transition Period program savings as well as the carryover savings. The Transition Period NTGRs come from the in-store intercept interviews that we conducted for ComEd as part of its PY8 evaluation.[1] Note that consistent with the IL-TRM V5.0, when calculating carryover net savings, we applied the approved NTGRs for the year of purchase. Table 2 summarizes the NTGRs used in the net impact analysis.

Table 2. SAG-Approved NTGRs

Measure Type	Transition Period NTGR	PY9 Electric NTGR	PY8 Electric NTGR
Standard CFLs	N/A	0.63	0.63
Standard LEDs	0.58	0.58	0.73
Specialty LEDs	0.60	0.60	

2.3 Lighting Base Wattage and EISA Compliance

The baseline wattages in the IL-TRM V5.0 vary depending on the bulb type. Baseline wattages for standard LEDs are based on the lumen output and account for EISA efficiency standards, where appropriate (see Table 3 below).

Table 3. Baseline Wattages for Standard LEDs

Lumen Range	Base Wattage
250–309	25
310–749	29
750–1,049	43
1,050–1,489	53
1,490–2,600	72
2,601–2,999	150
3,000–5,279	200
5,280–6,209	300

The baseline wattages for directional LEDs vary depending on the directional bulb type and lumen range and account for the Department of Energy (DOE) energy efficiency standards for incandescent reflector lamps and any appropriate exemptions to the standards. Table 4 specifies the baseline wattages we used in our savings calculations for directional LEDs.

[1] Opinion Dynamics conducted in-store intercepts in PY8 and estimated an LED NTGR, but the research was completed after the deadline for use in the PY9 evaluation.

Table 4. Baseline Wattages for Reflector LEDs

Bulb Type	Lumen Range	Base Wattage
R, ER, BR with medium screw bases w/diameter >2.25" (*see exceptions below)	420-472	40
	473-524	45
	525-714	50
	715-937	65
	938-1,259	75
	1,260-1,399	90
	1,400-1,739	100
	1,740-2,174	120
	2,175-2,624	150
	2,625-2,999	175
	3,000-4,500	200
*R, BR, and ER with medium screw bases w/diameter <=2.25"	400-449	40
	450-499	45
	500-649	50
	650-1,199	65
*ER30, BR30, BR40, or ER40	400-449	40
	450-499	45
	500-649	50
*BR30, BR40, or ER40	650-1,419	65
*R20	400-449	40
	450-719	45
*All reflector lamps below lumen ranges specified above	200-299	20
	300-399	30

For PAR and MR directional products, we used the Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. A formula is provided based on the Energy Star Center Beam Candle Power tool,[2] and specifies that the result of the equation should be rounded down to the nearest wattage established by Energy Star based on the table below.

Wattsbase =

2 http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g., for PAR20, D = 20)
BA = Beam angle
CBCP = Center beam candle power

Table 5. Permitted Baseline Wattages for PAR and MR LEDs

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

For specialty LEDs, we varied baseline wattages based on the specialty bulb type. Specialty bulbs are exempt from the first phase of EISA 2007, therefore the baseline wattages are based on incandescent products of equivalent lumen output. Table 6 details baseline wattages used to calculate savings for specialty LEDs.

Table 6. Baseline Wattages for Specialty LEDs

Bulb Type	Lumen Range	Base Wattage
3-Way	250-449	25
	450-799	40
	800-1,099	60
	1,100-1,599	75
	1,600-1,999	100
	2,000-2,549	125
	2,550-2,999	150
Globe (medium and intermediate bases less than 750 lumens)	90-179	10
	180-249	15
	250-349	25
	350-749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70-89	10
	90-149	15
	150-299	25
	300-749	40
Globe (candelabra bases less than 1050 lumens)	90-179	10
	180-249	15
	250-349	25
	350-499	40
	500-1,049	60
Decorative	70-89	10
	90-149	15

Bulb Type	Lumen Range	Base Wattage
(Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	150-299	25
	300-499	40
	500-1,049	60

2.4 Lighting Residential versus Commercial Installations

As part of in-store customer intercept interviews conducted as part of the PY8 evaluation, we asked customers if they intended to install the bulbs in a home or business. If a business, we further asked for the type of business and, if a rental property, inquired as to whether the bulbs would be installed in a common area or a tenant unit. We classified bulbs that would be installed in tenant units as residential installations. For customers who said that they would install the bulbs in both their home and business, we evenly divided the bulbs between the two locations. We found that 97% of discounted LED light bulbs would be installed in residential locations and 3% in commercial locations, as shown in Table 7.

Table 7. Bulb Installation Location

Location	LEDs
Residential	97%
Commercial	3%

2.5 Lighting Hours of Use

For the 97% of bulbs sold to residential customers, we applied the residential HOU assumptions, and for the 3% of bulbs sold to commercial entities we applied the commercial HOU assumptions from the IL-TRM V5.0 (see Table 8). The TRM provides different residential HOU assumptions for different bulb types as well as for exterior and interior installations. Where applicable and possible, we used custom HOU by product type and installation location. For specialty products, specifically, we applied a generic interior HOU value of 847.

For commercial HOU, one value is provided for exterior installations and another is given for installations that could be either indoors or outdoors. All were assumed to be interior installations for the purposes of this evaluation.

Table 8. Illinois Statewide TRM Version 5.0 LED HOU Assumptions

Bulb Type	Residential	Commercial
Standard	847	3,612
Reflector (BR/R)	891	3,612
Reflector (PAR)	891	3,612
Reflector (Exterior)	2,475	4,903
Specialty (CMB/CSB)	1,190	3,612
Specialty (G25/G16C)	639	3,612
Specialty (3-way)	850	3,612

2.6 Lighting Waste Heat Factors

The IL-TRM V5.0 provides different waste heat factor values for different installation locations. For energy savings, we used a waste heat factor of 1.06 for the 97% of bulbs that were installed in residential locations and 1.09 for the 3% that were installed in commercial locations.[3] For demand savings, we used a waste heat factor of 1.11 for the 97% of bulbs that were installed in residential locations and 1.36 for the 3% that were installed in commercial locations. Bulb types that customers would normally install in exterior locations take on a value of 1.00 because these bulbs do not affect the heated areas of a building. Table 9 outlines waste heat factor assumptions by installation location and bulb type.

Table 9. Illinois Statewide TRM Version 5.0 LED Waste Heat Factor Assumptions

Bulb Type	Residential		Commercial	
	WHFe	WHFd	WHFe	WHFd
Standard	1.06	1.11	1.09	1.36
Reflector (BR/R)	1.06	1.11	1.09	1.36
Reflector (PAR)	1.06	1.11	1.09	1.36
Reflector (Exterior)	1.00	1.00	1.00	1.00
Specialty (CMB/CSB)	1.06	1.11	1.09	1.36
Specialty (G25/G16C)	1.06	1.11	1.09	1.36
Specialty (3-way)	1.06	1.11	1.09	1.36

2.7 Lighting Coincidence Factors

The IL-TRM V5.0 provides peak CFs based on bulb type and installation location. For the 97% of bulbs sold to residential customers, we applied the residential factors and, for the remaining 3%, we applied the commercial factors (see Table 10).

Table 10. Illinois Statewide TRM Version 5.0 LED Coincidence Factor Assumptions

Bulb Type	Residential	Commercial
Standard	0.081	0.580
Reflector (BR/R)	0.091	0.580
Reflector (PAR)	0.094	0.580
Reflector (Exterior)	0.273	0.580
Specialty (CMB/CSB)	0.121	0.580
Specialty (G25/G16C)	0.075	0.580
Specialty (3-way)	0.078	0.580

[3] The TRM provides a large variety of waste heat factors for commercial installations based on building type. Because we do not know the installation locations of bulbs sold to commercial customers, we followed the TRM guidelines and chose the WHFe for unknown buildings.

2.8 Thermostat Savings Assumptions

The evaluation team used the following equations from the IL-TRM V5.0 to estimate energy, demand, and therm savings for smart thermostats.

$\Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating} + \Delta kWh_{Runtime}$

$\Delta kWh_{Cooling} = \%AC * ((FLH_{Cool} * Capacity_{Cool} * 1/SEER)/1000) * Clg\ Reduction * ISR$

$\Delta kWh_{Heating} = \%ElectricHeat * Elec\_Heating\_Consumption * Htg\ Reduction * HF * ISR$

$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$

$\Delta kW = \%AC * (Clg\ Reduction * Capacity_{Cool} * (1/EER)/1000) * ISR * CF$

$\Delta Therms = \%FossilHeat * Gas\_Heating\_Consumption * Htg\ Reduction * HF * ISR$

Where:

%AC = 100% if central cooling is present, 0% if no central cooling is present, 87% if unknown

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 11. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

$Capacity_{Cool}$ = Cooling capacity of air conditoiner = 33,600 BTU/hour (deemed)

SEER = Cooling efficiency of central air conditioner or heat pump controlled by the smart thermostat in units of SEER = Actual; If unknown assumed 8.60 SEER for air conditioners and 9.12 SEER for heat pumps

Clg Reduction = Reduction in cooling energy consumption due to installing a smart thermostat = 8.0%

ISR = Percentage of thermostats installed and effectively programmed = 100%

%ElectricHeat = 100% if electric space heating fuel, 0% if gas space heating fuel

%FossilHeat = 100% if gas space heating fuel, 0% if electric space heating fuel

Elec_Heating_Consumption = Estimated annual household heating consumption for electrically heated homes (applied per participant based on project location and electric heating type [i.e., electric resistance, heat pump])

Table 12. Electric Heating Consumption by Climate Zone

Climate Zone	kWh

	Electric Resistance	Heat Pump
1 (Rockford)	21,741	12,789
2 (Chicago)	20,771	12,218
3 (Springfield)	17,789	10,464
4 (Belleville)	13,722	8,072
5 (Marion)	13,966	8,215

Gas_Heating_Consumption = Estimated annual household heating consumption for gas-heated homes (applied per participant based on project location)

Table 13. Gas Heating Consumption by Climate Zone

Climate Zone	Therms
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664
5 (Marion)	676

Htg Reduction = Reduction in heating energy consumption = 7.4%

HF = Household factor to adjust heating consumption for single-family homes = 100%

EER = Cooling efficiency of central air conditioner or heat pump controlled by the smart thermostat in units of EER = Actual; If unknown assumed 8.15 EER for air conditioners and 8.55 EER for heat pumps

CF = Summer peak coincidence factor = 0.34

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

3. Behavioral Modification

3.1 Equivalency Analysis Results

We examined the average daily fuel consumption for the 12 pre-participation period months for treatment and control group customers used for modeling to ensure that attrition from the program did not bias findings in the Transition Period. and shows that all cohorts were generally equivalent based on ADC in the pre-participation period.

We found Expansion Cohort 8 to be equivalent in terms of gas and electric usage. For gas customers, ADC in the year before the start of the program was 1.60 therms/day for both treatment and control groups. For electric customers, ADC in the year before the start of the program was 31.24 kWh/day in the control group and 31.21 kWh/day in the treatment group.

Table 14. Pre-Participation Therm Average Daily Consumption

Cohort	Treatment (Pre-Participation) Consumption in Therms	Control (Pre-Participation) Consumption in Therms
Original Cohort	2.43	2.42
Expansion Cohort 1	3.14	3.13
Expansion Cohort 2	1.81	1.81
Expansion Cohort 3	2.11	2.11
Expansion Cohort 4	2.09	2.09
Expansion Cohort 5	2.77	2.77
Expansion Cohort 6	1.93	1.94
Expansion Cohort 7	1.63	1.63
Expansion Cohort 8	1.60	1.60

Table 15. Pre-Participation kWh Average Daily Consumption

Cohort	Treatment (Pre-Participation) Consumption in kWh	Control (Pre-Participation) Consumption in kWh
Original Cohort	33.59	33.53
Expansion Cohort 1	38.85	38.97
Expansion Cohort 2	27.02	27.00
Expansion Cohort 4	51.23	51.02
Expansion Cohort 5	34.87	34.88
Expansion Cohort 6	30.39	30.54
Expansion Cohort 7	31.24	31.21

Figure 1 presents the pre-participation period gas consumption for both treatment and control groups for all cohorts and exhibits equivalency. We present a similar figure for electric consumption in Figure 2, which also exhibits equivalency across the cohorts.

Figure 1. Pre-Participation Period Gas Consumption, Treatment vs. Control, All Waves

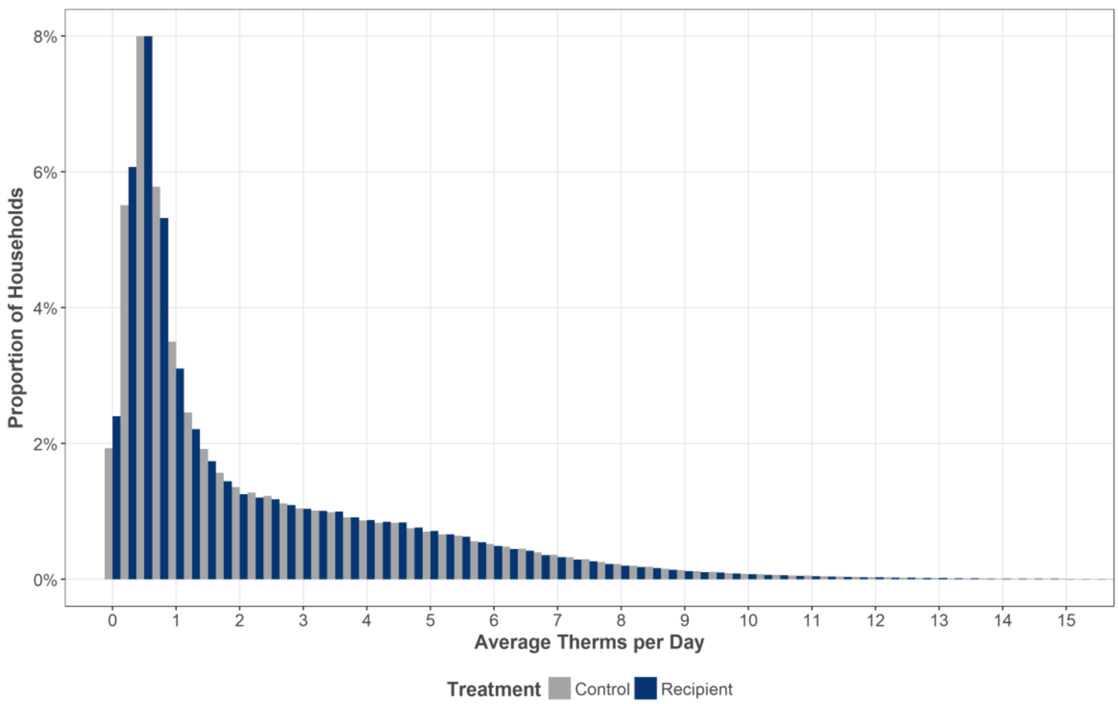
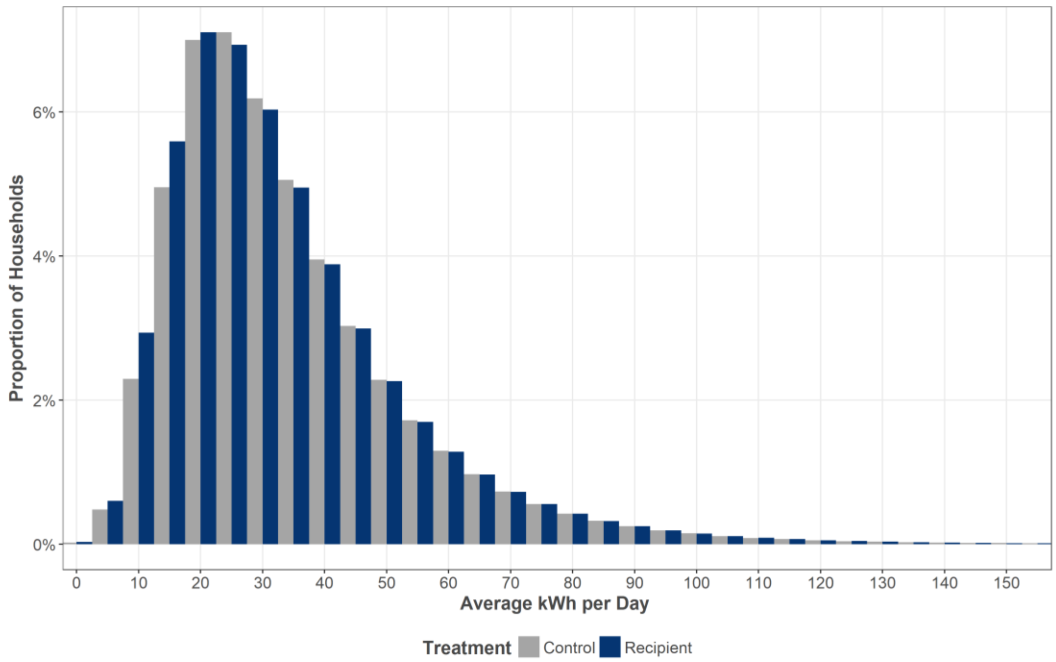


Figure 2. Pre-Participation Period Electric Consumption, Treatment vs. Control, All Waves



3.2 Billing Analysis Data Cleaning Results

This section shows the results of the data cleaning effort for the billing analysis (see Table 16 and Table 17). Results include all customers who were ever assigned to a treatment or control group with available billing data. We include both electric and gas data cleaning results to contextualize our results. The primary driver leading to removal of customers for the analysis is insufficient pre-participation period billing data.

Table 16. Cohort Level Data Cleaning Results for Treatment and Control Groups, Gas

Cohort	Metric	Unique Customers		Observations	
		Treatment	Control	Treatment	Control
Original Cohort	Initial #	49,694	49,688	4,225,785	4,236,641
	Final #	49,442	49,415	4,217,173	4,227,808
	% Remaining	99.49%	99.45%	99.80%	99.79%
Expansion Cohort 1	Initial #	75,688	25,203	5,718,379	1,912,934
	Final #	74,210	24,690	5,689,085	1,902,688
	% Remaining	98.05%	97.96%	99.49%	99.46%
Expansion Cohort 2	Initial #	112,674	19,583	7,853,743	1,364,173
	Final #	107,051	18,545	7,681,496	1,331,875
	% Remaining	95.01%	94.70%	97.81%	97.63%

Cohort	Metric	Unique Customers		Observations	
		Treatment	Control	Treatment	Control
Expansion Cohort 3	Initial #	20,632	10,108	1,285,251	624,118
	Final #	16,754	8,109	1,224,982	593,134
	% Remaining	81.20%	80.22%	95.31%	95.04%
Expansion Cohort 4	Initial #	31,488	10,494	1,653,083	551,504
	Final #	26,380	8,852	1,489,910	499,344
	% Remaining	83.78%	84.35%	90.13%	90.54%
Expansion Cohort 5	Initial #	62,998	12,599	2,724,754	543,254
	Final #	55,247	11,044	2,486,856	495,689
	% Remaining	87.70%	87.66%	91.27%	91.24%
Expansion Cohort 6	Initial #	37,799	16,500	1,351,811	589,907
	Final #	26,039	11,299	1,044,529	453,492
	% Remaining	68.89%	68.48%	77.27%	76.88%
Expansion Cohort 7	Initial #	46,183	18,490	1,151,424	460,813
	Final #	30,433	12,199	863,221	345,849
	% Remaining	65.90%	65.98%	74.97%	75.05%
Expansion Cohort 8	Initial #	52,448	12,589	888,306	213,253
	Final #	49,583	11,899	856,229	205,499
	% Remaining	94.54%	94.52%	96.39%	96.36%

Table 17. Cohort Level Data Cleaning Results for Treatment and Control Groups, Electric

Cohort	Metric	Unique Customers		Observations	
		Treatment	Control	Treatment	Control
Original Cohort	Initial #	49,694	49,688	4,228,155	4,238,623
	Final #	49,438	49,412	4,219,807	4,230,206
	% Remaining	99.48%	99.44%	99.80%	99.80%
Expansion Cohort 1	Initial #	75,688	25,203	5,723,715	1,914,628
	Final #	74,208	24,697	5,695,476	1,904,802
	% Remaining	98.04%	97.99%	99.51%	99.49%
Expansion Cohort 2	Initial #	112,674	19,583	7,859,348	1,364,688
	Final #	107,191	18,569	7,696,257	1,334,106
	% Remaining	95.13%	94.82%	97.92%	97.76%

Cohort	Metric	Unique Customers		Observations	
		Treatment	Control	Treatment	Control
Expansion Cohort 4	Initial #	31,489	10,497	1,658,011	553,207
	Final #	27,193	9,100	1,536,896	514,109
	% Remaining	86.36%	86.69%	92.70%	92.93%
Expansion Cohort 5	Initial #	62,998	12,599	2,727,043	543,682
	Final #	55,438	11,078	2,497,468	497,498
	% Remaining	88.00%	87.93%	91.58%	91.51%
Expansion Cohort 6	Initial #	37,798	16,500	1,354,475	591,219
	Final #	26,496	11,527	1,062,671	462,851
	% Remaining	70.10%	69.86%	78.46%	78.29%
Expansion Cohort 7	Initial #	46,183	18,490	1,153,126	461,420
	Final #	30,773	12,333	873,177	349,676
	% Remaining	66.63%	66.70%	75.72%	75.78%

3.3 Results Using Alternative Model Specifications

Overall Program Savings – Weather-Adjusted Model Results (Model 2)

To enable comparisons across years, we estimated models that incorporated weather terms for each cohort. This also improved the precision of the modeled results by accounting for possible differences in weather experienced by the analyzed population. We present the per household therm and electric savings for the Transition Period in Table 18 and Table 19. The evaluation team notes that gas savings for Expansion Cohort 6 are negative, indicating an increase in gas usage caused by the program. The evaluation team notes that average percent electric savings for all cohorts except Cohort 6 are equal to or greater than 1%.

Table 18. Transition Period Unadjusted Per-Household Net Therm Savings – Weather-Adjusted Model

Cohort	Unadjusted Net Savings (% per household)	Unadjusted Net Savings (therms per household)
Original Cohort	1.12%	3.68
Expansion Cohort 1	1.47%	5.51
Expansion Cohort 2	1.06%	2.69
Expansion Cohort 3	1.73%	4.93
Expansion Cohort 4	0.18%	0.52
Expansion Cohort 5	0.70%	2.23
Expansion Cohort 6	-1.44%	-2.85
Expansion Cohort 7	0.25%	0.62
Expansion Cohort 8	1.65%	1.84

Table 19. Transition Period Unadjusted Per-Household Net Electric Savings – Weather-Adjusted Model

Cohort	Unadjusted Net Savings (% per household)	Unadjusted Net Savings (therms per household)
Original Cohort	1.33%	98.55
Expansion Cohort 1	1.70%	139.38
Expansion Cohort 2	1.12%	64.79
Expansion Cohort 3	N/A	N/A
Expansion Cohort 4	1.00%	103.67
Expansion Cohort 5	1.30%	96.75
Expansion Cohort 6	0.47%	30.90
Expansion Cohort 7	1.08%	75.00
Expansion Cohort 8	N/A	N/A

Original Model (Model 3)

The results in Table 20 and Table 21 reflect estimated per household therm and electric savings from the original model. Similar to the weather adjusted model, gas savings for Expansion Cohort 6 are negative, indicating an increase in gas usage caused by the program. In this case, gas savings for Expansion Cohort 7 are also negative. The evaluation team notes that average percent electric savings for all cohorts except Cohort 6 are equal to or greater than 1%.

Table 20. Transition Period Unadjusted Per-Household Net Therm Savings – Original Model

Cohort	Unadjusted Net Savings (% per household)	Unadjusted Net Savings (therms per household)
Original Cohort	1.21%	3.98
Expansion Cohort 1	1.37%	5.06
Expansion Cohort 2	1.03%	2.58
Expansion Cohort 3	1.87%	5.32
Expansion Cohort 4	0.32%	0.91
Expansion Cohort 5	0.71%	2.30
Expansion Cohort 6	-1.65%	-3.22
Expansion Cohort 7	-0.23%	-0.56
Expansion Cohort 8	0.65%	1.78

Table 21. Transition Period Unadjusted Per-Household Net Electric Savings – Original Model

Cohort	Unadjusted Net Savings (% per household)	Unadjusted Net Savings (kWh per household)
Original Cohort	1.37%	101.51
Expansion Cohort 1	1.66%	135.49
Expansion Cohort 2	1.02%	58.57
Expansion Cohort 3	N/A	N/A

Cohort	Unadjusted Net Savings (% per household)	Unadjusted Net Savings (kWh per household)
Expansion Cohort 4	1.04%	107.93
Expansion Cohort 5	1.24%	91.97
Expansion Cohort 6	0.37%	24.55
Expansion Cohort 7	1.16%	80.45
Expansion Cohort 8	N/A	N/A

3.4 Per-Year Savings

In Figure 3 and Figure 4 below, we present the billing analysis results across program years based on the original model (Model 3). These provide the gas and electric percent household savings by cohort and by year, respectively. These include the two key factors that correlate with program energy impacts: pre-participation period usage and number of years a participant has been in the program.

Notably, because these results do not adjust for variations in weather year over year, they cannot be directly compared. However, we do provide weather-adjusted results in the accompanying evaluation binder of results.

Figure 3. Year-Over-Year Savings – Gas (Original Model)

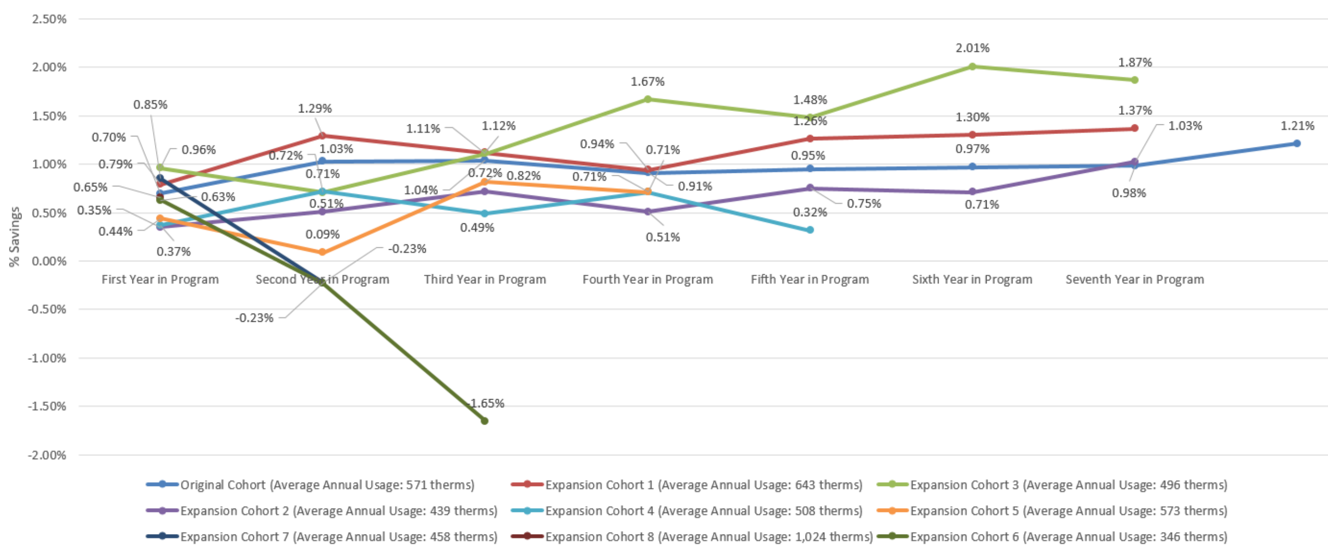
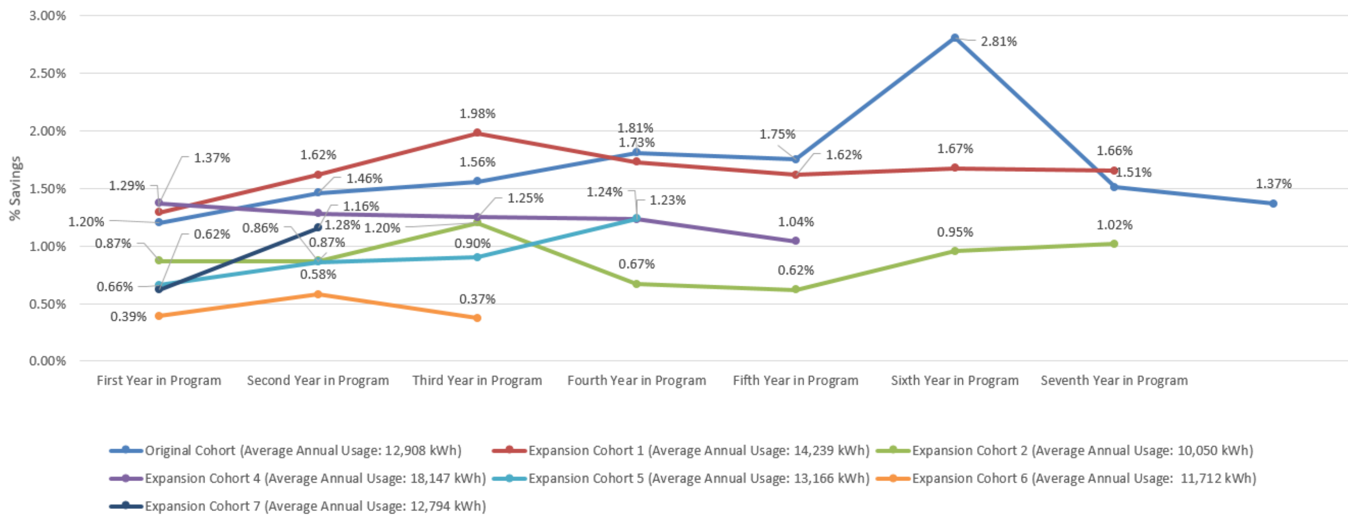


Figure 4. Year-Over-Year Savings – Electric (Original Model)



The evaluation team has estimated impacts using a weather-adjusted model since PY7, as it allows us to assess the changes in energy savings year over year that are not due to extreme changes in weather. Results from this model since PY7 are presented in Table 22 and Table 23 to show how estimated therm and electric savings have changed. As can be seen in Table 22, the gas-only cohorts (3 and 8) yield the highest percent therm savings year over year. Expansion Cohort 2 has shown relatively high contributions to gas savings compared to the other dual-fuel cohorts. In addition, with the exception of Expansion Cohort 6, all cohorts have increased savings annually. Table 23 shows that the Original Cohort and Expansion Cohorts 1 continue to yield the highest electric savings over the most recent years of the program.

Table 22. Weather Adjusted Percent Gas Savings – PY7 - Transition Period

Gas Cohorts	PY7	PY8	PY9	Transition Period
Original Cohort (Average Annual Usage: 571 therms)	0.90%	0.65%	1.03%	1.12%
Expansion Cohort 1 (Average Annual Usage: 643 therms)	0.93%	1.03%	1.36%	1.47%
Expansion Cohort 2 (Average Annual Usage: 439 therms)	0.60%	0.60%	0.70%	1.06%
Expansion Cohort 3 (Average Annual Usage: 496 therms)	1.61%	1.54%	2.01%	1.73%
Expansion Cohort 4 (Average Annual Usage: 508 therms)	0.80%	0.61%	0.83%	0.18%
Expansion Cohort 5 (Average Annual Usage: 573 therms)	0.36%	0.34%	0.89%	0.70%
Expansion Cohort 6 (Average Annual Usage: 346 therms)		0.79%	-0.05%	-1.44%
Expansion Cohort 7 (Average Annual Usage: 458 therms)			1.04%	0.25%
Expansion Cohort 8 (Average Annual Usage: 1,024 therms)[a]				1.65%

[a] The average annual usage for Expansion Cohort 8 is based on usage once this cohort was added to the program (October – December). As these are high gas usage months, we see a higher average for this cohort relative to the others.

Table 23. Weather Adjusted Percent Electric Savings – PY7 – Transition Period

Electric Cohorts	PY7	PY8	PY9	Transition Period
Original Cohort (Average Annual Usage: 12,908 kWh)	1.75%	1.17%	1.49%	1.33%
Expansion Cohort 1 (Average Annual Usage: 14,239 kWh)	1.70%	1.60%	1.61%	1.70%
Expansion Cohort 2 (Average Annual Usage: 10,050 kWh)	0.65%	0.68%	1.00%	1.12%
Expansion Cohort 4 (Average Annual Usage: 18,147 kWh)	1.25%	1.66%	1.24%	1.00%
Expansion Cohort 5 (Average Annual Usage: 13,166 kWh)	0.66%	1.29%	1.00%	1.30%
Expansion Cohort 6 (Average Annual Usage: 11,712 kWh)		0.57%	0.65%	0.47%
Expansion Cohort 7 (Average Annual Usage: 12,794 kWh)			0.47%	1.08%

3.5 Billing Analysis Model Coefficients

Below we provide the billing analysis model coefficients using Model 1. We include both electric and gas model coefficients to contextualize our results.

Table 24. Post-Only Model Billing Analysis Model Coefficients – Gas

Cohort	Coefficient	Robust Standard Error
Original Cohort		
treat	-0.016282298	0.002320055
pre_adc	0.38541319	0.014784857
pre_adc_summ	0.222930433	0.011659101
pre_adc_win	-0.090061254	0.005131752
Expansion Cohort 1		
treat	-0.021913348	0.003100121
pre_adc	0.357262911	0.011728122
pre_adc_summ	0.359406424	0.010361
pre_adc_win	-0.098056202	0.00466498
Expansion Cohort 2		
treat	-0.014606476	0.002117603
pre_adc	0.339745691	0.013738634
pre_adc_summ	0.394440524	0.012116657
pre_adc_win	-0.072825657	0.004659054
Expansion Cohort 3		
treat	-0.03134662	0.00428525
pre_adc	0.488069768	0.02952666
pre_adc_summ	0.270076564	0.021116466

Cohort	Coefficient	Robust Standard Error
pre_adc_win	-0.123226776	0.009997244
Expansion Cohort 4		
treat	-0.00446325	0.004888416
pre_adc	0.450648963	0.022524587
pre_adc_summ	0.438252547	0.015581064
pre_adc_win	-0.1424148	0.009697978
Expansion Cohort 5		
treat	-0.011306704	0.003812447
pre_adc	0.223334669	0.01093249
pre_adc_summ	0.518068147	0.012219898
pre_adc_win	-0.048424496	0.00410706
Expansion Cohort 6		
treat	0.004490963	0.003977991
pre_adc	0.136092926	0.027816182
pre_adc_summ	0.690431004	0.023100095
pre_adc_win	-0.03343733	0.013284682
Expansion Cohort 7		
treat	-0.007235388	0.002878373
pre_adc	0.383331663	0.013187771
pre_adc_summ	0.463919666	0.012421432
pre_adc_win	-0.099840371	0.005303865
Expansion Cohort 8		
treat	-0.012603047	0.005589106
pre_adc	0.994466498	0.034602632
pre_adc_summ	0.069176193	0.026164068
pre_adc_win	-0.203407574	0.011157276

Table 25. Original Model Billing Analysis Model Coefficients – Electric

Cohort	Coefficient	Robust Standard Error
Original Cohort		
treat	-0.50475115	0.04313201
pre_adc	0.910732783	0.023651043
pre_adc_summ	0.053638554	0.011833425
pre_adc_win	-0.233461158	0.00950451

Cohort	Coefficient	Robust Standard Error
Expansion Cohort 1		
treat	-0.665815405	0.055673023
pre_adc	1.101013202	0.017390657
pre_adc_summ	0.007000356	0.007344406
pre_adc_win	-0.323736121	0.008251734
Expansion Cohort 2		
treat	-0.282825697	0.041482825
pre_adc	1.16610626	0.016207879
pre_adc_summ	-0.047408991	0.007672315
pre_adc_win	-0.322599624	0.00722752
Expansion Cohort 4		
treat	-0.46437111	0.103281025
pre_adc	1.356515539	0.02992356
pre_adc_summ	-0.056288491	0.012536144
pre_adc_win	-0.502172813	0.013526351
Expansion Cohort 5		
treat	-0.416569788	0.065556791
pre_adc	0.759914706	0.026247862
pre_adc_summ	0.197589591	0.013920998
pre_adc_win	-0.208897038	0.01051987
Expansion Cohort 6		
treat	-0.228607406	0.057810077
pre_adc	0.920555893	0.031595054
pre_adc_summ	0.204868599	0.013553498
pre_adc_win	-0.355126897	0.015886776
Expansion Cohort 7		
treat	-0.316460478	0.051012921
pre_adc	0.814709857	0.020433625
pre_adc_summ	0.216304709	0.009941532
pre_adc_win	-0.18800294	0.009100753

3.6 Participation Lift and Channeling Analysis

3.6.1 Transition Period Uplift

To determine whether the Behavioral Modification Program treatment generated participation lift in the Transition Period (e.g., an increase in participation in other energy efficiency programs in the Transition Period as a result of the Behavioral Modification Program), we calculated whether more treatment than control group members participated in other AIC residential energy efficiency programs after receiving HERs compared to program participation before receiving HERs. We cross-referenced the Behavioral Modification Program database—both treatment and control groups (for all program cohorts)—with the databases of other residential energy efficiency programs in the Transition Period. We include only two residential programs in our analysis for the Transition Period:

- HVAC
- HEIQ

The participation lift analysis calculates the number of program participants who participated in both the Behavioral Modification Program **and** other energy efficiency programs in the Transition Period. To ensure the participation lift is attributable solely to the Behavioral Modification Program, we calculate participation lift using a difference-in-differences estimator (where possible) and test the result for statistical significance. To do so, we identify the total number of treatment and control group customers who participated in an AIC energy efficiency program in the Transition Period, as well as the total count of treatment and control group customers who participated in an AIC energy efficiency program prior to receiving HERs. Any positive difference in these calculations that is found to be statistically significant is the net participation due to the Behavioral Modification Program.

Table 26 presents the result of our participation lift analysis for the Transition Period. We observe a statistically significant channeling effect only for participation in the HVAC Program during the Transition Period. We observe a 0.24% participation lift into this program, among treatment group customers in Expansion Cohort 7.

Table 26. Transition Period Participation Lift Rate by Cohort and Program

Program Name	Original Cohort	Expansion Cohort 1	Expansion Cohort 2	Expansion Cohort 3 - Gas	Expansion Cohort 4	Expansion Cohort 5	Expansion Cohort 6	Expansion Cohort 7	Expansion Cohort 8
HEIQ	0.05%	0.04%	0.02%	0.00%	0.10%	0.00%	-0.03%	0.01%	0.00%
HVAC	0.03%	0.01%	0.06%	0.00%	0.28%	0.02%	0.00%	0.24%*	-0.01%

* Positive, statistically significant difference

While the percentage increase seems small, the overall effect is substantial given the size of the cohorts. The Behavioral Modification Program channeled about 88 customers into the HVAC Program in the Transition Period.

Table 27 presents estimated program savings due to participation uplift in this group. To compute these estimates, we multiply the net Transition Period participation uplift due to the Behavioral Modification Program by the median first year ex post net savings per treatment group customer participating in the HVAC Program during the Transition Period.

Table 27. Transition Period Uplift Adjustment – Expansion Cohort 7

Transition Period, Expansion Cohort 7	Fuel	
	MWh	Therms
Median savings per participant	0.194	26
Treatment group customers	36,092	
Treatment group rate of Transition Period participation	0.45%	
Change in rate of treatment group participation from pre-program year	0.11%	
Control group customers	14,443	
Control group rate of Transition Period participation	0.26%	
Change in rate of control group participation from pre-program year	-0.14%	
Difference-in-differences statistic	0.24%	
Participant uplift	88	
Total savings attributable to other programs	17.0	2,270

3.6.2 Legacy Uplift

The Behavioral Modification Program consumption analysis captures savings within the model for each year of a given measure's estimated useful life. To ensure that AIC does not inappropriately attribute savings to the Behavioral Modification Program that are associated with other programs and to accurately reflect the evaluation paradigm in Illinois, we also net out the savings from equipment rebated through other energy efficiency programs in past years for each year of the estimated useful life of the measure.

Savings are calculated in the same manner as the uplift adjustment for the Transition Period, with one adjustment. We multiply the net participation uplift due to the Behavioral Modification Program for each of the past years analyzed by the median first year ex post net savings per treatment group customer participating in another AIC residential program in for that year. However, when a measure has reached the end of its effective useful life by the Transition Period, we exclude it from our analysis (e.g., if a measure installed in PY4 has only a three-year effective useful life, it is not considered in the median first year ex post net savings value for PY4 customers).

Table 28 presents the programs considered in our legacy uplift savings adjustment. We include discontinued programs (e.g., Residential Efficient Products) as energy savings from this program's past activity still persist in following years.

Table 28. Programs Included in Legacy Uplift Savings Adjustment

Program	Years Included					
	PY4	PY5	PY6	PY7	PY8	PY9
Residential Lighting (Online Store Component Only) (OLS)	✓	✓	✓	✓		
ARP	✓	✓	✓	✓	✓	✓
HEIQ	✓	✓	✓	✓	✓	✓
Home Efficiency Standard (HES)	✓	✓	✓	✓	✓	
HVAC	✓	✓	✓	✓	✓	✓
MICK					✓	✓
Residential Efficient Products (REEP)	✓	✓	✓			

Gas Legacy Uplift

Table 29 through Table 34 present gas legacy uplift savings from PY4 through PY9 that we deduct from Transition Period Behavioral Modification Program savings.

Table 29. PY4 Legacy Uplift Therms Savings

Cohort	Savings Attributable to PY4 Programs (Therms)							Total Savings Attributable to PY4 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 1	N/A	0	2,970	0	N/A	0	0	2,970
Expansion Cohort 2	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 3	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**0**	**2,970**	**0**	**N/A**	**0**	**0**	**2,970**

Table 30. PY5 Legacy Uplift Therms Savings

Cohort	Savings Attributable to PY5 Programs (Therms)							Total Savings Attributable to PY5 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	942	0	N/A	0	0	942
Expansion Cohort 1	N/A	0	4,460	0	N/A	0	0	4,460
Expansion Cohort 2	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 3	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**0**	**5,402**	**0**	**N/A**	**0**	**0**	**5,402**

Table 31. PY6 Legacy Uplift Therms Savings

Cohort	Savings Attributable to PY6 Programs (Therms)							Total Savings Attributable to PY6 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 1	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 2	N/A	0	0	0	N/A	0	2,060	2,060
Expansion Cohort 3	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 4	N/A	0	0	0	N/A	0	0	0
Expansion Cohort 5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**0**	**0**	**0**	**N/A**	**0**	**2,060**	**2,060**

Table 32. PY7 Legacy Uplift Therms Savings

Cohort	Savings Attributable to PY7 Programs (Therms)							Total Savings Attributable to PY7 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	2,256	0	N/A	0	N/A	2,256
Expansion Cohort 1	N/A	0	0	0	N/A	0	N/A	0
Expansion Cohort 2	N/A	0	0	0	N/A	0	N/A	0
Expansion Cohort 3	N/A	0	0	0	N/A	0	N/A	0
Expansion Cohort 4	N/A	0	0	0	N/A	0	N/A	0
Expansion Cohort 5	N/A	0	0	0	N/A	0	N/A	0
Expansion Cohort 6	N/A	0	0	0	N/A	0	N/A	0
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**0**	**2,256**	**0**	**N/A**	**0**	**N/A**	**2,256**

Table 33. PY8 Legacy Uplift Therms Savings

Cohort	Savings Attributable to PY8 Programs (Therms)							Total Savings Attributable to PY8 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 1	N/A	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 2	N/A	12,539	N/A	0	0	N/A	N/A	12,539
Expansion Cohort 3	N/A	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 4	N/A	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 5	N/A	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 6	N/A	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 7	N/A	4,135	N/A	1,185	0	N/A	N/A	5,320
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**16,674**	**N/A**	**1,185**	**0**	**N/A**	**N/A**	**17,858**

Table 34. PY9 Legacy Uplift Therms Savings

Cohort	Savings Attributable to PY9 Programs (Therms)							Total Savings Attributable to PY9 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	3,547	0	0	0	0	3,547
Expansion Cohort 1	N/A	0	7,430	0	0	0	0	7,430
Expansion Cohort 2	N/A	12,539	0	0	0	0	2,060	14,599
Expansion Cohort 3	N/A	0	0	0	0	0	0	0
Expansion Cohort 4	N/A	0	0	0	0	0	0	0
Expansion Cohort 5	N/A	0	0	0	0	0	0	0
Expansion Cohort 6	N/A	0	0	0	0	0	0	0
Expansion Cohort 7	N/A	4,135	0	1,185	0	0	0	5,320
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**16,674**	**10,977**	**1,185**	**0**	**0**	**2,060**	**30,896**

Table 42 summarizes total legacy uplift savings from PY4 through PY9 by cohort.

Table 35. Total Legacy Uplift Therms Savings (PY4-PY9)

Cohort	Savings Attributable to PY4-PY9 Programs (Therms)							Total Savings Attributable to PY4-PY9 Programs (Therms)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	N/A	0	3,547	0	0	0	0	3,547
Expansion Cohort 1	N/A	0	7,430	0	0	0	0	7,430
Expansion Cohort 2	N/A	12,539	0	0	0	0	2,060	14,599
Expansion Cohort 3	N/A	0	0	0	0	0	0	0
Expansion Cohort 4	N/A	0	0	0	0	0	0	0
Expansion Cohort 5	N/A	0	0	0	0	0	0	0
Expansion Cohort 6	N/A	0	0	0	0	0	0	0
Expansion Cohort 7	N/A	4,135	0	1,185	0	0	0	5,320
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**N/A**	**16,674**	**10,977**	**1,185**	**0**	**0**	**2,060**	**30,896**

Electric Legacy Uplift

Table 36 through Table 41 present electric legacy uplift savings from PY4 through PY9 that we deduct from Transition Period Behavioral Modification Program savings.

Table 36. PY4 Legacy Uplift MWh Savings

Cohort	Savings Attributable to PY4 Programs (MWh)							Total Savings Attributable to PY4 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	0	0	0	0	N/A	0	0	0
Expansion Cohort 1	54	0	25	0	N/A	0	0	79
Expansion Cohort 2	0	0	0	0	N/A	0	0	0
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**54**	**0**	**25**	**0**	**N/A**	**0**	**0**	**79**

Table 37. PY5 Legacy Uplift MWh Savings

Cohort	Savings Attributable to PY5 Programs (MWh)							Total Savings Attributable to PY5 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	0	0	14	0	N/A	0	0	14
Expansion Cohort 1	0	0	49	0	N/A	0	0	49
Expansion Cohort 2	0	0	0	0	N/A	0	0	0
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**0**	**0**	**63**	**0**	**N/A**	**0**	**0**	**63**

Table 38. PY6 Legacy Uplift MWh Savings

Cohort	Savings Attributable to PY6 Programs (MWh)							Total Savings Attributable to PY6 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	0	0	0	0	N/A	0	0	0
Expansion Cohort 1	0	0	0	0	N/A	0	0	0
Expansion Cohort 2	0	0	0	0	N/A	0	2	2
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	12	0	19	49	N/A	0	0	80
Expansion Cohort 5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**12**	**0**	**19**	**49**	**N/A**	**0**	**2**	**82**

Table 39. PY7 Legacy Uplift MWh Savings

Cohort	Savings Attributable to PY7 Programs (MWh)							Total Savings Attributable to PY7 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	43	0	15	0	N/A	0	N/A	58
Expansion Cohort 1	0	0	0	0	N/A	0	N/A	0
Expansion Cohort 2	0	0	0	0	N/A	0	N/A	0
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	0	0	0	0	N/A	0	N/A	0
Expansion Cohort 5	0	0	0	0	N/A	0	N/A	0
Expansion Cohort 6	0	0	12	0	N/A	0	N/A	12
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**43**	**0**	**27**	**0**	**N/A**	**0**	**N/A**	**70**

Table 40. PY8 Legacy Uplift MWh Savings

Cohort	Savings Attributable to PY8 Programs (MWh)							Total Savings Attributable to PY8 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	0	0	9	0	0	N/A	N/A	9
Expansion Cohort 1	0	0	0	0	0	N/A	N/A	0
Expansion Cohort 2	0	0	0	0	0	N/A	N/A	0
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	0	0	7	0	0	N/A	N/A	7
Expansion Cohort 5	0	0	0	0	0	N/A	N/A	0
Expansion Cohort 6	9	39	13	0	0	N/A	N/A	60
Expansion Cohort 7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**9**	**39**	**30**	**0**	**0**	**N/A**	**N/A**	**77**

Table 41. PY9 Legacy Uplift MWh Savings

Cohort	Savings Attributable to PY9 Programs (MWh)							Total Savings Attributable to PY9 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	0	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 1	0	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 2	0	74	N/A	0	0	N/A	N/A	74
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	0	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 5	0	0	N/A	0	0	N/A	N/A	0
Expansion Cohort 6	0	28	N/A	0	0	N/A	N/A	28
Expansion Cohort 7	0	28	N/A	18	0	N/A	N/A	46
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**0**	**130**	**N/A**	**18**	**0**	**N/A**	**N/A**	**148**

Table 42 summarizes total legacy uplift savings from PY4 through PY9 by cohort.

Table 42. Total Legacy Uplift MWh Savings (PY4-PY9)

Cohort	Savings Attributable to PY4-PY9 Programs (MWh)							Total Savings Attributable to PY4-PY9 Programs (MWh)
	ARP	HEIQ	HES	HVAC	MICK	OLS	REEP	
Original Cohort	43	0	38	0	0	0	0	81
Expansion Cohort 1	54	0	75	0	0	0	0	128
Expansion Cohort 2	0	74	0	0	0	0	2	76
Expansion Cohort 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Expansion Cohort 4	12	0	26	49	0	0	0	87
Expansion Cohort 5	0	0	0	0	0	0	0	0
Expansion Cohort 6	9	66	25	0	0	0	0	100
Expansion Cohort 7	0	28	0	18	0	0	0	46
Expansion Cohort 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	**118**	**168**	**163**	**67**	**0**	**0**	**2**	**518**

4. Home Efficiency Income Qualified

The impact evaluation efforts estimated gross impact savings for the HEIQ Program by applying savings algorithms from the IL-TRM V5.0 using the information provided in the program tracking database. We present the algorithms and input variables used to calculate all evaluation program savings below.

4.1 Lighting Algorithms

The evaluation team determined ex post lighting savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 5. Lighting Algorithms

$$\Delta kWh = ((Watts_{Base} - Watts_{EE})/1{,}000) * ISR * Hours * WHF_e$$

$$\Delta kW = ((Watts_{Base} - Watts_{EE})/1{,}000) * ISR * WHF_d * CF$$

Where:

$Watts_{Base}$ = Wattage of existing equipment

Table 43. Baseline Wattages for Lighting Measures

Measure	EISA Adjusted[a]	Baseline Wattage	Resource
CFL - Low (13W–15W)	Yes	43	IL-TRM V5.0
CFL - Medium (18W–20W)	Yes	53	
CFL - High (23W–25W)	Yes	72	
Specialty CFL – 9W Candelabra	No	40	
Specialty CFL – 14W Globe	No	60	
Specialty CFL – 15W Reflector	No	65	
LED - 10W (6 pack)	Yes	43	
LED - 9W	Yes	43	
LED - Candelabra	No	40	
LED - Globe	No	40	
LED - Reflector	No	65	

[a] The Energy Independence and Security Act of 2007 (EISA) schedule requires baseline adjustments to measures with incandescent baseline wattages of 100W (as of June 2012), 75W (as of June 2013), and 60W (as of June 2014).

$Watts_{EE}$ = Wattage of installed CFL or LED

Table 44. CFL Wattages for Lighting Measures

Measure	CFL Wattage	Resource
CFL - Low (13W–15W)	13	Actual installed CFL or LED wattage
CFL - Medium (18W–20W)	20	
CFL - High (23W–25W)	23	
Specialty CFL – 9W Candelabra	9	
Specialty CFL – 14W Globe	14	

Measure	CFL Wattage	Resource
Specialty CFL – 15W Reflector	15	
LED - 10W (6 pack)	10	
LED - 9W	9	
LED - Candelabra	5	
LED - Globe	7	
LED - Reflector	9	

Hours = Annual operating hours

Table 45. Annual Hours of Use for Lighting Measures

Measure	Hours
Standard CFL (Spiral)	793
Specialty CFL (Candelabra)	1,190
Specialty CFL (Globe)	639
Specialty CFL (Reflector)	861
Standard LED	759
Specialty LED (Candelabra)	1,190
Specialty LED (Globe)	639
Specialty LED (Reflector)	861

WHF_e = Waste heat factor for energy (accounts for cooling savings from efficient lighting)

Table 46. Waste Heat Factors for Energy

Bulb Location	WHF_e
Interior single family or unknown location	1.06
Exterior or uncooled location	1.00

WHF_d = Waste heat factor for demand (accounts for cooling savings from efficient lighting)

Table 47. Waste Heat Factors for Demand

Bulb Location	WHF_d
Interior single family or unknown location	1.11
Exterior or uncooled location	1.00

CF = Summer peak coincidence factor

Table 48. Coincidence Factors for Lighting Measures

Measure	CF
Standard CFL (Spiral)	0.074
Specialty CFL (Candelabra)	0.121
Specialty CFL (Globe)	0.075
Specialty CFL (Reflector)	0.091
Standard LED	0.071

Measure	CF
Specialty LED (Candelabra)	0.121
Specialty LED (Globe)	0.075
Specialty LED (Reflector)	0.091

ISR = In-service rate of installed CFLs or LEDs

Table 49. In-Service Rates for Lighting Measures

Measure	ISR
Standard CFL (Spiral)	96.9%
Specialty CFL (Candelabra)	
Specialty CFL (Globe)	
Specialty CFL (Reflector)	
Standard LED (Pack of 6)[a]	93.0%
Standard LED	96.9%
Specialty LED (Candelabra)	
Specialty LED (Globe)	
Specialty LED (Reflector)	

[a] The database indicated these were mailed kits. The IL-TRM V5.0 specifies a different ISR for mailed lighting kits.

4.2 Lighting Measures Heating Penalty

The evaluation team determined heating penalties for all lighting measures using the algorithm below. By agreement with the ICC, we do not include heating penalties in the ex post energy savings but include these results to support cost-effectiveness analysis (see Appendix A of Volume I of this report).

Equation 6. Heating Penalty Algorithms

$$\Delta kWh = -\left(\left(\left(Watts_{Base} - Watts_{EE}\right)/1{,}000\right) * ISR * Hours * HF\right)/\eta_{Heat}$$

$$\Delta therms = -\left(\left(\left(Watts_{Base} - Watts_{EE}\right)/1{,}000\right) * ISR * Hours * HF * 0.03412\right)/\eta_{Heat}$$

Where:

$Watts_{Base}$ = Wattage of existing equipment (see Table 43)

$Watts_{EE}$ = Wattage of installed CFLs (see Table 44)

Hours = Annual operating hours (see Table 45)

HF = Heating Factor = 0.49

η_{Heat} = Efficiency of heating equipment

Table 50. nHeat for Heating Fuel Penalties

Heating Equipment	nHeat	
	COP	AFUE
Gas Furnace/Boiler	N/A	0.70

Heating Equipment	nHeat	
	COP	AFUE
Electric Resistance	1.00	N/A
Heat Pump	2.26	N/A

ISR = In-service rate or the percentage of units rebated that get installed

Table 51. In-Service Rates for Lighting Measures

Measure	ISR
Standard CFL (Spiral)	96.9%
Specialty CFL (Candelabra)	
Specialty CFL (Globe)	
Specialty CFL (Reflector)	
Standard LED (Pack of 6)[a]	93.0%
Standard LED	96.9%
Specialty LED (Candelabra)	
Specialty LED (Globe)	
Specialty LED (Reflector)	

[a] The database indicated these were mailed kits. The IL-TRM V5.0 specifies a different ISR for mailed lighting kits.

Table 52 summarizes the heating penalties (by heating equipment) for the six CFL lighting measures offered through the program.

Table 52. Per-Measure Heating Fuel Penalties for CFL Lighting

Heating Equipment	Measure	ΔkWh[a]	Δtherms[a]
Gas Heating	CFL - Low (13W–15W)	N/A	−0.55
	CFL - Medium (18W–20W)	N/A	−0.61
	CFL - High (23W–25W)	N/A	−0.90
	Specialty CFL - 9W Candelabra	N/A	−0.85
	Specialty CFL - 14W Globe	N/A	−0.68
	Specialty CFL - 15W Reflector	N/A	−1.00
Electric Resistance	CFL - Low (13W–15W)	−11.30	N/A
	CFL - Medium (18W–20W)	−12.43	N/A
	CFL - High (23W–25W)	−18.45	N/A
	Specialty CFL - 9W Candelabra	−17.52	N/A
	Specialty CFL - 14W Globe	−13.96	N/A
	Specialty CFL - 15W Reflector	−20.44	N/A
Heat Pump	CFL - Low (13W–15W)	−5.00	N/A
	CFL - Medium (18W–20W)	−5.50	N/A
	CFL - High (23W–25W)	−8.16	N/A
	Specialty CFL - 9W Candelabra	−7.75	N/A
	Specialty CFL - 14W Globe	−6.18	N/A
	Specialty CFL - 15W Reflector	−9.04	N/A

[a] Heating penalties include a 96.9% ISR

Table 52 summarizes the heating penalties (by heating equipment) for the five LED lighting measures offered through the program.

Table 53. Per-Measure Heating Fuel Penalties for LED Lighting

Heating Equipment	Measure	ΔkWh[a]	Δtherms[a]
Gas Heating	LED - 10W (6 pack)	N/A	−3.34
	LED - 9W	N/A	−0.60
	LED - Candelabra	N/A	−1.05
	LED - Globe	N/A	−0.53
	LED - Reflector	N/A	−0.68
Electric Resistance	LED - 10W (6 pack)	−30.30	N/A
	LED - 9W	−5.42	N/A
	LED - Candelabra	−9.50	N/A
	LED - Globe	−4.83	N/A
	LED - Reflector	−6.15	N/A
Heat Pump	LED - 10W (6 pack)	−68.48	N/A
	LED - 9W	−12.25	N/A
	LED - Candelabra	−21.47	N/A
	LED - Globe	−10.92	N/A
	LED - Reflector	−13.90	N/A

[a] Heating penalties include a 96.9% ISR for direct install measures and 93.0% ISR for mailed kits.

4.3 Water Heating Conservation Measure Algorithms

The evaluation team determined ex post water heating conservation measure savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 7. Low-Flow Shower Head Algorithms

$$\Delta kWh = \%ElectricDHW * ((GPM_{Base} * L_{Base} - GPM_{Low} * L_{Low}) * HH * SPCD * 365.25/SPH) * EPG_{Electric} * ISR$$

$$\Delta kW = \Delta kWh/Hours * CF$$

$$\Delta Therms = \%FossilDHW * ((GPM_{Base} * L_{Base} - GPM_{Low} * L_{Low}) * HH * SPCD * 365.25/SPH) * EPG_{Gas} * ISR$$

Equation 8. Low-Flow Faucet Aerator Algorithms

$$\Delta kWh = \%ElectricDHW * ((GPM_{Base} * L_{Base} - GPM_{Low} * L_{Low}) * HH * 365.25 * DF/FPH) * EPG_{Electric} * ISR$$

$$\Delta kW = \Delta kWh/Hours * CF$$

$$\Delta Therms = \%FossilDHW * ((GPM_{Base} * L_{Base} - GPM_{Low} * L_{Low}) * HH * 365.25 * DF/FPH) * EPG_{Gas} * ISR$$

Where:

%ElectricDHW = 100% if electric water heater, 0% if gas water heater

%GasDHW = 100% if gas water heater, 0% if electric water heater

GPM_{Base} = Flow rate of the baseline shower head or faucet aerator in gallons per minute (GPM)

GPM_{Low} = As-used flow rate of the low-flow shower head or faucet aerator

Table 54. GPM for Water Heating Measures

Measure	GPM_{Base}	GPM_{Low}
Faucet Aerator	1.39	0.94
Shower Head	2.67	1.75

L_{Base} = Length (in minutes) per baseline shower head or baseline

L_{Low} = Length (in minutes) per low-flow shower head or low-flow faucet

Table 55. L_{Base} and L_{Low} for Water Heating Measures

Measure	Minutes
Faucet Aerator – Kitchen	4.5
Faucet Aerator – Bathroom	1.6
Shower Head	7.8

HH = Average number of people per household = 2.56

SPCD = Showers per capita per day = 0.60

SPH = Shower heads per household for single family homes = 1.79

DF = Drain factor

Table 56. Drain Factor for Faucet Aerators

Measure	DF
Faucet Aerator – Kitchen	75%
Faucet Aerator – Bathroom	90%

FPH = Faucets per household for single-family homes

Table 57. Faucets Per Household

Measure	FPH
Faucet Aerator – Kitchen	1.00
Faucet Aerator – Bathroom	2.83

$EPG_{Electric}$ = Energy per gallon (EPG) of hot water supplied by electric water heater

EPG_{Gas} = Energy per gallon of hot water supplied by gas water heater

Table 58. EPG for Water Heating Measures

Measure	$EPG_{Electric}$	EPG_{Gas}
Faucet Aerator – Kitchen	0.09690	0.00415
Faucet Aerator – Bathroom	0.07950	0.00341
Shower Head	0.11700	0.00501

Hours = Annual recovery hours for shower head or faucet use for single family homes

Table 59. Hours for Water Heating Measures

Measure	Hours
Faucet Aerator – Kitchen	94
Faucet Aerator – Bathroom	14
Shower Head	302

CF = Summer peak coincidence factor

Table 60. Coincidence Factors for Water Heating Measures

Measure	CF
Faucet Aerator	0.0220
Shower Head	0.0278

ISR = In-Service Rate of installed low-flow shower heads or low-flow aerators

Table 61. ISR for Water Heating Measures

Measure	ISR
Faucet Aerator	95%
Shower Head	98%

4.4 Programmable Thermostat Algorithms

The evaluation team determined ex post programmable thermostat measure savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 9. Programmable Thermostat Algorithms

$$\Delta kWh_{Heating} = \%ElectricHeat * Elec\_Heating\_Consumption * Htg\ Reduction * HF * ISR$$

$$\Delta Therms = \%FossilHeat * Gas\_Heating\_Consumption * Htg\ Reduction * HF * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

%ElectricHeat = 100% if electric space heating fuel, 0% if gas space heating fuel

%FossilHeat = 100% if gas space heating fuel, 0% if electric space heating fuel

Elec_Heating_Consumption = Estimated annual household heating consumption for electrically heated homes (applied per participant based on project location and electric heating type [i.e., electric resistance, heat pump])

Table 62. Electric Heating Consumption by Climate Zone

Climate Zone	kWh	
	Electric Resistance	Heat Pump
1 (Rockford)	21,741	12,789
2 (Chicago)	20,771	12,218
3 (Springfield)	17,789	10,464
4 (Belleville)	13,722	8,072
5 (Marion)	13,966	8,215

Gas_Heating_Consumption = Estimated annual household heating consumption for gas-heated homes (applied per participant based on project location)

Table 63. Gas Heating Consumption by Climate Zone

Climate Zone	Therms
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664
5 (Marion)	676

Htg Reduction = Reduction in heating energy consumption = 6.2%

HF = Household factor to adjust heating consumption for single-family homes = 100%

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

ISR = Percentage of thermostats installed and effectively programmed = 100%

4.5 Smart Thermostat Algorithms

The evaluation team determined ex post smart thermostat measure savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 10. Smart Thermostat Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = \%AC * ((FLH_{Cool} * Capacity_{Cool} * 1/SEER)/1000) * Clg\ Reduction * ISR$$

$$\Delta kWh_{Heating} = \%ElectricHeat * Elec\_Heating\_Consumption * Htg\ Reduction * HF * ISR$$

$$\Delta kW = (Clg\ Reduction * Capacity_{Cool} * (1/EER)/1000) * ISR * CF$$

$$\Delta Therms = \%FossilHeat * Gas\_Heating\_Consumption * Htg\ Reduction * HF * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

%AC = 100% if central cooling is present, 0% if no central cooling is present

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 64. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

$Capacity_{Cool}$ = Cooling capacity of air conditoiner in units of Btuh = Acutal; If unknown assumed 33,600 BTUh

SEER = Cooling efficiency of central air conditioner or heat pump controlled by the smart thermostat in units of SEER = Actual; If unknown assumed 8.60 SEER for air conditioners and 9.12 SEER for heat pumps

EER = Cooling efficiency of central air conditioner or heat pump controlled by the smart thermostat in units of EER = Actual; If unknown assumed 8.15 EER for air conditioners and 8.55 EER for heat pumps

Clg Reduction = Reduction in cooling energy consumption due to installing a smart thermostat = 8.0%

%ElectricHeat = 100% if electric space heating fuel, 0% if gas space heating fuel

%FossilHeat = 100% if gas space heating fuel, 0% if electric space heating fuel

Elec_Heating_Consumption = Estimated annual household heating consumption for electrically heated homes (applied per participant based on project location and electric heating type [i.e., electric resistance, heat pump])

Table 65. Electric Heating Consumption by Climate Zone

Climate Zone	kWh	
	Electric Resistance	Heat Pump
1 (Rockford)	21,741	12,789
2 (Chicago)	20,771	12,218
3 (Springfield)	17,789	10,464
4 (Belleville)	13,722	8,072
5 (Marion)	13,966	8,215

Gas_Heating_Consumption = Estimated annual household heating consumption for gas-heated homes (applied per participant based on project location)

Table 66. Gas Heating Consumption by Climate Zone

Climate Zone	Therms
1 (Rockford)	1,052
2 (Chicago)	1,005
3 (Springfield)	861
4 (Belleville)	664
5 (Marion)	676

Htg Reduction = Reduction in heating energy consumption = 7.4%

HF = Household factor to adjust heating consumption for single-family homes = 100%

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

CF = Summer peak coincidence factor = 0.34

ISR = Percentage of thermostats installed and effectively programmed = 100%

4.6 Central Air Conditioner Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) air conditioners using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for cooling load reduction as a result of installing envelope improvement measures (e.g., insulation, air sealing, duct sealing).[4] All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

[4] Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

Equation 11. Central Air Conditioner Algorithms

$$(TOS)\ \Delta kWh_{Cooling} = (((FLH_{Cool} * Capacity_{exist} * (1 / SEER_{base})/1000) - ((FLH_{Cool} * Capacity_{eff} * (1 / SEER_{eff})/1000)) * ISR$$

$$(ER)\ \Delta kWh_{Cooling} = (((FLH_{Cool} * Capacity_{exist} * (1 / SEER_{exist})/1000) - ((FLH_{Cool} * Capacity_{eff} * (1 / SEER_{eff})/1000)) * ISR$$

$$(TOS)\ \Delta kW = ((Capacity_{exist} * (1 / EER_{base})/1000) - (Capacity_{eff} * (1 / EER_{eff})/1000)) * CF * ISR$$

$$(ER)\ \Delta kW = ((Capacity_{exist} * (1 / EER_{exist})/1000) - (Capacity_{eff} * (1 / EER_{eff})/1000)) * CF * ISR$$

Where:

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 67. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

$Capacity_{exist}$ = Cooling capacity of existing central air conditioner in units of Btuh = Actual; If unknown assumed same capacity as installed energy efficient central air conditioner

$Capacity_{eff}$ = Cooling capacity of installed energy efficient central air conditioner in units of Btuh = Actual

$SEER_{base}$ = Baseline central air conditioner cooling efficiency for TOS installations in units of SEER = 13 SEER

$SEER_{exist}$ = Baseline central air conditioner cooling efficiency for ER installations in units of SEER = Actual; If unknown assumed 10 SEER

$SEER_{eff}$ = Cooling efficiency of newly installed central air conditioner in units of SEER = Actual

EER_{base} = Baseline central air conditioner cooling efficiency for TOS installations in units of EER = 11.2 EER

EER_{exist} = Baseline central air conditioner cooling efficiency for ER installations in units of EER = Actual; If unknown assumed 9.2 EER

EER_{eff} = Cooling efficiency of newly installed central air conditioner in units of EER = Actual; If unknown assumed 12.0 EER

CF = Summer peak coincidence factor = 0.68

ISR = In-service rate of installed central air conditioners = 100%

4.7 Air Source Heat Pump Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) air source heat pumps using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for cooling and heating load reductions as a result of installing envelope improvement measures (e.g., insulation, air sealing, duct sealing).[5] All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 12. Air Source Heat Pump Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$(TOS)\ \Delta kWh_{Cooling} = (((FLH_{Cool} * Capacity_{Cool\_exist} * (1 / SEER_{base})/1000) - ((FLH_{Cool} * Capacity_{Cool\_eff} * (1 / SEER_{eff})/1000)) * ISR$$

$$(ER)\ \Delta kWh_{Cooling} = (((FLH_{Cool} * Capacity_{Cool\_exist} * (1 / SEER_{exist})/1000) - ((FLH_{Cool} * Capacity_{Cool\_eff} * (1 / SEER_{eff})/1000)) * ISR$$

$$(TOS)\ \Delta kWh_{Heating} = (((FLH_{Heat} * Capacity_{Heat\_exist} * (1 / HSPF_{base})/1000) - ((FLH_{Heat} * Capacity_{Heat\_eff} * (1 / HSPF_{eff})/1000)) * ISR$$

$$(ER)\ \Delta kWh_{Heating} = (((FLH_{Heat} * Capacity_{Heat\_exist} * (1 / HSPF_{exist})/1000) - ((FLH_{Heat} * Capacity_{Heat\_eff} * (1 / HSPF_{eff})/1000)) * ISR (TOS)\ \Delta kW = ((Capacity_{Cool\_exist} * (1 / EER_{base})/1000) - (Capacity_{Cool\_eff} * (1 / EER_{eff})/1000)) * CF * ISR$$

$$(ER)\ \Delta kW = ((Capacity_{Cool\_exist} * (1 / EER_{exist})/1000) - (Capacity_{Cool\_eff} * (1 / EER_{eff})/1000)) * CF * ISR$$

Where:

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 68. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

$Capacity_{Cool\_exist}$ = Cooling capacity of existing cooling equipment in units of Btuh = Acutal; If unknown assumed same capacity as installed ASHP

$Capacity_{Cool\_eff}$ = Cooling capacity of installed energy efficient ASHP in units of Btuh = Actual

$Capacity_{Heat\_exist}$ = Heating capacity of existing heating equipment in units of Btuh = Acutal; If unknown assumed same capacity as installed ASHP

[5] Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

$Capacity_{Heat\_eff}$ = Heating capacity of installed energy efficient ASHP in units of Btuh = Actual$SEER_{base}$ = Baseline ASHP cooling efficiency for TOS installations in units of Seasonal Energy Efficiency Ratio (SEER)= 14 SEER

$SEER_{exist}$ = Baseline ASHP cooling efficiency for ER installations in units of SEER = Actual; If unknown assumed TRM defaults (see Table 69)

Table 69. Early Replacement Cooling Efficiency ($SEER_{exist}$)

Replaced Equipment	$SEER_{exist}$
ASHP	9.12
Central Air Conditioner	8.60

$SEER_{eff}$ = Cooling efficiency of newly installed ASHP in units of SEER = Actual

FLH_{Heat} = Full Load Heating Hours (applied per participant based on project location)

Table 70. Full Load Heating Hours by Climate Zone

Climate Zone	FLH_{Heat}
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

$Capacity_{Heat}$ = Heating capacity of ASHP in units of Btuh = Actual

$HSPF_{base}$ = Baseline ASHP heating efficiency for TOS installations in units of HSPF = 8.2

$HSPF_{exist}$ = Baseline ASHP heating efficiency for ER installations in units of HSPF

Table 71. Early Replacement Heating Efficiency ($HSPF_{exist}$)

Replaced Equipment	$HSPF_{exist}$
ASHP	5.44
Electric Resistance	3.41

$HSPF_{eff}$ = Heating efficiency of newly installed ASHP in units of HSPF = Actual

EER_{base} = Baseline ASHP cooling efficiency for TOS installations in units of EER = 11.8 EER

EER_{exist} = Baseline ASHP cooling efficiency for ER installations in units of EER

Table 72. Early Replacement Cooling Efficiency (EER_{exist})

Replaced Equipment	EER_{exist}
ASHP	8.55
Central Air Conditioner	8.15

EER_{eff} = Cooling efficiency of newly installed ASHP in units of EER = Actual

CF = Summer peak coincidence factor = 0.72

ISR = In-service rate of installed ASHPs = 100.0%

4.8 Gas Boiler Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) gas boilers using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for heating load reduction as a result of installing envelope improvement measures (e.g., insulation, air sealing, duct sealing).[6] All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 13. Gas Boiler Algorithms

$$(TOS)\ \Delta Therms = (Heat\_Load - (\Delta therms_{Envelope\&Duct} * AFUE_{exist})) * HF * ((1 / AFUE_{base}) - (1 / AFUE_{eff})) * ISR$$

$$(ER)\ \Delta Therms = (Heat\_Load - (\Delta therms_{Envelope\&Duct} * AFUE_{exist})) * HF * ((1 / AFUE_{exist}) - (1 / AFUE_{eff})) * ISR$$

Heating load calculations vary depending on the condition of the home at the time of the boiler installation. Since the HEIQ program offers both HVAC replacement and envelope improvement measures, heating load calculations for homes that install a combination of envelope measures and a new boiler differ from heating loads for those who only install a new boiler within the program. The following formulas were used to calculate heating loads:

Equation 14. Gas Boiler Heating Loads

$$Heat\ Load_{Boiler\_Only} = ((1/AFUE_{eff} * Capacity_{eff} * FLH_{heat})/100{,}000) * AFUE_{eff}$$

$$Heat\ Load_{Boiler\_Envelope} = ((1/AFUE_{exist} * Capacity_{exist} * FLH_{heat})/100{,}000) * AFUE_{exist}$$

Where:

Heat_Load = Calculated using formulas in Equation 14

$\Delta therms_{Envelope\&Duct}$ = Total therm savings for insulation, air sealing, and duct sealing measures for those who installed both envelope measures and boiler replacements

$AFUE_{base}$ = Baseline boiler efficiency for TOS installations in units of AFUE = 82% AFUE[7]

$AFUE_{exist}$ = Baseline boiler efficiency for ER installations in units of AFUE = Actual; If unknown assumed 61.6% AFUE

$AFUE_{eff}$ = Efficiency of newly installed boiler in units of AFUE = Actual; If unknown assumed 92.5% AFUE

HF = Household factor to adjust heating consumption for single-family homes = 100%

$Capacity_{exist}$ = Heating capacity of existing boiler in units of Btuh = Acutal

[6] Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

[7] Illinois TRM V4.0 specifies a baseline boiler efficiency of 82% AFUE for program years beyond 2013.

$Capacity_{eff}$ = Heating capacity of installed energy efficient boiler in units of Btuh = Actual

FLH_{Heat} = Full Load Heating Hours (applied per participant based on project location)

Table 73. Full Load Heating Hours by Climate Zone

Climate Zone	FLH_{Heat}
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

ISR = In-service rate of installed boilers = 100%

4.9 Gas Furnace Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) gas furnaces using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for heating load reduction as a result of installing envelope improvement measures (e.g., insulation, air sealing, duct sealing).[8]All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 15. Gas Furnace Algorithms

$$(TOS)\ \Delta Therms = (Heat\_Load - (\Delta therms_{Envelope\&Duct} * AFUE_{exist})) * HF * ((1 / AFUE_{base}) - (1 / AFUE_{eff})) * ISR$$

$$(ER)\ \Delta Therms = (Heat\_Load - (\Delta therms_{Envelope\&Duct} * AFUE_{exist})) * HF * ((1 / AFUE_{exist}) - (1 / AFUE_{eff})) * ISR$$

Heating load calculations vary depending on the condition of the home at the time of the furnace installation. Since the HEIQ program offers both HVAC replacement and envelope improvement measures, heating load calculations for homes that install a combination of envelope measures and a new furnace differ from heating loads for those who only install a new furnace within the program. The following formulas were used to calculate heating loads:

Equation 16. Gas Furnace Heating Loads

$$Heat\ Load_{Furnace\_Only} = ((1/AFUE_{eff} * Capacity_{eff} * FLH_{heat})/100{,}000) * AFUE_{eff}$$

$$Heat\ Load_{Furnace\_Envelope} = ((1/AFUE_{exist} * Capacity_{exist} * FLH_{heat})/100{,}000) * AFUE_{exist}$$

Where:

Heat_Load = Calculated using formulas in Equation 16

$\Delta therms_{Envelope\&Duct}$ = Total therm savings for insulation, air sealing, and duct sealing measures for those who installed both envelope measures and furnace replacements

$AFUE_{base}$ = Baseline furnace efficiency for TOS installations in units of AFUE = 80% AFUE

[8] Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

$AFUE_{exist}$ = Baseline furnace efficiency for ER installations in units of AFUE = 64.4% AFUE

$AFUE_{eff}$ = Efficiency of newly installed furnace in units of AFUE = Actual; If unknown assumed 95% AFUE

HF = Household factor to adjust heating consumption for single-family homes = 100%

$Capacity_{exist}$ = Heating capacity of existing furnace in units of Btuh = Acutal

$Capacity_{eff}$ = Heating capacity of installed energy efficient furnace in units of Btuh = Actual

FLH_{Heat} = Full Load Heating Hours (applied per participant based on project location)

Table 74. Full Load Heating Hours by Climate Zone

Climate Zone	FLH_{Heat}
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

ISR = In-service rate of installed furnaces = 100%

4.10 ECM Algorithms

The evaluation team determined ex post ECM savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 17. ECM Algorithms

$$\Delta kWh = (\Delta kWh_{Cooling} + \Delta kWh_{Heating} + \Delta kWh_{Shoulder}) * ISR$$

$$(CAC\ present)\ \Delta kWh_{Cooling} = 263\ kWh\ (deemed\ value)$$

$$(CAC\ not\ present)\ \Delta kWh_{Cooling} = 175\ kWh\ (deemed\ value)$$

$$\Delta kWh_{Heating} = 418\ kWh\ (deemed\ value)$$

$$\Delta kWh_{Shoulder} = 51\ kWh\ (deemed\ value)$$

$$\Delta kW = \Delta kWh_{Cooling} / FLH_{Cool} * CF * ISR$$

$$\Delta therms = -\ \Delta kWh_{Heating} * 0.03412 * ISR$$

Where:

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 75. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor = 0.68

ISR = In-service rate of installed ECMs = 100%

4.11 Duct Sealing Algorithms

The evaluation team determined ex post duct sealing measure savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 18. Duct Sealing Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = ((((DE_{after} - DE_{before})/DE_{after}) * FLH_{Cool} * Capacity_{Cool} * TRF_{Cool})/1000/n_{Cool}) * ISR$$

$$\Delta kWh_{Heating} = ((((DE_{after} - DE_{before})/DE_{after}) * FLH_{Heat} * Capacity_{Heat} * TRF_{Heat})/1000/n_{Heat}/3412) * ISR$$

$$\Delta Therms = (((DE_{after} - DE_{before})/DE_{after}) * FLH_{Heat} * Capacity_{Heat} * TRF_{Heat}) * (n_{Heat} / n_{System}))/100{,}000 * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

DE_{after} = Distribution efficiency after duct sealing (Cooling: 92%; Heating: 93%)[9]

DE_{before} = Distribution efficiency before duct sealing (Cooling: 80%; Heating: 87%)[10]

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 76. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

FLH_{Heat} = Full Load Heating Hours (applied per participant based on project location)

Table 77. Full Load Heating Hours by Climate Zone

Climate Zone	FLH_{Heat}
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

$Capacity_{Cool}$ = Cooling capacity of air conditioner or heat pump in units of Btuh = Actual; If unknown assumed 33,600 BTUh

$Capacity_{Heat}$ = Heating capacity of heating equipment in units of Btuh = Actual; If unknown applied average from database

TRF_{Cool} = Thermal regain factor for cooling; 1 = unconditioned space; 0 = semi-conditioned space

TRF_{Heat} = Thermal regain factor for heating; 1 = unconditioned space; 0.4 for semi-conditioned space

[9] Average DEs for those with “tight” ducts

[10] Average DEs for those with “leaky” and “average” ducts

n_{Cool} = Cooling efficiency in units of SEER = Actual; if unknown applied values in Table 78 based on equipment age

Table 78. nCool for Duct Sealing Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central Air Conditioning (AC) After 1/1/2015	13.0
Heat Pump After 1/1/2015	14.0
Unknown[a]	9.6

[a] For measures where the actual SEER and cooling equipment age is not provided in the database (n=1), we applied the average cooling efficiency using data from all participants in the database where the actual SEER value is provided (n=1,007)

n_{Heat} = Heating efficiency in units of COP = Actual; if unknown applied values in Table 79 based on equipment age

Table 79. nHeat for Duct Sealing Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	2.00
	2006–2014	2.26
	2015 and beyond	2.40
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.83

n_{System} = Pre duct sealing heating system efficiency; calculated using = nHeat * DEbefore; if unable to calculate, assume 0.70

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 80. Coincidence Factors for Air Sealing Measures

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

ISR = In-service rate of installed duct sealing = 100%

4.12 Air Sealing Algorithms

The evaluation team determined ex post air sealing savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 19. Air Sealing Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = [(((CFM50_{Existing} - CFM50_{New})/N_{Cool}) * 60 * 24 * CDD * DUA * 0.018)/(1{,}000 * \eta_{Cool})] * LM * ISR$$

$$\Delta kWh_{Heating} = (((CFM50_{Existing} - CFM50_{New})/N_{Heat}) * 60 * 24 * HDD * 0.018)/(\eta_{Heat} * 3{,}412) * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta Therms = (((CFM50_{Existing} - CFM50_{New})/N_{Heat}) * 60 * 24 * HDD * 0.018)/(\eta_{Heat} * 100{,}000) * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

$CFM_{Existing}$ = Infiltration at 50 Pascals as measured by blower door before air sealing = Actual

CFM_{New} = Infiltration at 50 Pascals as measured by blower door after air sealing = Actual

N_{Cool} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions (applied per participant based on project location and height of home)[11]

Table 81. N_{Cool} by Climate Zone and Number of Stories

Climate Zone	N_{Cool} (by # of stories)					
	1	1.5	2	2.5[a]	3	Unknown[b]
1 (Rockford)	39.5	35.0	32.1	30.3	28.4	33.8
2 (Chicago)	38.9	34.4	31.6	29.8	28.0	33.2
3 (Springfield)	41.2	36.5	33.4	31.5	29.6	35.2
4 (St. Louis, MO)	40.4	35.8	32.9	31.0	29.1	34.6
5 (Paducah, KY)	43.6	38.6	35.4	33.4	31.3	37.2

[a] An average of N-cool values for 2 and 3 stories
[b] An average of N_cool values for 1, 1.5, 2, and 3 stories

CDD = Cooling Degree Days (applied per participant based on location)

Table 82. Cooling Degree Days by Climate Zone

Climate Zone	CDD
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

[11] For projects where the height of the home (number of stories) was not provided in the tracking database, the evaluation team applied the N_cool value for an unknown number of stories.

DUA = Discretionary Use Adjustment = 0.75

η_{Cool} = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 83 based on equipment age

Table 83. η_{Cool} for Air Sealing Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central Air Conditioning (AC) After 1/1/2015	13.0
Heat pump After 1/1/2015	14.0
Unknown[a]	9.6

[a] For measures where the actual SEER and cooling equipment age is not provided in the database (n=99), we applied the average cooling efficiency using data from all participants in the database where the actual SEER values is provided (n=1,007).

LM = Latent Multiplier to account for latent cooling demand (applied per participant based on project location)

Table 84. Latent Multiplier by Climate Zone

Climate Zone	Latent Multiplier
1 (Rockford)	3.3
2 (Chicago)	3.2
3 (Springfield)	3.7
4 (Belleville)	3.6
5 (Marion)	3.7

N_{Heat} = Conversion factor from leakage at 50 Pascal to leakage at natural conditions (applied per participant based on project location and height of home)[12]

Table 85. N_{Heat} by Climate Zone and Number of Stories

Climate Zone	N_{Heat} (by # of stories)					
	1	1.5	2	2.5[a]	3	Unknown[b]
1 (Rockford)	23.8	21.1	19.3	18.2	17.1	20.3
2 (Chicago)	23.9	21.1	19.4	18.3	17.2	20.4
3 (Springfield)	24.2	21.5	19.7	18.6	17.4	20.7
4 (St. Louis, MO)	25.4	22.5	20.7	19.5	18.3	21.7
5 (Paducah, KY)	27.8	24.6	22.6	21.3	20.0	23.8

[a] An aveage of N_heat values for 2 and 3 stories
[b] An average of N_heat values for 1, 1.5, 2, and 3 stories

12 For projects where the height of the home (number of stories) was not provided in the tracking database, the evaluation team applied the N_heat value for an unknown number of stories.

HDD = Heating Degree Days (applied per participant based on project location)

Table 86. Heating Degree Days by Climate Zone

Climate Zone	HDD
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438

η_{Heat} = Efficiency of space heating equipment = Actual; if unknown applied values in Table 87 based on equipment age

Table 87. η_{Heat} for Air Sealing Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
	Unknown[a]	1.77
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

[a] For heat pumps where the actual COP and equipment age are not provided in the database (n=5), we assigned the appropriate TRM values for all participants in the database with air source heat pumps and equipment age (n=39), calculated the average COP for these 39 participants, and applied the average value to the 5 participants with missing COPs and equipment age.

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 88. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 89. Coincidence Factors for Air Sealing Measures

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

ISR = In-service rate of air sealing = 100%

4.13 Attic and Wall Insulation Algorithms

The evaluation team determined ex post attic and wall insulation savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 20. Attic Insulation Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = (((1/R_{Old} - 1/R_{New}) * A_{Attic} * (1 - FF_{Attic})) * 24 * CDD * DUA)/(1{,}000 * \eta_{Cool}) * ADJ_{Cool} * ISR$$

$$\Delta kWh_{Heating} = (((1/R_{Old} - 1/R_{New}) * A_{Attic} * (1 - FF_{attic})) * 24 * HDD)/(3{,}412 * \eta_{Heat}) * ADJ_{Heat} * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta Therms = (((1/R_{Old} - 1/R_{New}) * A_{Attic} * (1 - FF_{attic})) * 24 * HDD)/(\eta_{Heat} * 100{,}067) * ADJ_{Heat} * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Equation 21. Wall Insulation Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = ((((1/R_{Old} - 1/R_{New}) * A_{Wall} * (1 - FF_{wall})) * 24 * CDD * DUA)/(1{,}000 * \eta_{Cool})) * ADJ_{Cool} * ISR$$

$$\Delta kWh_{Heating} = (((1/R_{Old} - 1/R_{New}) * A_{Wall} * (1 - FF_{Wall})) * 24 * HDD)/(3{,}412 * \eta_{Heat}) * ADJ_{Heat} * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta Therms = (((1/R_{Old} - 1/R_{New}) * A_{Wall} * (1 - FF_{wall})) * 24 * HDD)/(\eta_{Heat} * 100{,}067) * ADJ_{Heat} * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

R_{Old} = Total attic or wall assembly R-value prior to installing insulation. For attic insulation we used actual preexisting R-values provided in the program tracking database. For wall insulation we used actual pre-existing R-values (if they are greater than R-5) and R-5 for all others.

R_{New} = Total attic or wall assembly R-value after the installation of additional insulation. For attic insulation we used actual post-retrofit R-values provided in the program tracking database. For wall insulation we used actual post-retrofit R-values provided in the program tracking database. For those with missing R-values (or R-values exceeding typical wall insulation R-values (>R-23)) we applied the average R-value (R-13.5) from participants with post-retrofit wall insulation R-value data (n=240; 92%).

A_{Wall} = Total area of insulated wall (sq. ft.) = Actual

A_{Attic} = Total area of insulated attic (sq. ft.) = Actual

FF = Framing factor adjustment to account for area of framing

Table 90. Framing Factors for Attic and Wall Areas

Measure	Framing Factor
Attic Insulation	0.07
Wall Insulation	0.25

ADJ_{Cool} = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 80%

ADJ_{Heat} = Adjustment for heating savings wall to account for prescriptive engineering algorithms over claiming savings = 60%

CDD = Cooling Degree Days (applied per participant based on project location)

Table 91. Cooling Degree Days by Climate Zone

Climate Zone	CDD
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

DUA = Discretionary Use Adjustment = 0.75

η_{Cool} = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 92 based on equipment age

Table 92. η_{Cool} for Attic and Wall Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0
Heat pump after 1/1/2015	14.0
Unknown[a]	9.6

[a] For measures where the actual SEER and cooling equipment age is not provided in the database (n=63 for wall insulation; n=94 for attic insulation), we applied the average cooling efficiency using data from all participants in the database where the actual SEER value is provided (n=1,007).

HDD = Heating Degree Days (applied per participant based on project location)

Table 93. Heating Degree Days by Climate Zone

Climate Zone	HDD
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438

η_{Heat} = Efficiency of space heating equipment = Actual; if unknown applied values in Table 94 based on equipment age

Table 94. η_{Heat} for Attic and Wall Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
	Unknown[a]	1.77
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

[a] For heat pumps where the actual COP and equipment age are not provided in the database (n=5 for attic; n=1 for wall), we assigned the appropriate TRM values for all participants in the database with air source heat pumps and equipment age (n=39), calculated the average COP for these 39 participants, and applied the average value to the 6 participants with missing COPs and equipment age.

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 95. FLH_{Cool} by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 96. Coincidence Factors for Attic and Wall Insulation Measures

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

ISR = In-service rate of installed attic and wall insulation = 100%

4.14 Rim Joist Insulation Algorithms

The evaluation team calculated ex post rim joist insulation savings using the algorithms below. The IL-TRM does not provide algorithms specifically for rim joists; therefore, we applied the basement sidewall insulation algorithms to determine rim joist savings. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 22. Rim Joist Insulation Algorithms

$$\text{Energy Savings: } \Delta kWh = (\Delta kWh_{Cooling} + \Delta kWh_{Heating})$$

$$\Delta kWh_{Cooling} = (((((1/R_{Old\_AG}) - (1/(R_{Added} + R_{old\_AG}))) * L * H * (1 - FF)) * 24 * CDD * DUA)/(1{,}000 * \eta_{Cool})) * ADJ_{Cool} * ISR$$

$$\Delta kWh_{Heating} = (((((1/ R_{Old\_AG}) - (1/(R_{Added} + R_{old\_AG}))) * L * H * (1 - FF)) * 24 * HDD)/(3{,}412 * \eta_{Heat}) * ADJ_{Heat}) * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta Therms = (((((R_{Old\_AG}) - (1/(R_{Added} + R_{old\_AG}))) * L * H * (1 - FF)) * 24 * HDD)/(100{,}067 * \eta_{Heat}) * ADJ_{Heat}) * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

R_{Old_AG} = R-value of existing foundation wall assembly above grade

Table 97. Rim Joist Above Grade R-Value

Variable	R-Value
R-value_{Joist} (1.5”)	1.88
$\text{R-value}_{outdoor\ air\ film}$	0.17
$\text{R-value}_{wallboard}$	0.45
$\text{R-value}_{indoor\ air\ film}$	0.68
Total R-value	**3.18**

Source: ASHRAE Fundamentals, 2013 Section 27.3.

R_{Added} = R-value of additional insulation. Actual R-values provided in the program tracking database. For those with missing R-values (or R-values exceeding typical rim joist R-values (>R-22)) we applied the average R-value (R-13.3) from participants with added insulation R-value data (n=454; 99%).

L = Total linear feet of installed insulation (ft.) = Actual

H = Height of floor joist in which insulation is installed = 0.85 ft. (average of 2x10 and 2x12 framing)

FF = Framing factor that accounts for area of framing = 0.05[13]

ADJ_{Cool} = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80

ADJ_{Heat} = Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60

CDD = Cooling Degree Days (applied per participant based on project location)

Table 98. Cooling Degree Days by Climate Zone

Climate Zone	Unconditioned CDD
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570

DUA = Discretionary Use Adjustment = 0.75

η_{Cool} = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 99 based on equipment age

Table 99. η_{Cool} for Rim Joist Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0
Heat pump after 1/1/2015	14.0
Unknown[a]	9.6

[a] For measures where the actual SEER and cooling equipment age is not provided in the database (n=88), we applied the average cooling efficiency using data from all participants in the database where the actual SEER value is provided (n=1,007).

HDD = Heating Degree Days (applied per participant based on project location)

Table 100. Heating Degree Days by Climate Zone for Unconditioned Basement

Climate Zone	Unconditioned HDD
1 (Rockford)	3,322
2 (Chicago)	3,079
3 (Springfield)	2,550

[13] Average framing factor for joists running from front-to-back (0.094) and from side-to-side (0). The front-to-back FF was calculated based on 1.5" joists for every 16" (1.5"/16" = 0.094). The side-to-side FF is 0 since joists are continuous and uninterrupted.

Climate Zone	Unconditioned HDD
4 (Belleville)	1,789
5 (Marion)	1,796

η_{Heat} = Efficiency of space heating equipment = Actual; if unknown applied values in Table 101 based on equipment age

Table 101. η_{Heat} for Rim Joist Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
	Unknown[a]	1.77
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

[a] For heat pumps where the actual COP and equipment age are not provided in the database (n=4), we assigned the appropriate TRM values for all participants in the database with air source heat pumps and equipment age (n=39), calculated the average COP for these 39 participants, and applied the average value to the 4 participants with missing COPs and equipment age.

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 102. FLH_{Cool} by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 103. Rim Joist Insulation Coincidence Factors

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

ISR = In-service rate of installed rim joist insulation = 100%

4.15 Crawl Space Insulation Algorithms

The evaluation team calculated the ex post crawl space insulation savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 23. Crawl Space Insulation Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = (((((1/R_{Old\_AG}) - (1/(R_{Added} + R_{Old\_AG}))) * LF * H_{AG} * (1 - FF)) * 24 * CDD * DUA)/(1{,}000 * \eta_{Cool})) * ADJ_{Cool} * ISR$$

$$\Delta kWh_{Heating} = [(((((1/R_{Old\_AG}) - (1/(R_{Added} + R_{Old\_AG}))) * LF * H_{AG} * (1 - FF)) + ((1/R_{Old\_BG} - (1/R_{Added} + R_{Old\_BG}))) * LF * H_{BG} * (1 - FF))) * 24 * HDD]/(3{,}412 * \eta_{Heat}) * ADJ_{Heat}) * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta Therms = [(((((1/R_{Old\_AG}) - (1/(R_{Added} + R_{Old\_AG}))) * LF * H_{AG} * (1 - FF)) + ((R_{Old\_BG} - (1/R_{Added} + R_{Old\_BG}))) * LF * H_{BG} * (1 - FF))) * 24 * HDD]/(100{,}067 * \eta_{Heat}) * ADJ_{Heat}) * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

Where:

R_{Old_AG}	= Above-grade existing R-value of crawl space = 1.0
R_{Old_BG}	= Below-grade existing R-value of crawl space insulation (assume 2.0' below grade) = 5.41
R_{Added}	= R-value of additional insulation. Actual R-values provided in the program tracking database. For those with missing R-values (or R-values exceeding typical crawl space R-values (>R-21)) we applied the average R-value (R-12.1) from participants who installed with added insulation R-value data (n=245; 97%).
ADJ_{cool}	= Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80
ADJ_{Heat}	= Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60
LF	= Total linear feet of installed insulation (sq. ft.) = Actual
H_{AG}	= Height of crawl space wall above grade = 1 foot
H_{BG}	= Height of crawl space wall below grade = 2 feet
FF	= Framing factor that accounts for area of framing = 0 (spray foam)

CDD = Cooling Degree Days (applied per participant based on project location)

Table 104. Cooling Degree Days by Climate Zone

Climate Zone	Unconditioned CDD
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570

DUA = Discretionary Use Adjustment = 0.75

η_{Cool} = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 105 based on equipment age

Table 105. η_{Cool} for Crawl Space Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0
Heat pump after 1/1/2015	14.0
Unknown[a]	9.6

[a] For measures where the actual SEER and cooling equipment age is not provided in the database (n=47), we applied the average cooling efficiency using data from all participants in the database where the actual SEER value is provided (n=1,007).

HDD = Heating Degree Days (applied per participant based on project location)

Table 106. Heating Degree Days by Climate Zone for Unconditioned Basement

Climate Zone	Unconditioned HDD
1 (Rockford)	3,322
2 (Chicago)	3,079
3 (Springfield)	2,550
4 (Belleville)	1,789
5 (Marion)	1,796

η_{Heat} = Efficiency of space heating equipment = Actual; if unknown applied values in Table 107 based on equipment age

Table 107. η_{Heat} for Crawl Space Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
	Unknown[a]	1.77
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

[a] For heat pumps where the actual COP and equipment age are not provided in the database (n=3), we assigned the appropriate TRM values for all participants in the database with air source heat pumps and equipment age (n=39), calculated the average COP for these 39 participants, and applied the average value to the 3 participants with missing COPs and equipment age.

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 108. FLH_{Cool} by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 109. Crawl Space Insulation Coincidence Factors

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

ISR = In-service rate of installed crawl space insulation = 100%

4.16 Basement Sidewall Insulation

The evaluation team calculated the ex post basement wall insulation savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 24. Basement Sidewall Insulation Algorithms

$$\text{Energy Savings: } \Delta kWh = \Delta kWh_{Cooling} + \Delta kWh_{Heating}$$

$$\Delta kWh_{Cooling} = (((1 / R_{Old\_AG} - (1 / (R_{Added} + R_{Old\_AG}))) * L_{Total} * H_{AG} * (1 - FF)) * 24 * CDD * DUA) / (1{,}000 * \eta_{Cool}) * ADJ_{Cool} * ISR$$

$$\Delta kWh_{Heating} = [(((1 / R_{Old\_AG} - (1 / (R_{Added} + R_{Old\_AG}))) * L_{Total} * H_{AG} * (1 - FF)) + ((1 / R_{Old\_BG} - (1 / R_{Added} + R_{Old\_BG}))) * L_{Total} * (H_{Total} - H_{AG}) * (1 - FF))) * 24 * HDD] / (3{,}412 * \eta_{Heat}) * ADJ_{Heat} * ISR$$

$$\Delta kW = (\Delta kWh_{Cooling} / FLH_{Cool}) * CF$$

$$\Delta Therms = [(((1 / R_{Old\_AG} - (1 / (R_{Added} + R_{Old\_AG}))) * * L_{Total} * H_{AG} * (1 - FF)) + ((1 / R_{Old\_BG} - (1 / R_{Added} + R_{Old\_BG}))) * L_{Total} * (H_{Total} - H_{AG}) * (1 - FF))) * 24 * HDD] / (100{,}067 * \eta_{Heat}) * ADJ_{Heat} * ISR$$

$$\Delta kWh_{Runtime} = \Delta Therms * F_e * 29.3$$

R_{Old_AG} = Above-grade existing R-value = 1.0

R_{Old_BG} = Below-grade existing R-value of basement wall insulation (assume 6.0' below grade) = 9.46

R_{Added} = R-value of additional insulation = Actual

ADJ_{cool} = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80

ADJ_{Heat} = Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60

L_{Total} = Total length of insulated basement wall perimeter = Actual

H_{AG} = Height of basement wall above grade = 1 foot

H_{BG} = Height of basement wall below grade = 6 feet

H_{Total} = Total height of basement wall (H_{AG} + H_{BG}) = 7 feet

FF = Framing factor that accounts for area of framing = 0 (spray foam)

CDD = Cooling Degree Days (applied per participant based on project location)

Table 110. Cooling Degree Days by Climate Zone

Climate Zone	Unconditioned CDD
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570

DUA = Discretionary Use Adjustment = 0.75

$\eta Cool$ = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 111 based on equipment age

Table 111. η_{Cool} for Crawl Space Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0
Heat Pump after 1/1/2015	14.0
Unknown[a]	9.6

[a] For measures where the actual SEER and cooling equipment age is not provided in the database (n=4), we applied the average cooling efficiency using data from all participants in the database where the actual SEER value is provided (n=1,007).

HDD = Heating Degree Days (applied per participant based on project location)

Table 112. Heating Degree Days by Climate Zone for Unconditioned Basement

Climate Zone	Unconditioned HDD
1 (Rockford)	3,322
2 (Chicago)	3,079
3 (Springfield)	2,550
4 (Belleville)	1,789
5 (Marion)	1,796

η_{Heat} = Efficiency of space heating equipment = Actual; if unknown applied values in Table 113 based on equipment age

Table 113. η_{Heat} for Crawl Space Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
	Unknown[a]	1.77
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

[a] There were no cases for basement sidewall insulation where there was a need to apply the “unknown” heat pump COP. The database provided actual COP or equipment age for all heat pumps.

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 114. FLH_{Cool} by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 115. Crawl Space Insulation Coincidence Factors

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

ISR = In-service rate of installed basement sidewall insulation = 100%

5. Public Sector CAC

The impact evaluation efforts estimated gross impact savings for the PHA CAC Program by applying savings algorithms from the IL-TRM V5.0 using the information provided in the program tracking database. We present the algorithms and input variables used to calculate all evaluation program savings below.

5.1 Central Air Conditioner Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) air conditioners using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for cooling load reduction as a result of right-sizing the newly installed HVAC equipment. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 1. Central Air Conditioner Algorithms

$$(TOS)\ \Delta kWh_{Cooling} = (((FLH_{Cool} * Capacity_{exist} * (1 / SEER_{base})/1000) - ((FLH_{Cool} * Capacity_{eff} * (1 / SEER_{eff})/1000)) * ISR$$

$$(ER)\ \Delta kWh_{Cooling} = (((FLH_{Cool} * Capacity_{exist} * (1 / SEER_{exist})/1000) - ((FLH_{Cool} * Capacity_{eff} * (1 / SEER_{eff})/1000)) * ISR$$

$$(TOS)\ \Delta kW = ((Capacity_{exist} * (1 / EER_{base})/1000) - (Capacity_{eff} * (1 / EER_{eff})/1000)) * CF * ISR$$

$$(ER)\ \Delta kW = ((Capacity_{exist} * (1 / EER_{exist})/1000) - (Capacity_{eff} * (1 / EER_{eff})/1000)) * CF * ISR$$

Where:

FLH_{Cool} = Full Load Cooling Hours (applied per participant based on project location)

Table 116. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_{Cool}
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

$Capacity_{exist}$ = Cooling capacity of existing central air conditioner in units of Btuh = Actual; If unknown assumed same capacity as installed energy efficient central air conditioner

$Capacity_{eff}$ = Cooling capacity of installed energy efficient central air conditioner in units of Btuh = Actual

$SEER_{base}$ = Baseline central air conditioner cooling efficiency for TOS installations in units of SEER = 13 SEER

$SEER_{exist}$ = Baseline central air conditioner cooling efficiency for ER installations in units of SEER = Actual; If unknown assumed 10 SEER

$SEER_{eff}$ = Cooling efficiency of newly installed central air conditioner in units of SEER = Actual

EER_{base} = Baseline central air conditioner cooling efficiency for TOS installations in units of EER = 11.2 EER

EER_{exist} = Baseline central air conditioner cooling efficiency for ER installations in units of EER = Actual; If unknown assumed 9.2 EER

EER_{eff} = Cooling efficiency of newly installed central air conditioner in units of EER = Actual; If unknown assumed 12.0 EER

CF = Summer peak coincidence factor = 0.68

ISR = In-service rate of installed central air conditioners = 100%

6. Commercial and Industrial Custom

In this section, we present detailed project-level desk review and on-site M&V reports for 5 of the largest C&I Custom projects completed during the Transition Period.

6.1 Project 900062

Project ID#:	900062
Ex Ante Measure:	Surgery Addition and HVAC Renovation
Facility Type:	Hospital
End Use:	HVAC

Measure Description

The project involves a 49,932-square foot addition and renovation for the surgery areas in a hospital. The addition is comprised of a 12,513-square foot area for more operating rooms, an 11,300-square foot operating room renovation, and 26,119-square foot renovation for endoscopy services.

Summary of Ex Ante Calculations

Custom calculations were based on a Trane Trace 700 version 6.3.1 energy model. The project documentation included a savings summary written by the energy modeler. The actual model was not provided.

The base model was based on ASHRAE 90.1-2010, Appendix G, ASHRAE 170 and the Illinois Department of Public Health (IDPH) requirements. The project documentation stated the lighting power density for both base and proposed models is 1.21 W/ft2 so lighting savings was zero. Follow-up information provided by the site contact indicated that lighting projects were on a separate rebate project. The savings for project 900062 all are from the heating, ventilation and air conditioning (HVAC) systems.

A review of the project documentation provides some explanation for the model savings. The baseline condition was System 5: Packaged rooftop variable air volume (VAV) with reheat and direct expansion (DX) cooling. The proposed HVAC system was also VAV with reheat but used chilled water cooling. Much of the cooling and heat rejection savings result from the higher efficiency of chilled water and cooling tower systems compared to DX and air cooled systems. Since chilled water and cooling tower system require more pumps, the proposed case included an increase in the system pumping energy.

The documentation states that while the code requires VAV for the base model, the system was modeled as constant volume to maintain space pressurization as required by ASHRAE 170 and IDPH. The boiler efficiency in the base case was 80% while the boiler efficiency in the proposed case was 83.3%.

The project includes a new makeup air unit (MUA) for the new surgery space. This unit has an energy wheel and desiccant wheel cooling coil. The total energy wheel reduces preheat and cooling loads required to condition the outdoor air. The desiccant wheel helps to obtain dryer air without cooling the air to a lower temperature.

A summary of model savings is shown in Table 117.

Table 117. Summary of Savings

	Base Model	Proposed Model	Savings
Interior Lighting, kWh	265, 837	265, 837	0
Receptacle Equipment, kWh	223,816	223,816	0
Fans- Interior, kWh	630, 971	320,514	310,457
Space Cooling, kWh	596,518	247,792	348,726
Heat Rejection, kWh	50,866	6,785	44,081
Pumps, kWh	23,971	61,376	-37,405
Space Heating, therms	78,975	37,824	41,151
Humidifier, therms	3,987	3,235	752
Total Electric Usage, kWh	**1,791,979**	**1,126,120**	**665,859**
Total Gas Usage, therms	**82,962**	**41,059**	**41,903**

The ex ante savings for this project are summarized below in Table 118. The ex ante demand savings were calculated by dividing energy savings by 8,760 hours.

Table 118. Summary of Ex Ante Savings

Surgery Addition and HVAC Renovation	Annual Energy Savings (kWh)	Demand Savings (kW)	Gas Savings (Therms)
Modeled Baseline	1,791,979	204.6	82,962
Modeled Proposed	1,126,120	128.6	41,059
Modeled Savings	665,859	76.0	41,903

Measurement and Verification Plan

Data for the individual measures was collected consistent with IPMVP Option A, partially measured retrofit isolation. The measure level data was used on conjunction with the model description to develop measure level corrections. A bottom up approach. Additionally, IPMVP Option C, Whole Facility, was used to validate the savings for the entire project. A top down approach. The two approaches were synthesized to determine the ex post savings.

A site visit was performed during which the completed measures were verified to have been implemented. The customer was interviewed regarding the completion dates for each measure. Control setpoints both before and after the project was completed were obtained from the customer and the facility's building automation system (BAS).

The customer was interviewed in detail regarding the previous operation of the facilities systems and controls. The electric and gas meter data pre and post-project completion was collected from the utility. The customer was asked to provide a copy of the model, however the customer did not have any of the files.

Description of Verification

A site visit was conducted on January 30, 2018 to verify the installation of HVAC system modifications. The site contact and contractor representative were interviewed and a site walkthrough was completed. The project was completed in three phases over a 30-month period.

Table 119 provides a summary of the project. The first phase was an addition which included more surgery space. The second phase was an existing space that was taken out of service for seven months while the new HVAC equipment was installed and tested. The third phase was also an existing space that was taken out of service while the new HVAC equipment was installed. At the time of the site visit on January 30, 2018, the third phasehad not been fully tested and the affected area was unoccupied. Based on discussions with the site contact, the third phase is expected to be fully occupied by March of 2018.

Table 119. Summary of Base, New, and Retrofit Spaces

Space	Square Footage
Base SF	258,537
Phase 1 New SF Surgery Addition Occupied October 2016	12,513
New SF	271,050
Phase 2 Surgery Renovation SF out of service from Nov 2016 to June 2017	11,300
Phase 3 Endoscopy Retrofit SF out of service from July 2017 to March 2018	26,119
Amount of SF in service at time of site visit	23,813
Total New/Retrofit SF	49,932
% of renovated SF in operation at time of site visit	48%

The site contact explained that the original air handling units were constant volume units. These were all replaced with variable air volume (VAV) systems with tracking return air VAV boxes to reduce airflows during low load periods or unoccupied hours. Occupancy sensors were used in these spaces to monitor occupancy throughout the day.

The site contact also explained that the new operating rooms and support spaces would be served by a make-up air unit that used a desiccant wheel to obtain dryer air without cooling. He explained this was the design feature that provided a significant amount of energy savings. However this unit only served the new surgery addition and not the entire renovated area.

A walkthrough of the mechanical rooms provided an opportunity to ensure that the fans were running in variable speed mode. All fan speeds were recorded and these were all running in variable speed mode. The site contact explained that the boiler was an 80% efficient hot water boiler that was not replaced. The chillers and cooling towers were also not modified.

Calculation Description

The ex post energy savings was estimated by two methods. One involved a review and adjustments based on information provided on the energy model. The other involved a review of baseline and proposed energy use using a regression analysis.

Model Review and Adjustments

The model predicted savings was adjusted based on changes to fans savings and space heating savings. For the fan savings, the baseline energy usage was reduced based on fan power limitations provided in the code. Table 6.5.3.1.1A, Fan Power Limitation, in ASHRAE 90.1-2010 provides factors that limit fan power for constant volume and variable volume systems.

While code requires the baseline system to be VAV, it was modeled as a constant volume system. Based on the code, the fan brake horsepower (bhp) should be limited to the values allowed for a constant volume system. The factor for constant volume is 0.00094 and the factor for a variable volume system is 0.0013. Using these factors, the baseline fan consumption was adjusted using the following equation:

$$kWh_{CV} = kWh_{VAV} \times \frac{0.0094}{0.0013}$$

This results in a baseline fan usage of 456,241 kWh versus the ex ante value of 630,971 kWh.

For the space heating the proposed case used a boiler efficiency of 83.3% while the baseline case used a boiler efficiency of 80%. The project documentation and the site contact confirmed the boilers were not changed in this project. The proposed space heating therms was adjusted using the following equation:

$$therms_{proposed} = therms_{base} \times \frac{0.833}{0.800}$$

This results in a proposed space heating therm usage of 39,384 versus the ex ante value of 37,824.

Using this adjustment, the overall project energy usage was adjusted and is shown in Table 120. When compared to Table 118, this shows that baseline energy usage and demand decreased and proposed gas usage increased.

Table 120. Summary of Project Savings Using Model Values

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Baseline	184.62	1,617,249	82,962
Proposed	128.55	1,126,120	42,619
Savings	56.065	491,129	40,343

Regression Analysis and Adjustments

A billed regression was also completed for the overall project. The base case was defined as the 10-month period before the new surgery addition was occupied. This was from January 2016 through October 2016. The monthly utility data was used for the analysis. The post case was defined as the 12-month period when the Phase 1 project was in service and the 6-month period when the Phase 2 project was in service. This was from January 2017 through December 2017.

Since this project only analyzed the first two phases of the project it was only analyzing 48% of the square footage affected, as shown in Table 119. This required an adjustment to the monthly utility data in the post case so it could be compared to the base case.

$$kWh_{adjusted} = kWh_{utility} \times \frac{SF_{base}}{SF_{occupied}}$$

If the square feet occupied was greater than the base square feet, the adjusted energy use was less than the utility bill. This occurred during the period from January 2017 through June 2017 when the actual occupied space was larger than the base case. If the square feet occupied was less than the base square feet the adjusted energy use was greater than the utility bill. This occurred during the period from July 2017 through

December 2017 when the actual occupied space was less than the base case. This adjustment is based on the assumption that energy use is directly correlated to square feet occupied. Since all areas are surgery areas this is a reasonable assumption.

The regression analysis showed the energy and demand savings for the first two phases was 205,100 kWh and 23.41 kW. The coefficient of Variation (CV) for the baseline was 2.8% and for the post case was 10.2%. The gas savings was 16,217 Therms. The coefficient of Variation (CV) for the baseline was 15.5% and for the post case was 12.8%. These values should be less than 20% for a valid regression analysis.

Since these savings values only represented 48% of affected square footage, the ex ante savings was adjusted so a fair comparison could be made. The following equation was used:

$$Savings_{ex\ ante\ adjusted} = Savings_{ex\ ante} \times 48\%$$

The adjusted ex ante savings values were 317,554 kWh, 23.413 kW, and 19,984 Therms. Using these values and the values from the regression analysis the realization rates were calculated. For energy and demand the realization rates were 64.6%. For gas the realization rate was 81.1%.

The realization rates were then applied to the ex ante savings estimates to provide the ex post savings estimates. The ex ante and ex post savings are present in Table 121.

Table 121. Summary of Project Savings using Billed Regression

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	76.01	665,859	41,903
Ex Post	49.09	430,062	34,004
Realization Rate	64.6%	64.6%	81.1%

Summary of Ex Post Calculations

After a review of both calculation methodologies, it was decided that the calculation based on model inputs was most appropriate for this project. There were many adjustments needed to complete the regression analysis since the space was not fully occupied. The savings in Table 122 provides the final project savings estimate. The reduced savings is due to the higher fan power assumed in the baseline case and the more efficient boiler assumed in the proposed case.

Table 122. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	76.01	665,859	41,903
Ex Post	56.06	491,129	40,343
Realization Rate	74%	74%	96%

6.2 Project 9000826

Project ID#:	900826
Measure:	New Air Compressors & Air Dryer
Facility Type:	Industrial
End Use:	Process

Measure Description

A new production line was built at the facility which required new compressed air equipment. The new equipment included: (2) 250 HP 2-stage air compressors, (1) 250 HP 2-stage VFD compressor, and (1) 4,500 CFM cycling refrigerated air dryer.

Summary of Ex Ante Calculations

The ex ante savings for this project are 127.3 kW and 847,042 kWh. Since this project involves a new production line, there is not any existing equipment. Therefore, the baseline is considered to be standard efficiency equipment that is able to provide sufficient airflow at the desired pressure.

The baseline equipment for this project was considered to be:

- (2) 300 HP 1-Stage Compressors (4.85 cfm/kW)
- (1) 300 HP 1-Stage Compressor (4.85 cfm/kW)
- Non-Cycling Refrigerated Dryer
- General Purpose Flanged Filter

The proposed equipment for this project was considered to be:

- (2) 250 HP 2-Stage Compressors (5.81 cfm/kW)
- (1) 250 HP 2-Stage VFD Compressor (6.19 cfm/kW)
- Cycling Dryer
- Non-Lube Module

The ex-ante calculation used software to estimate pre-case and post-case demand and energy consumption. There were additional calculations provided that used compressor energy efficiency data and rules of thumb. No compressor efficiency curves were provided with the project documentation. The ex-ante savings for this project are presented below in Table 123.

Table 123. Ex Ante Savings

New Air Compressors and Air Dryers	kWh	kW
Pre-Case	3,060,562	459.8
Post-Case	2,213,519	332.6
Savings	847,043	127.3

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project.

For the evaluation of this project, a site visit will be completed, the equipment and compressed air system will be inspected, and the site representative will be interviewed. The installation of the new air compressors and compressed air dryers will be verified during the visit. The rated capacity, demand, and efficiency of the new compressors will be documented during the visit.

Additional questions for the customer include but are not limited to:

- What is the peak and average air demand (CFM) of the compressed air system?
- How are the air compressors controlled?
- What is the typical operating schedule (hrs/day, day/week)? Do you observe any holidays?
  - Are the compressors able to be turned off when there is no production?
- How many compressors typically operate during production?
- What are the pressure set points for the compressors (ex ante calc assumes 95 psig)?
- What air pressure is required for the process equipment?
- Are there any seasonal variations in the use of the compressed air?
- What are the primary uses of the compressed air?
- Are the compressors monitored and/or controlled with a system that has trending capabilities? If so, does the system have the capability to export historical data trends (air flow, amps, or kW)?

There is no post-case operating data available, so data loggers will be installed to develop operating profiles. HOBO external-input loggers will be installed with current transducers to monitor the amperage of the compressors and air dryer. The loggers will record amps at 1-minute intervals and be left in place for a minimum of two weeks. Instantaneous measurements of voltage, amps, power, and power factor will be taken at the time of deployment or removal to calibrate logged amperage.

Description of Verification

A site visit was completed on January 30, 2018. The site contact was interviewed and the installation of the compressors were verified. The facility is an aluminum extrusion plant that produces aluminum automotive parts. The new compressors were added to provide cooling for a new extrusion operation.

During the site visit recruitment call, the site contact explained that the compressors run 18 hours per day, five days per week, over three shifts. The facility operates 50 weeks per year with an average of seven holidays per year. The compressors operate between 80 and 90 psi. Process equipment requires an air pressure of 80 psi. There are no seasonal variations in the use of the compressed air.

Nameplates of the compressors were found to be consistent with the information in the project files.. The compressor operating pressures were recorded from the compressor control displays and were found to be 98 psi.

The site contact explained that the current operation includes two 2-stage compressors running based loaded 100% of the time during production, while the VFD compressor trims and operates 50-75% of the time. The logger data shows the peak air demand is between 3,188 and 3,588 CFM. For comparison, the ex ante analysis assumed an average of 1,976 CFM would be needed. Due to the high usage following project completion, a fourth compressor was added to handle large uses and provide backup. The fourth compressor was also noted to be a 2-stage compressor.

Data loggers were installed on three of the four compressors. An amperage meter was installed on the fourth compressor, which was not part of the project, inadvertently. Therefore, only one of the baseline compressors was being monitored. To address this issue, the data collected for the actual baseload compressor was used to represent the operation of the second baseload compressor. A second amperage logger was installed on another 2-stage compressors to log the amperage at one minute intervals. A DENT ELITEpro power data logger was installed on the variable speed compressor to log the kW at one minute intervals.

The time on site was limited to one hour. Therefore, installing loggers on the air compressors was prioritized over the compressed air dryer since the savings for the air compressors comprise 90.5% of the claimed savings. Dryer information as collected during the visit but loggers were not installed due to the time constraints.

During the monitoring period, the VFD compressor failed after eight days of operation. It was out of service until the day before the loggers were picked up. All of the operating data during the eight day period of abnormal VFD compressor operation was excluded from the ex post analysis. The remaining metered data comprised of one week of typical compressor operation and confirmed the ex ante assumption of compressor operation for five days per week and 18 hours per day.

Calculation Description

The ex post savings were determined using the logged data from the site visit. Figure 5 shows the kW load profile for the base load compressors (two 2-stage compressors). The graph shows that the base load compressor was either on at full flow, at minimum power at zero flow, or off at zero power. The CFM for the two base load compressors was calculated using the flow rating of 1,249 CFM, which is the rated flow of this compressor. At all other times the flow was calculated as zero.

Figure 5. Logged Power of Base Load Compressor

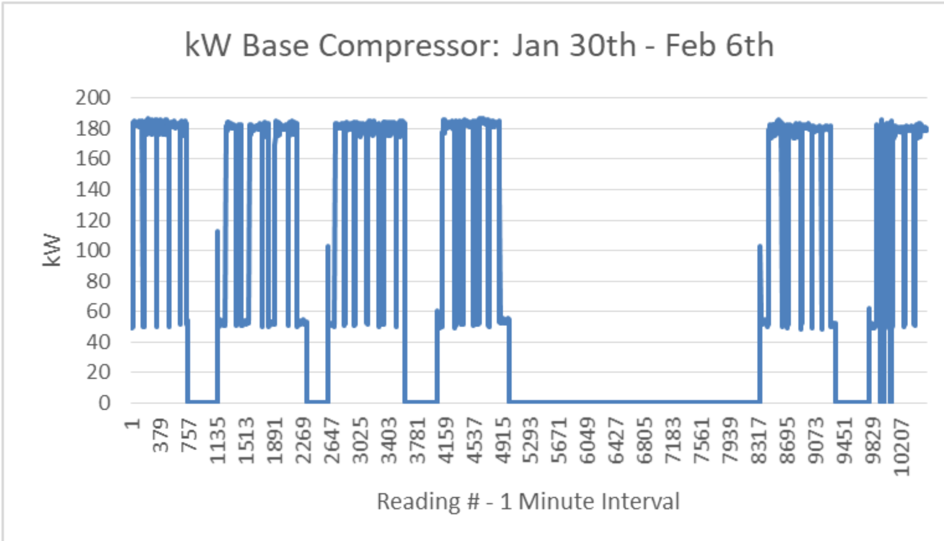
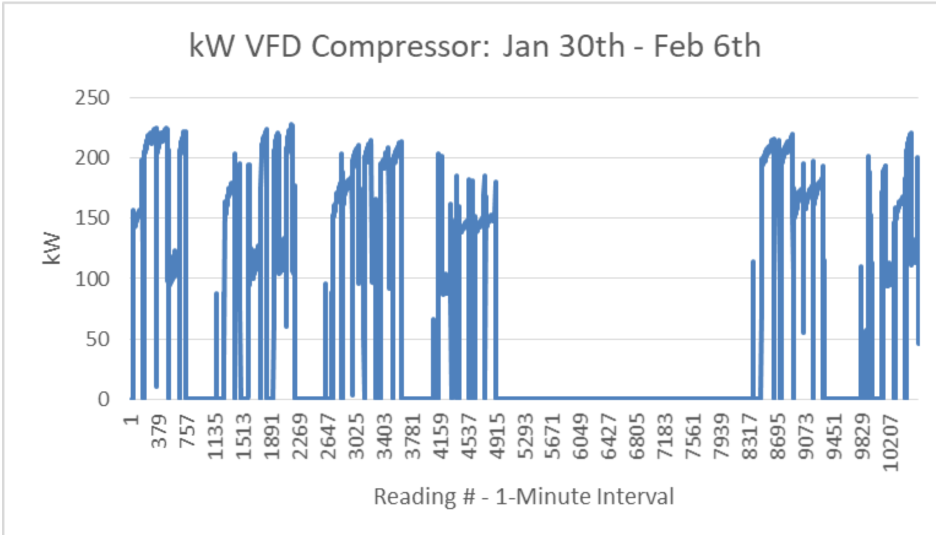


Figure 5 shows the kW load profile for the VFD compressor during the same period. The graph shows compressor modulating to meet the air demand. The VFD compressor is able to turn off when not needed. Since the data was collected in 1-minute increments, it could be seen there were times when the power was less than 11 kW. This was the power level where the compressor was on but there was no demand for air. For all power levels less than 11 kW, the CFM was set to zero. At all other power levels, the CFM was calculated using the compressor curve for a VFD that has 5% power at zero flow. The efficiency rating of 16.15 kW/cfm was used. It was based on the rated full load power of 222.9 kW, full load rated flow of 1,380 cfm, and rated pressure of 100 psi. The efficiency rating of 16.15 kW was then adjusted to 15.99 to account for the actual operating pressure of 98 psig which was documented during the site visit.

These calculations resulted in a minimum CFM demand of 1,412 to maximum cfm of 3,928. The average CFM demand was 2,585 CFM.

Figure 6. Logged Power of Trim Compressor



The ex post calculation for the baseline condition depended on the assumptions used for the baseline equipment. The project documentation did not provide any Compressed Air and Gas Institute (CAGI) curves for the baseline compressors and these were not available on the manufacturer's website. Therefore, the ex post calculations use the efficiency curve for compressors with inlet modulation and blowdown to model the baseline compressors.

The compressors were assumed to have a full load rated power of 258 kW, full load rated flow of 1,252 cfm, and rated pressure of 125 psi. This resulted in a calculated rated efficiency of 20.6 kW/100 CFM. The power and corresponding compressor efficiency was adjusted based on the actual operating pressure of 98 psig. This resulted in a full load efficiency of 17.82 kW/100 CFM for the baseload compressors.

Using the calculated CFM load profile from the logged kW, the kW for the base pre-case was calculated. The base loaded compressors were either at zero kW when off, 58 kW at zero flow, or 223 kW at full flow. The trim (VFD) compressor was modeled using a standard VFD compressor efficiency curve. The power at minimum load was set at 58 kW and the power was calculated using the compressor curve up to full flow.

These data provided the estimate for the pre-case power consumption. A summary of ex post compressor savings is shown in Table 123Table 124.

Table 124. Ex Post Compressor Savings

New Air Compressors and Air Dryers	kWh	kW
Baseline	2,474,616	585.54
Post-case	1,942,787	471.24
Savings	531,829	114.30

Summary of Ex Post Calculations

Table 125 provides a summary of project savings and realization rates. The changes in rates are likely due to the difference between assumptions on load profiles and taking actual measurements using logging. The ex ante calculation assumed 6.656 hours per year while the logged data showed only 4,784 hours per year. The ex ante assumed 1,976 CFM while the logged data showed an average of 2,585 CFM. The ex ante calculation did not provide enough data to verify the assumptions of power consumption across the load profile. The ex post analysis used logger data to determine the compressor power across of the load profile and at zero flow.

Table 125. Summary of Project Savings

New Air Compressors and Air Dryers	kWh	kW
Ex Ante	847,043	127.26
Ex Post	531,829	114.30
Realization Rate	62.8%	89.8%

6.3 Project 900958

Project ID#:	900958
Ex Ante Measure:	NC Lighting
Facility Type:	Warehouse
End Use:	Lighting

Measure Description

This project includes the installation of interior and exterior light fixtures at a new warehouse facility. The new lights were noted to be LED lamps. A total of (283) interior and (29) exterior light fixtures were noted to be installed at the facility. The ex ante savings analysis used a new construction baseline. A list of installed fixtures is summarized in Table 126.

Table 126. Summary of Fixtures Installed

Area	Fixture	Quantity	Watts	Occ. Sensor
Warehouse	F1- HBLED-LD4-48-W-CLI-UNV-L850-ED4-MS-U - DLC listed	257	401	273
Exterior	S1- GLEON-AE-03-LED-E1-TW4 - DLC listed	17	157	
Exterior	S2- GLEON-AE-04-LED-E1-5WQ - DLC listed	5	213	
Exterior	S3- GLEON-AE-03-LED-E1-SL3 - DLC listed	7	157	
Exterior	WP1- GLEON-AE-03-LED-480-SL4-BZ-WM - DLC listed	14	157	
Warehouse	A-4SNLED-LD4-41SL-LW-UNV-L850-CD1-U - DLC listed	6	37	1
Warehouse	C-PDM6A840/PD615ED010 - ES listed	6	17	

Summary of the Ex Ante Calculations

The ex ante savings were calculated using a calculation approach that compared the newly installed light fixtures to a new construction baseline LPD based on the space type and area. The building comprised of 624,150 square feet of warehouse space, 485,788 square feet of exterior space, and 3,438 linear feet of building façade. The ex ante calculations use ASHRAE 90.1-2013 baseline LPDs for each space type. The ex ante savings for this project are summarized below in Table 127.

Table 127. Summary of Project Savings

	Annual Energy Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)
NC Lighting	2,320,972	264.95	0

Measurement & Verification Plan

During the site visit, the following items should be evaluated:

- Operating hours
- Area of each space
- Fixture wattage and quantity
- Occupancy sensors in warehouse space and occupancy schedule for areas with occupancy sensors
- Confirm if impacted spaces are conditioned

U12-012 light level loggers will be deployed for approximately 2 weeks to monitor a representative sample of occupancy sensor controlled lights. Once this data has been collected, the ex post savings will be using a hand calculation in an Excel spreadsheet.

Description of Verification

A site visit was completed on February 1, 2018. The site contact was interviewed and the installation of the lights and controls were verified. The facility was used for hand assembly work for short term contracts. The space usage and working hours are specific for each contract. The facility is currently operated two shifts per day, Monday through Friday. Weekend work is scheduled only rarely. There are fewer workers on the second shift but at least one person is on that shift. Based on this occupancy pattern, the annual hours of operation are 4,171 hours.

A walkthrough of the space was completed. Approximately 95% of the space is used for storage of materials. Approximately 4%, or 27,485 square feet, is used for assembly. Approximately 1%, or 3,120 square feet, is used for offices. The only area that is cooled is the office space.

The overall interior square footage matched the quantity specified in the documentation. The linear feet of the building perimeter also matched the quantity specified in the documentation. The predominant space type of “warehouse” seemed reasonable since only 4% was used for manufacturing. Since the office lights were not included in the application, the office area was subtracted from the total building area. This reduced the total building area to 620,880 square feet.

The installation of the interior lights and controls were physically verified. For the main warehouse and assembly areas, the light fixtures matched the description provided in the documentation. All fixtures had integral occupancy sensors. The total number of occupancy sensors was reduced from (273) to (257) match the total number of fixtures. The lighting in the pump room was verified and the fixture types and quantities seemed reasonable.

Seven light loggers were installed in various locations in the storage areas to measure lighting hours of operation. No loggers were installed in the assembly area because that area was occupied during all shifts. Five loggers were installed in the “reserve storage” area, where finished products were stored before shipment. This area had much less activity to trigger lights.

Two loggers were installed in the "active storage" area, where materials were stored prior to assembly. This area had more activity to trigger light operation. This area also provided confirmation of building occupied hours. As can be seen in Figure 7, the occupancy of 16 hours per day is clearly shown by the logger data. As can be seen in Figure 8, there is no occupancy on Saturday and Sunday.

Figure 7. Average Hours for Seven Days of the Week

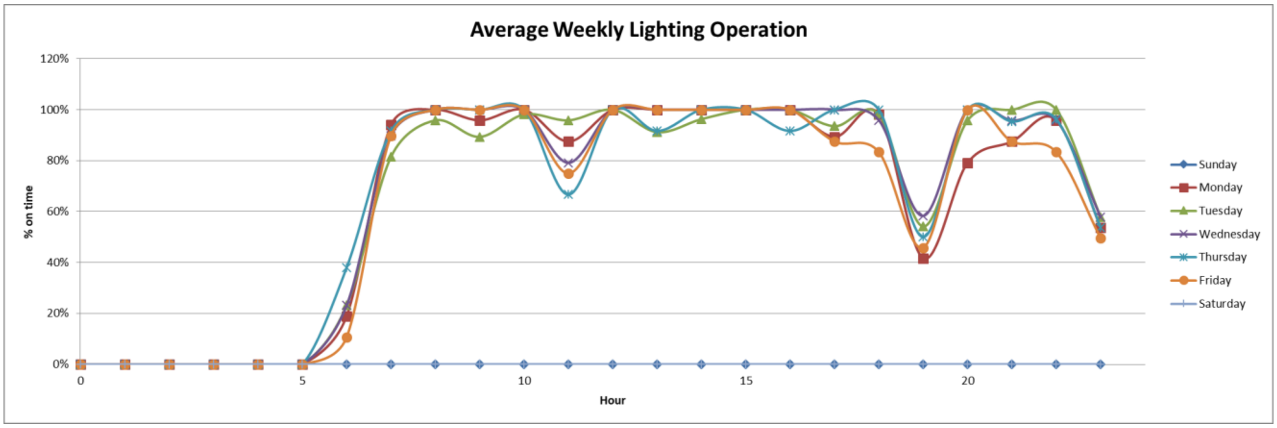
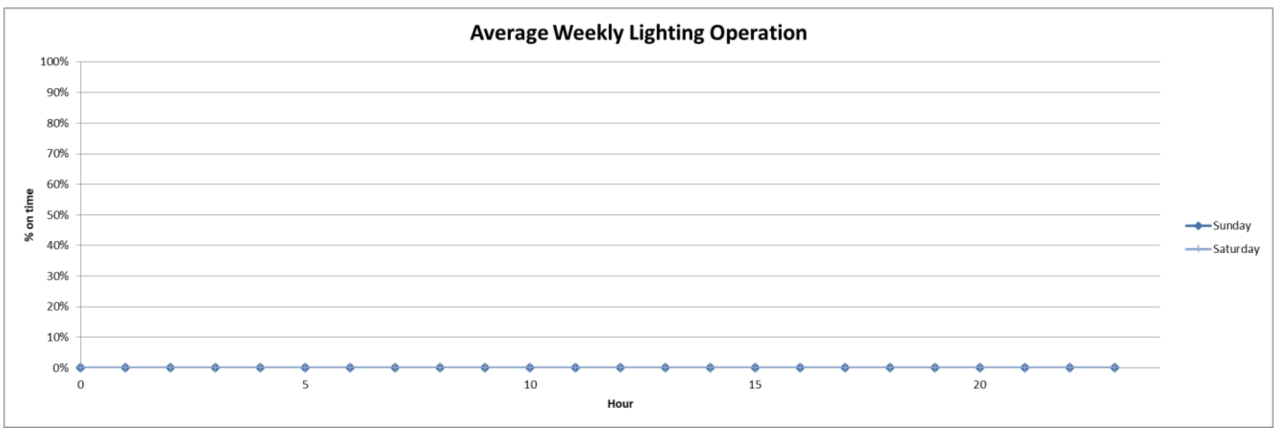


Figure 8. Average Hours Saturday and Sunday Only



The controls factor for each area was calculated and then a weighted average for the entire storage was calculated. The resulting controls factor of 55% is shown in Table 128.

Table 128. Logger Results

Area	SF	Controls Factor
Assembly	27,487	0%
Reserve Storage	487,403	67%
Active Storage	105,596	12%
Weighted Average		**55%**

The installation of the exterior lights and controls were physically verified. A total of (29) parking pole fixtures were verified which matches the project documentation. However, all parking pole fixtures were the same, with only three light squares in each head. The original documentation showed that five of these fixtures had four light squares and were rated at 213 Watts. All pole fixtures were adjusted to 157 input Watts.

A total of (12) wall pack fixtures were verified which is two less than the value of (14) shown in the project documentation. All these fixtures had (3) light squares which matches the project documentation. These fixtures remained at 157 input Watts.

Calculation Description

The ex post analysis used fixture quantities and input wattage, areas, and operating hours that were confirmed during the site visit. The baseline operating hours were calculated using the data from the light loggers that were installed at the facility.

The calculation was adjusted for the data verified during the site visit. A summary of adjustments includes:

- The annual operating hours was reduced from 8,760 to 4,171 for all interior light fixtures;
- The fixture wattage for (5) parking pole fixtures was reduced from 213 Watts to 157 Watts;
- The total number of wall pack fixtures was reduced from (14) to (12);
- The total building area was reduced from 624,000 to 620,880 square feet; and
- The controls factor for warehouse lighting was increased from 0.24 to 0.55.

Summary of Ex Post Calculations

Two adjustments were made in the ex post savings analysis. The baseline operating hours were reduced from 8,760 hours to 4,171 hours which decreased the energy savings. The reduction in savings from the adjusting the operating hours was offset due to increasing the controls factor from 0.24 to 0.55. These adjustments combine to reduce the energy savings. Table 129 provides a summary of project savings and realization rates.

Table 129. Summary of Project Savings

	NC Lighting	
	kWh	kW
Ex Ante	2,320,972	209.82
Ex Post	1,785,104	208.35
Realization Rate	**77%**	**99%**

6.4 Project 1000152

Project Information

Project ID#:	1000152
Project:	Waste Water Treatment Plant Improvements
Facility Type:	Municipal Waste Water Treatment
End Use:	Waste Water Treatment: Process

Project Description

The waste water treatment plant prior to the completion of this project was a conventional activated sludge waste water plant that used centrifugal blowers to accomplish waste water treatment. The plant did not include automated process controls. The project consisted of the following:

- Upgrade the treatment process to utilize enhanced biological phosphorous removal
- Install automated dissolved oxygen controls
- Replace the existing centrifugal blowers with turbo blowers
- Replace three facility transformers and remove two unused transformers.

The facility receives 45% of its biological oxygen demand (BOD) content from one customer that supplies only a small fraction of their hydraulic load on a daily basis. The intent of the project is to improve the BOD removal by adjusting the treatment process to be more flexible with how loads are handled while also installing controls to lower aeration supply CFM so as to not oversupply air. This would effectively maintain BOD effluent levels below EPA requirements without removing more BOD content than required.

Summary of the Ex Ante Calculations

The savings were calculated based on blower CFM/kW/kWh savings. The savings for each measure of the project were calculated sequentially by looking at the impact each measure had on the air flow profile. The blower CFM profile and quantity of blowers operating was determined for each measure. The CFM profile is the percentage time that the system operates at each CFM airflow bin. The baseline CFM profile was calculated based on a measured CFM load profile and the additional CFM required based on an expected BOD load increase. The expected BOD load increase is due to a Discharge Permit increase given to the facility's primary customer. The baseline projected CFM is then the required CFM load needed to meet effluent BOD levels using the facility's existing infrastructure and existing blower system. The savings were then calculated based on the new flow profile required given the installation of the measure, in a sequential order, ultimately compared to the baseline system.

The weighted average system kW usage is calculated as the blower kW required at each bin multiplied by the percentage time at each bin. The annual kWh system usage is calculated as the weighted average system kW multiplied by 8,760 annual operating hours.

No description is given as to how the % CFM bin profiles are determined or as to how the blower kW for each CFM bin is determined.

The turbo blower savings are calculated using the same method as described above. However, instead of adjusting the % CFM bin profile, the blower kW is adjusted to account for the existing blowers being used in the baseline case versus the actual system.

The transformer kW savings are calculated based on the core losses and load losses of the pre-case transformers compared to the post-case transformers. The kW savings are multiplied by 8,760 annual operating hours to calculate the kWh savings.

The ex ante savings for this project are presented below in Table 130.

Table 130. Ex Ante Savings

	Annual Energy Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)
Diffusers	998,910		0.0
DO Controls	1,172,093		0.0
Blowers	1,395,055		0.0
Process Change	343,894		0.0
Transformers	279,516		0.0
Total Project Savings	4,189,468	478.25	0.0

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed, trended data will be collected, the equipment will be inspected, and the site representative will be interviewed.

Blower specification information will be collected for both the pre and post-case blowers. The customer will be asked to provide make and model numbers for all pre and post-case blowers. All blowers located at the facility will be inspected and nameplate information will be collected. Additionally, the transformers will be inspected for make and model numbers and the site representative will be asked if any transformer specifications can be provided.

Additional questions for the customer include but are not limited to:

- Were the pre-case/existing blowers viable for usage with the expected additional loads?
- How old were the pre-case blowers at the time of replacement?
- Were the pre-case blowers in good operating condition?
- Are SCADA system trends for the past three years available for:
  - Blower kW,
  - Blower CFM,
  - MGPD of Influent water,
  - Influent BOD levels,
  - Effluent BOD levels?

- Is the customer who discharges ~45% of the facility's daily BOD intake planning on increasing their effluent load?
- Did the facility expect increased influent loads any time in the near future (annual basis)?
- When was project construction started?
- When did the project go online?
- What were the expected CFM reductions for?
  - Installing the new aeration diffusers.
  - Installing the new DO controls.
  - Implementing the additional process changes.

Description of Verification

A site visit was completed on February 13th 2018 and the project was inspected. The new transformers, new diffusers, dissolved oxygen controls, and new blowers were confirmed to have been installed and the process changes were confirmed to have been completed.

The pre-case transformers were visually confirmed to have been removed by inspecting the empty transformer pads and by inspecting the Google Maps satellite image of the area. The pre-case transformers were no longer onsite and could not be observed. The site representative was not able to provide specific details about the pre-case transformers, but was able to confirm the pre-case transformer sizes and that there were (2) 1,500 KVA transformers which were still live but not in use. Additionally, the site representative confirmed that the (3) other transformers were also 1,500 kVA. All of the pre-case transformers were originally installed in the 1970's. The post-case transformers were visually inspected and nameplate pictures were provided by the customer due to the nameplates being located inside the transformers. The post-case transformers were found to consist of (1) 2,000 KVA transformer and (2) 750 KVA transformers.

The facility was found to use (12) activated sludge tanks in the pre-case, each of which had submerged fine bubble air diffusers. Each of the (12) tanks acted as a separate activated sludge system in the pre-case. For post-case operation, the tanks were modified to serve as EBPR (enhanced biological phosphorus removal) systems which required the (12) individual tanks to be reconfigured as (4) sets of (3) tanks. While all the activated sludge tanks used air supply for aerobic digestion, the new process consists of anaerobic digestion in the first tank and an increased level of aerobic digestion in the second and third tank for each set. The pre-case diffusers were reconfigured and additional diffusers were added to be able to supplement the necessary increased CFM supply loads to the second and third tank in the series of each tank group. All the tanks have a full assembly of diffusers in case the process needs to be altered for unusual circumstances. This configuration change results in not only an adjustment to blower CFM demand, but also the removal of a series of mixer and process pumps and some supplemental blower capacity located at the tank location. In addition, a small number of additional small mixers were added.

It should be noted that the process change from activated sludge system process to the EBPR system process was not required to meet EPA requirements for BOD limits or other water quality requirements; however, it was desirable to the facility and the city because the waste water treatment plant could better handle BOD limits and additionally remove the high levels of phosphorus in their waste water. This process change is possible because the EBPR process uses a different biological bug that prefers both BOD and phosphorus as its food source compared to the activated sludge process biological bug which prefers just BOD for its food source.

In the pre-case, the blowers were manually turned on/off and the blower inlet vanes and plant valves were manually adjusted as needed. Since approximately 45% of the facilities BOD content comes from one customer, the facility would be in regular contact with that customer throughout the day and night so that they could supply enough air to handle the waste water loads, but also not excessively over supply air. The post-case dissolved oxygen controls use probes to measure the ammonia concentration in the waste water as well as the dissolved oxygen levels, which the system uses to calculate the necessary dissolved oxygen levels and the blower capacity needed to meet the demand. In the pre-case, oxygen levels were monitored manually and the blowers were adjusted at the very most on an hourly basis. While in the post-case, the blowers are automatically adjusted in real-time based on probe sensor readings resulting in only supplying the necessary amount of CFM to the system and reducing effluent BOD level volatility.

The pre-case blower system was confirmed via site representative interviews to consist of (3) Root blowers and (2) Hoffman blowers. The site representative provided pictures of the blowers showing that all (5) blowers were centrifugal blowers; however, the site representative was not able to provide blower nameplate information or make and model numbers. The new Turbo Blowers were inspected and were found to consist of (5) NX350-C070 7,050 SCFM 350 HP Blowers.

During the site visit, the site representative was interviewed concerning the influent waste water loads (gallons of water and BOD content). According to the site representative, their loads may have increased to some degree; however, the source of this increase would be due to one industrial customer. This customer discharges approximately 45% of the BOD content of the influent waste water, but is responsible for only a small fraction of the volume of waste water discharged to the facility. This customer has occasionally been exceeding their permitted discharge levels for several years and determined that it would be more advantageous to purchase a higher discharge limit. This does not mean that this customer’s average discharge would necessarily increase, but that they would no longer be fined for exceeding the pre-existing limit. The customer does have an incentive to increase production when possible which would result in an increase in their discharge water; however, this would be subject to if the customer has a buyer for their increased available product. Based on this customer’s known history as a participant in Ameren’s energy efficiency programs and based on this customer’s industry, it is reasonable to expect at least some degree of increased discharge, though this degree cannot be accurately forecasted without detailed information from this customer.

The site representative provided SCADA data for the facility which included the volume of influent, mass of BOD, and average CFM required on a daily basis from May 1st 2014 up until January 31st 2018. It should be noted that the site representative also provided monthly blower kWh usage for each blower for two time periods (5/1/2014 – 4/30/2015 & 9/1/2017 – 1/31/2018). SCADA data shows the facility influent BOD load to vary significantly on a daily basis with a maximum daily load during the last 5 years of 134,187 pounds of BOD and a minimum during the last 5 years of 13,723 pounds of BOD. It should also be noted that the water treatment process takes multiples of days for the influent water to work its way through the process and to the effluent point.

Calculation Description

The ex post savings for this project were determined using the SCADA data and the blower kWh data provided by the site representative in addition to utility electrical billed usage.

The baseline for this project is considered to be the existing system only with an increased system load. The average annual baseline load was calculated by increasing the pre-case billed data by a factor of 10.8% based on the estimated blower CFM increase and estimating that this increase would be consistent with the increased equipment loads throughout the facility. The ex ante supplied information estimates that 26,912

CFM of blower air would have been required on average to handle the increased BOD loads. No BOD loads were supplied in the ex ante information and the site representative was not able to provide details on the BOD design operating levels of the facility per blower CFM. Due to these reasons, it was estimated that the 26,912 CFM of blower air requirement for the hypothetical baseline operation is reasonable.

The customer was able to verify that no notable facility changes occurred during the pre-case time periods other than the implementation of this project and changes associated with it.

The post-case annual energy usage was determined based on actual billed data and the savings were calculated by subtracting the post-case annual energy from the baseline annual energy usage. It should be noted that the ex post post-period usage is based on the actual facility post-implementation period energy usage.

Summary of Ex Post Calculations

A summary of ex post waste water treatment plant project savings is shown in Table 131.

Table 131. Ex Post Savings

	kWh	kW
Baseline	18,332,092	2,092.7
Post-case	14,146,570	1,614.9
Savings	4,185,522	477.8

The ex ante and ex post savings for this project are summarized below in Table 132. Note that the realization rate was set to 100% due to the ex post analysis showing that the claimed savings are reasonable.

Table 132. Summary of Ex Post Savings

	kWh	kW	Therms
Ex Ante	4,189,468	478.2	0
Ex Post	4,189,468	478.2	0
Realization Rate	**100%**	**100%**	**N/A**

6.5 Project 1800059

Project ID#:	1800059
Ex Ante Measure:	DDC System
Facility Type:	Prison
End Use:	HVAC

Measure Description

This project involves the replacement of existing direct digital control (DDC) systems and installation of DDC systems in areas where they did not exist prior to this project. The replacement of the existing DDC systems include the administration building, housing units with one AHU each, and one large housing unit with (10) AHUs. The areas where DDC controls were added include an education building, food service building, visitation area, religious services, two chapels, health services, and the gymnasium.

The savings are attributed to typical measures such as scheduling start/stop with temperature override, variable speed control of AHUs, day/night unoccupied temperature setback, and outdoor air control. The project also includes automatic control of baseboard radiators in the housing units and main corridors. The project documentation provides information on specific measures that were applicable to each building. Based on a review of available documentation it appears that only measures associated with “ECM #03” were part of this project.

The total conditioned area affected by this measure was 296,680 square feet of a total of 645,500 square feet or 46%.

Summary of the Ex Ante Calculations

Custom calculations were based on an eQuest energy model completed by the project contractor. These numbers were then transferred into an Excel spreadsheet which is shown in Table 132. The energy and demand saving estimates were reduced slightly in the rebate application submitted by the customer.

Table 133. Summary of Savings

Area	Model	SF	Baseline			Retrofit			Model Savings		
			kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
Administration	eQUEST	22000	580,651	99	44,047	470,519	84	31,077	110,132	15	12,970
Chapel	Spreadsheet	1385	68,246	27	0	25,982	24	0	42,264	3	0
Corridors	eQUEST	19800	61,536	7	11,027	61,536	7	9,052	0	0	1,975
Dining Hall	Spreadsheet	8185	410,777	82	8,531	352,604	77	5,242	58,173	5	3,289
Education	eQUEST	8600	215,655	41	96,601	162,536	34	1,303	53,119	7	95,298
Gym	Spreadsheet	8115	41,229	7	1,501	35,228	7	847	6,001	0	654
Gym Offices	Spreadsheet	1138	25,224	9	0	12,318	9	0	12,906	0	0
Health and Service/R&D	Spreadsheet	20700	422,345	84	12,376	329,910	75	8,024	92,435	9	4,352
Kitchen	Spreadsheet	11355	324,444	45	4,092	305,547	45	2,646	18,897	0	1,446

Area	Model	SF	Baseline			Retrofit			Model Savings		
			kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
Religious Services	Spreadsheet	2475	51,664	16	808	38,785	15	173	12,879	1	635
Unit B	eQUEST	8600	132,905	19	17,710	92,209	16	12,841	40,696	3	4,869
Unit C	eQUEST	13300	115,813	16	16,388	72,314	13	10,600	43,499	3	5,788
Unit D	eQUEST	13300	115,813	16	16,388	72,314	13	10,600	43,499	3	5,788
Unit E	eQUEST	13300	115,813	16	16,388	72,314	13	10,600	43,499	3	5,788
Unit F	eQUEST	13300	115,813	16	16,388	72,314	13	10,600	43,499	3	5,788
Unit G	eQUEST	8600	132,905	19	17,710	92,209	16	12,841	40,696	3	4,869
Unit H	eQUEST	24100	197,728	25	19,401	153,552	22	12,836	44,176	3	6,565
Unit I	eQUEST	13300	115,813	16	16,388	72,314	13	10,600	43,499	3	5,788
Unit LNXY	eQUEST	82400	1,698,541	313	45,614	1,544,550	295	39,757	153,991	18	5,857
Visitation	Spreadsheet	2727	26,643	10	1,759	12,157	9	511	14,486	1	1,248
		296680	4,969,558	883	363,117	4,051,212	800	190,150	918,346	83	172,967
									18.48%		47.63%

These estimates were then reviewed for reasonableness by the implementer. The gas savings estimate was 47% of baseline usage. To be conservative, the gas savings were capped at 20% of the gas usage for the impacted area. The gas usage for the impacted area was estimated to be 46% of the total gas usage. Based on the documentation, it is not clear if the implementer or utility capped the savings.

This review noted in the transfer process for the Education building. This entry is highlighted yellow in Table 133. The base gas usage for the Education building was entered as 96,601 instead of 9,601 therms. Once that error is corrected, the predicted savings is 85,967 therms. Since the gas savings was capped at 60,200 therms, this error was accounted for.

The ex ante savings for this project are summarized below in Table 134.

Table 134. Ex Ante Savings

Measure	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
DDC System	81.98	913,286	60,200

Measurement & Verification Plan

IPMVP Option A, partially measured retrofit isolation, will be used to establish savings for this project. Additionally, IPMVP Option D, Whole Building Simulation, will also be used to validate and verify the measure level savings estimates.

A site visit will be performed during which the completed measures will be verified to have been implemented. The customer will be interviewed regarding the completion dates for each measure. Control setpoints both before and after the project was completed will also be obtained from the customer or the facilities building automation system (BAS). These will be confirmed against the measure level assumptions used in the building simulations.

The customer will be interviewed in detail regarding the previous operation of the facilities systems and controls. Finally, the customer's billed usage history will be obtained and a billed regression will be completed. While not definitive, this will provide further validation of the modeled energy and natural gas savings.

Description of Verification

A site visit was completed on January 31, 2018. Time on site was very limited due to the customer's limited availability and security protocols at the site. Therefore, as much information was collected during the visit as possible.

The site contacts provided access to the controls system so the existing controls could be reviewed. They explained that the project was only recently finished. The controls upgrade was completed over a 5-month period starting in September 2017. The last area converted to the new controls was only one week prior to the site visit on January 23, 2018.

The site contact confirmed that the controls upgrade was completed. They were still getting familiar with the controls and were not able to show some of the measures implemented. They were provided training on the controls system, but were not confident moving through the control screens and understanding the controls.

Overall there was a general sense of skepticism that the controls upgrade would achieve the desired savings. They shared that there was a concurrent lighting upgrade in the last year where outdoor lighting was upgraded to LED. They felt this was a very successful project by comparison. This initial reaction may be due to the project just coming on line and the site personnel needing more time to become familiar with the project.

Calculation Description

With the site review limited to only a half hour, only a selection of controls upgrades were reviewed. A summary of the actual projects review is shown in Table 135. The specific areas chosen were the larger areas or areas representing common areas. The two largest areas were the administration building and Unit LNXY, which was the education and library building. The other area, Unit G, was for inmate housing. This represented 41% of the overall area covered by this controls project.

Table 135. Summary of Evaluated Projects

Area	Baseline			Evaluated?	% of SF	Ex Post Savings			Realization Rate		
	kWh	kW	Therms			kWh	kW	Therms	kWh	kW	Therms
Administration	109,525	15	4,514	Yes	256%	109,525	15	4,514	100%	100%	100%
Chapel	42,031	3	0	No							
Corridors	0	0	687	No							
Dining Hall	57,852	5	1,145	No							
Education	52,826	7	33,168	No							
Gym	5,968	0	228	No							
Gym Offices	12,835	0	0	No							
Health and Service/R&D	91,926	9	1,515	No							
Kitchen	18,793	0	503	No							
Religious Services	12,808	1	221	No							

Area	Baseline			Evaluated?	% of SF	Ex Post Savings			Realization Rate		
	kWh	kW	Therms			kWh	kW	Therms	kWh	kW	Therms
Unit B	40,472	3	1,695	Yes	100%	40,472	3	1,695	100%	100%	100%
Unit C	43,259	3	2,014	No							
Unit D	43,259	3	2,014	No							
Unit E	43,259	3	2,014	No							
Unit F	43,259	3	2,014	No							
Unit G	40,472	3	1,695	Yes	100%	40,472	3	1,695	100%	100%	100%
Unit H	43,933	3	2,285	No							
Unit I	43,259	3	2,014	No							
Unit LNXY	153,143	18	2,038	Yes	958%	119,408	14	2,038	78%	78%	100%
Visitation	14,406	1	434	No							
Total	**913,286**	**81.98**	**60,200**		**1414%**	**309,877**	**35**	**9,942**	**90%**	**90%**	**100%**

The following provides a summary of the observations completed.

Administration:

- Night Setback: This setback was confirmed by site personnel. They have been in the building during unoccupied periods and temperature setbacks were in place.
- Cold Deck Reset: This control could not be verified during the site visit. A review of the project documentation showed this was part of ECM #03.
- Dual Enthalpy Economizer with 50°F low limit: During the site visit outside air temperature was 34°F and economizer was at 0%. This supports the 50°F low limit. It was assumed this was working.

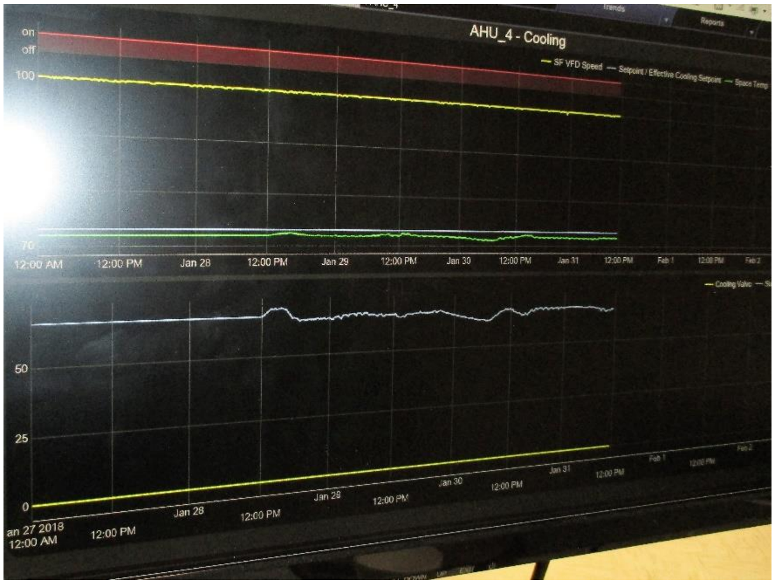
Units B and G:

- Variable Air Flow: A screenshot of the AHU for Building G was recorded. This showed the supply fan speed at 60% and return fan speed at 48%. The project documentation stated that speed would have a minimum flow of 50% during the heating season. This indicates the control system is working as intended.

Units LNXY:

- Fan Speed Control: A screenshot of fan speed for AHU-4 over a 4-day period showed that fan speed was constant at 100%. This indicates that fan speed was in manual control set at 100% speed. The site contacts explained that the occupants liked higher air flows so that reducing fan speed was difficult. An adjustment was made to the savings calculation to remove savings for fan speed control. The screenshot is provided in Figure 9.

Figure 9. AHU-4 Fan Speed Trend



- Dual Enthalpy Economizer Control of Mixed Air Dampers: A screenshot of AHU-4 economizer damper operation was trended over a 7-day period. This showed the damper modulating between 0% and 100% open. This indicated the economizer damper is working.

Figure 10. AHU-4 Economizer Damper Operation

- Cold Deck and Hot Deck Reset: This control could not be verified during the site visit due to limited time on site. A review of the project documentation showed this was part of ECM #03.
- Space Temperature Setpoints: A screen shot of space temperature setpoints for AHU-4 was recorded. This showed that setpoints were similar to the proposed case setpoints.

Summary of Ex Post Calculations

Table 135 provides the ex post savings estimates for all the areas evaluated. This provided a weighted average realization rate of 90% for kWh, 87% for kW, and 100% for therms. These realization rates were then applied to the ex ante savings for all spaces.

The main difference between the ex ante and ex post calculations was the measure for fan speed control in Units LNXY. A screenshot of fan speed for AHU-4 over a 4-day period showed that fan speed was constant at 100%. This indicates that fan speed was in manual control set at 100% speed. The site contacts explained that the occupants liked higher air flows so that reducing fan speed was difficult. A summary of ex post savings is shown in Table 136.

Table 136. Ex Post Savings

DDC System	Annual Energy Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)
Ex Ante	913,286	81.98	60,200
Ex Post	823,623	73.76	60,200
Realization Rate	**90%**	**90%**	**100%**

For more information, please contact:

Hannah Howard
Managing Director

510 444 5050 tel
510 444 5222 fax
hhoward@opiniondynamics.com

1 Kaiser Plaza
Suite 445
Oakland, CA 94612