Evaluation of the Black Hills Energy Arkansas (BHE) Program Year 2019 (PY2019) Demand Side Management (DSM) Portfolio

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Black Hills Energy Arkansas

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In final, we would like to thank staff at the Independent Evaluation Monitor for their involvement in providing thorough answers and clarification to the evaluation team when higher-level questions arose over the course of the PY2019 EM&V effort.

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1. Executive Summary

In June of 2016, BHE filed its 2017–2019 Energy Efficiency Plan[1] in response to Commission Order No. 25 in Docket No. 13-002-U.[2] The APSC approved the 2017–2019 programs, which build upon BHE's Quick Start Energy Efficiency programs that have been implemented since late 2007[3] and the Comprehensive programs that have been implemented in Arkansas since 2011[4]. This was filed in compliance with Order No. 31 of Docket No. 13-002-UF,[5] which required investor-owned natural gas utilities in Arkansas to capture energy savings equivalent to 0.50% of their 2015 energy sales.

This report presents the EM&V results for BHE's energy efficiency programs implemented in PY2019. In accordance with APSC C&EE Rules[6], BHE selected an independent, third-party EM&V contractor. The selected EM&V team is led by ADM Associates. The ADM staff, collectively referred to as the Evaluators, evaluated the BHE portfolio.

The PY2019 BHE evaluation included impact and process analyses that are specified in the APSC rules and follow the Arkansas TRM Version 8.0 protocols and savings algorithms. In addition, ADM developed the program evaluation activities based upon discussions with BHE staff and its implementation contractors, reviews of program tracking and program documentation, a review of prior years' EM&V efforts and BHE annual reports, and input from the IEM.

As in previous APSC rulings, the Arkansas utilities retain flexibility to make up to 10% adjustments to program budgets and may adjust energy savings and demand reduction goals as appropriate within the modified budgets. Thus, BHE's PY2019 budgets and energy savings goals, reflecting allowable adjustments as described above, serve as the basis against which its PY2019 portfolio of programs were evaluated.

BHE's Plan includes a portfolio of energy efficiency programs designed to facilitate energy savings in every customer class. BHE services approximately 169,000 customers in Arkansas. BHE's service area is primarily comprised of communities in Northwest Arkansas, including Fayetteville, Springdale, and Rogers, as well as North-central (Mountain Home) and Northeast (Manila, Osceola) communities.

[1] PY2017-PY2019 Plan, filed in Docket 07-078-TF: http://www.apscservices.info/pdf/07/07-078-TF_270_1.pdf

[2] Order #25 in Docket 13-002-U: http://www.apscservices.info/pdf/13/13-002-U_198_1.pdf

[3] Quick Start Plan, filed in Docket 07-078-TF: http://www.apscservices.info/pdf/07/07-078-tf_2_1.pdf

[4] Comprehensive Program Plan, filed in Docket 07-078-TF: http://www.apscservices.info/pdf/07/07-078-tf_70_1.pdf

[5] Order #31 in Docket 13-002-U: http://www.apscservices.info/pdf/13/13-002-U_226_1.pdf

[6] APSC C&EE Rules: http://www.apscservices.info/pdf/16/16-075-SD_5_1.pdf

1.1 Summary of BHE Energy Efficiency Programs

In PY2019, the BHE DSM portfolio contained the following programs:

- Equipment Rebates;
- Home Energy Savings Program; and
- C&I Solutions.

BHE designed its programs to achieve the following objectives:

- 2019 net savings of 1,180,976 Therms;
- Significant energy-saving opportunities for all customers and market segments;
- Broad ratepayer benefits; and
- Comprehensiveness in seven areas (i.e., comprehensiveness factors) defined by the APSC.[7]

The Evaluators evaluated the results for PY2019 for one residential program, one commercial and industrial (C&I) program, and one jointly residential and C&I program. The Equipment Rebates Program (ERP), the Commercial & Industrial Solutions Program (C&I Solutions) and the Home Energy Savings Program (HESP)[8] were all existing programs at the onset of PY2019.

Table 1-1: BHE PY2019 Energy Efficiency Portfolio Overview

Program	Channel	Sector
Equipment Rebates	Space Heating Equipment	Residential, Commercial, Industrial
	Water Heating Equipment	Residential, Commercial, Industrial
	Smart Thermostats	Residential
	Water Conservation Kits[9]	Residential
C&I Solutions	Custom	Commercial, Industrial
	Prescriptive	Commercial, Industrial
	Direct Install	Commercial, Industrial
Home Energy Savings Program	N/A	Residential

Through its energy efficiency portfolio, BHE also seeks to provide customers with easy program entry points, flexible options for saving energy, and ongoing support for those who want to pursue deeper energy savings. Refer to Table 1-2 for a list of the BHE programs and targeted customer segments.

[7] As defined by the APSC in the C&EE Rules of Order No. 17 in Docket 08-144-U

[8] A Consistent Weatherization Approach (CWA) program.

[9] No kits were administered in PY2019, but they were included in the program design as an option.

Table 1-2: BHE PY2019 Energy Efficiency Portfolio Sectors Served

Channel	Single Family	Multifamily	Small Business	Large C&I	Municipal	Agricultural
Equipment Rebates	✓	✓	✓	✓	✓	✓
C&I Solutions		✓	✓	✓	✓	✓
Home Energy Savings	✓	✓				

1.2 Evaluation Objectives

The goals of the PY2019 Evaluation, Measurement, & Verification (EM&V) effort are as follows:

- Develop sampling plans that allow for attaining 90% confidence and ±10% precision for each of the (3) programs in the BHE portfolio.
- For prescriptive measures, verify that savings are being calculated according to appropriate Technical Resource Manual (TRM) V8.0 guidelines.
- For custom measures, this effort comprises the calculation of savings according to accepted protocols (such as International Performance Measurement and Verification Protocol). This is to ensure that custom measures are cost-effective and provide reliable savings.
- Assign net-to-gross (NTG) values for each channel in the BHE portfolio. Most programs and channels had NTG values based on research completed in PY2017 and PY2018. In PY2019, the Evaluators conducted NTG research only for C&I custom projects.
- Conduct process evaluation of all BHE programs and of the portfolio overall. This is to provide a comprehensive review of program operations, marketing and outreach, quality control procedures, and program successes relative to goals. From this, the Evaluators are to provide program and portfolio-level recommendations for BHE. Process evaluation activities include interviews of key program actors, surveys of participants and non-participants, literature reviews and best-practices assessments, and documentation of program activities, successes, and shortcomings. Further, this includes a summary of utility and implementer response to recommendations made in the PY2018 process evaluations.

1.3 Summary of Findings

1.3.1 Impact Findings

Table 1-3 and 1-4 present the gross and net impact by program.

Table 1-3: Gross Impact Summary

Program	Annual Energy Savings (Therms)		Lifetime Energy Savings (Therms)		Gross Realization Rate
	Ex Ante	Ex Post	Ex Ante	Ex Post	
Equipment Rebates	188,568	210,743	2,477,489	2,768,834	111.8%
Commercial & Industrial Solutions	717,962	729,405	6,674,409	6,780,787	101.6%
Home Energy Savings	399,876	403,637	6,680,417	6,743,249	100.9%
Total	**1,306,406**	**1,343,785**	**15,832,315**	**16,292,870**	**102.9%**

Table 1-4: Net Impact Summary

Program	Annual Energy Savings (Therms)		Lifetime Energy Savings (Therms)		NTGR	Net Realization Rate
	Ex Ante	Ex Post	Ex Ante	Ex Post		
Equipment Rebates	153,665	170,929	2,009,706	2,235,493	81.1%	111.2%
Commercial & Industrial Solutions	710,194	719,575	6,516,473	6,602,550	98.7%	101.3%
Home Energy Savings	374,884	378,410	6,262,891	6,321,797	93.8%	100.9%
Total	**1,238,743**	**1,268,914**	**14,789,070**	**15,159,840**	**94.4%**	**102.4%**

Figure 1-2 and Figure 1-3 summarize the share of savings by measure category for residential and non-residential segments, respectively.

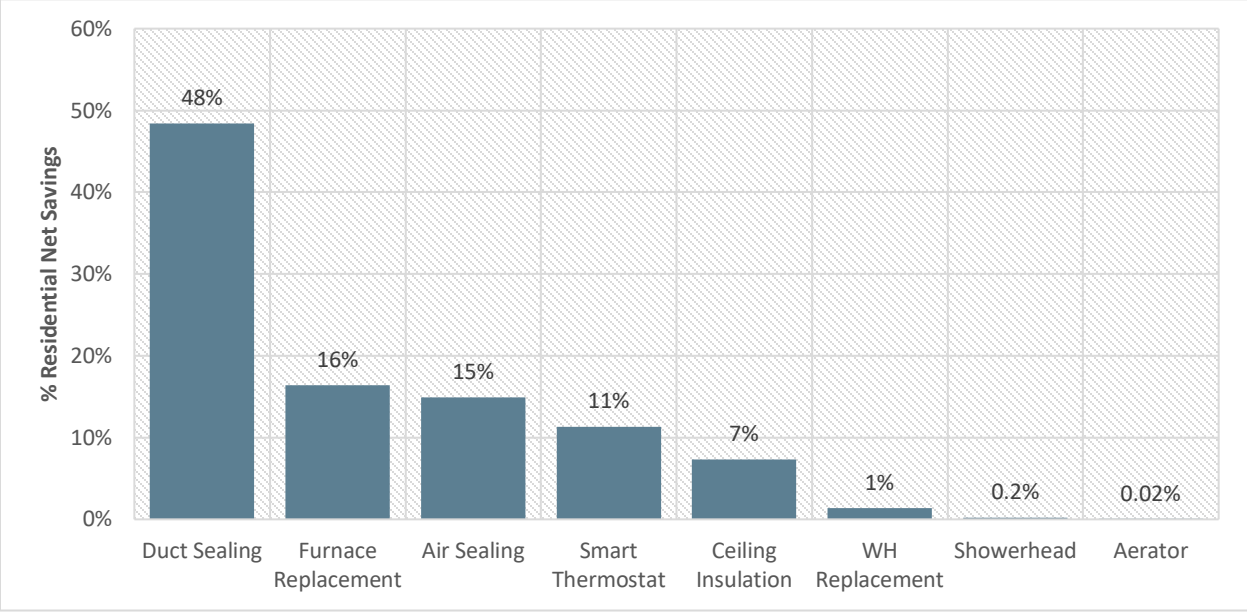


Figure 1-1: Savings Share by Measure – Residential

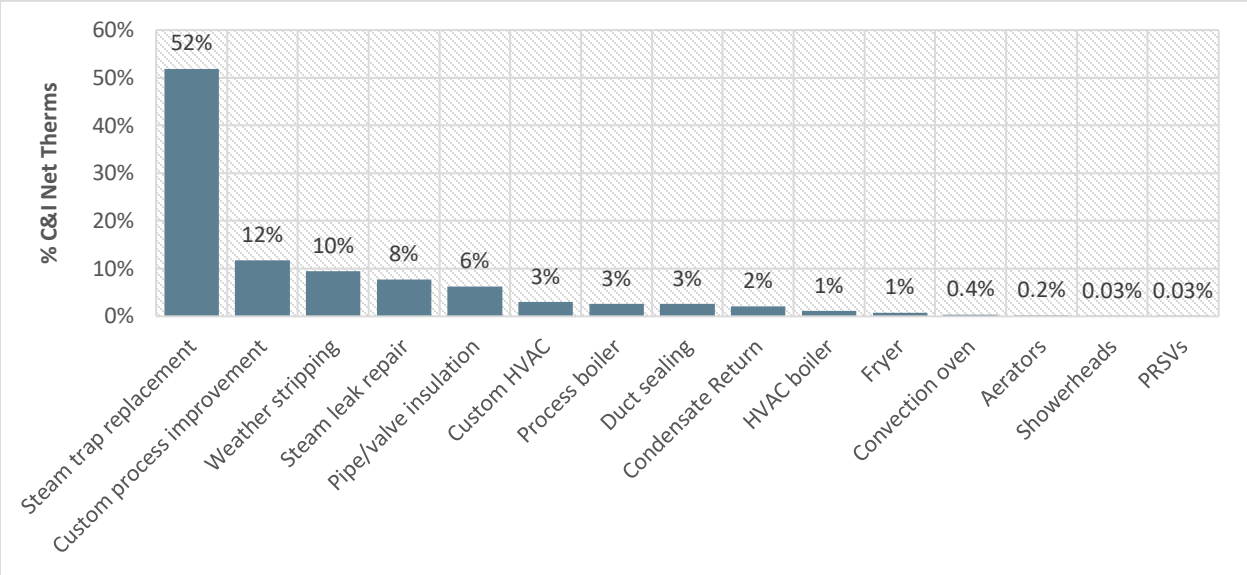


Figure 1-2: Savings Share by Measure – C&I

From this, the Evaluators have identified the following High Impact Measure (HIMs):

- Residential
  - Duct sealing
  - Furnace replacement
  - Air sealing
  - Smart thermostat
  - Ceiling insulation
- Non-residential
  - Steam trap replacement
  - Custom process improvement
  - Steam leak repair
  - Weather stripping
  - Pipe/valve insulation

Further, the Evaluators put the net savings into the context of BHE's PY2019 goal. Table 1-3 summarizes the performance against goals of programs evaluated in this report.

Table 1-5: BHE PY2019 DSM Portfolio Performance against Goals

Program	2019 Ex Post Net Therms	2019 Net Therms Goal	% Goal Reached
Equipment Rebates	170,929	87,946	194.4%
C&I Solutions	719,575	713,150	100.9%
Home Energy Savings	378,410	379,880	99.6%
Total	**1,268,914**	**1,180,976**	**107.4%**

The BHE portfolio overall met 107.4% of the filed savings goal, compared to 109.9% in PY2018. Percent of goal attained and budget spent by program is summarized in Figure 1-3. This was achieved while spending 95.6% of the program budget, compared to 90.7% in PY2018.

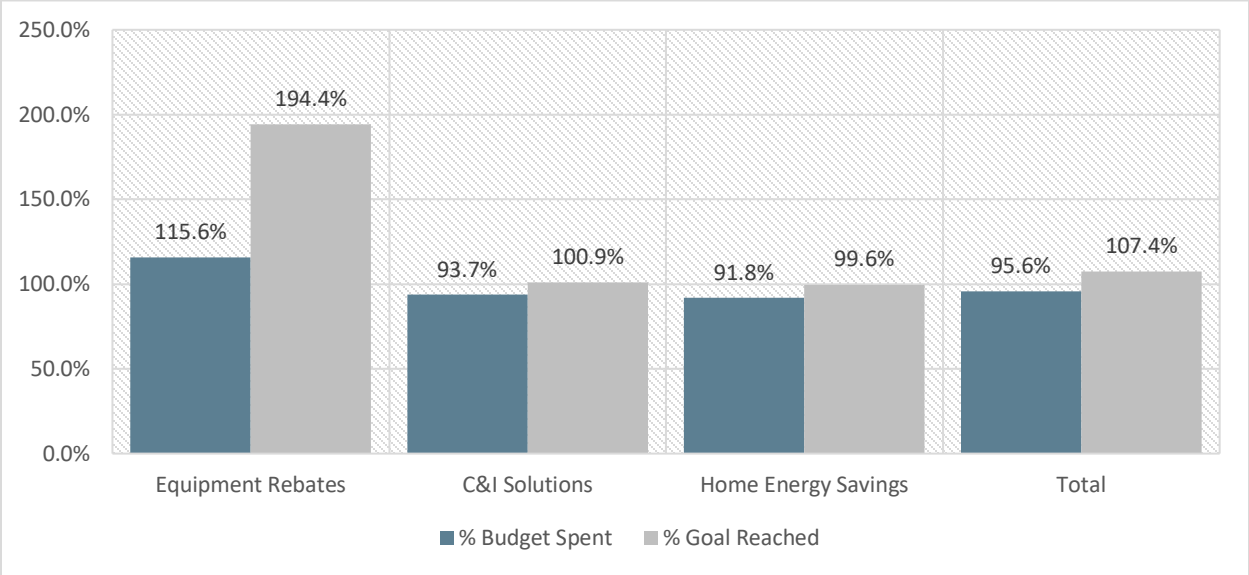


Figure 1-3: Summary of Goal Attainment & Budget Expenditure by Program

The non-energy benefits (NEBs) attained by the BHE portfolio in PY2019 are detailed in the tables to follow.

Table 1-6 BHE PY2019 Ex Post Electric Savings

Program	Measure	Net Annual kWh	Net Peak kW	Lifetime Net kWh
Equipment Rebates	Smart Thermostats	737,114	0	8,108,173
C&I Solutions	Weather Stripping	35,510	29.15	390,610
Home Energy Savings	Duct Sealing	604,143	282.37	10,874,565
	Air Sealing	74,875	44.57	823,623
	Ceiling Insulation	89,733	74.91	1,794,661
Total		1,541,375	431.00	21,991,632

Table 1-7 BHE PY2019 Ex Post Water Savings (Gallons)

Program	Measure	Net Annual Water	Net Lifetime Water
C&I Solutions[10]	Custom	3,110,691	31,110,619
	Direct Install	421,301	4,021,384
	Prescriptive	0	0
Home Energy Savings	Aerators	22,503	225,028
	Showerheads	307,356	3,073,556
Total		3,861,851	38,430,587

[10] Direct Install comprised showerheads, PRSVs, and faucet aerators. Custom comprised of steam leak repair and condensate return improvement. Prescriptive projects included combi ovens and steam cookers.

Table 1-8: BHE PY2019 Avoided/Deferred Replacement Cost

Program	Measure	Gross ARC/DRC per Unit	Total DRC
Equipment Rebates	Res Furnace Early Retirement	$989.83	$221,450.44
	Res Tankless WH	$271.61	$24,444.99
	C&I Tankless WH	$124.73	$1,995.68
		Total	$378,086.51

1.3.2 Key Findings

Following a review of present program offerings and interviews with utility and third-party implementation staff, the Evaluators found that:

1.3.2.1 Portfolio Findings

- The portfolio and all programs within it met the PY2019 savings goal.
- Non-energy benefits contribute significantly to the portfolio, accounting for 26.8% of net TRC benefits
- BHE and third-party implementation staff have been very responsive to recommendations; most recommendations have been adopted and several others remain under consideration.

1.3.2.2 Equipment Rebates

- Savings increased dramatically. After having increased by 39% in PY2018, they have increased again by 55% in PY2019. This is especially notable since no water conservation kits were provided in PY2019.
- Smart thermostats have increased as a share program savings. In PY2019, smart thermostat accounted for 35.3% of program net annual therms.
- Tracking data for smart thermostats is missing some potentially useful elements. Though program tracking contains all information needed to calculate savings per AR TRM 8.0 protocols, some additional tracking elements would be useful to help understand the market.

1.3.2.3 C&I Solutions

- Custom projects are accounting for an increasing share of savings. In PY2019, custom projects accounted for 85.2% of program savings.
- Program EUL has increased. Due to lower reliance on steam trap replacement, the program EUL has increased from 5.79 to 9.17 from PY2017 to PY2019.

1.3.2.4 *Home Energy Savings*

- High prevalence of Act 1102-eligible customers: The Evaluators found that 33% of survey respondents have a household member at least 65 years of age and that 21% of survey respondents had household income lower than 150% of the federal poverty line. In total, 43% of survey respondents were eligible for Act 1102 programs under at least one criterion (lower than the sum of the two criteria as some respondents are both age- and income-eligible.

1.3.2.5 *Response to Program Recommendations*

In PY2018, three program or portfolio level recommendations were provided to BHE as part of the EM&V of their portfolio. The Evaluators reviewed BHE's response to recommendations from the PY2018 EM&V report and categorized them as follows:

1) **Adopted.** This applied to recommendations that pertained to the correction of an issue (such as using an incorrect baseline methodology) or modifications in program outreach that do not require a filing (such as adding 'thank you' messaging to the Water Conservation Program).
2) **Under consideration.** This applies most typically to larger recommendations that would require APSC approval.
3) **Rejected.** This applies to recommendations which are reviewed by BHE and rejected. A recommendation by the Evaluators to consider a midstream approach for storage tank units was rejected, in lieu of adopting higher minimum qualifying standards for the program.
4) **Not applicable.** This would apply to recommendations which are no longer applicable to the BHE portfolio. An example of this included a recommendation pertaining to the residential furnace application form; the Evaluators recommended that BHE remove "Old Unit Age" as an application requirement, and BHE responded that an application rejection would not be triggered due to that missing field.
5) **Incomplete.** This applies to recommendations which were included in the PY2018 EM&V report but have either not yet been adopted or have been explicitly rejected by BHE.

The Evaluators found the disposition of the recommendations as follows:

- **Adopted:** 66.7%
- **Under consideration:** 33.3%

1.4 Report Organization

This report is organized with one chapter providing the full impact and process summary of a specified program. The report is organized as follows:

- Chapter 2 provides general methodologies;
- Chapter 3 provides a summary of portfolio-level issues;
- Chapter 4 provides results for the Equipment Rebates Program (ERP);
- Chapter 5 provides results for the C&I Solutions Program;
- Chapter 6 provides results for the Home Energy Savings Program;
- Chapter 7 provides a summary of TRM recommendations; and
- Appendix A provides the site-level custom reports for the C&I Solutions Program.
- Appendix B provides Deferred Replacement Cost Calculations

2. General Methodology

This section details general impact evaluation methodologies by program-type as well as data collection methods applied. This section will present full descriptions of:

- Gross Savings Estimation;
- Sampling Methodologies;
- Free-Ridership determination;
- Process Evaluation Methodologies; and
- Data Collection Procedures.

2.1 Glossary of Terminology

As a first step to detailing the evaluation methodologies, the Evaluators provide a glossary of terms to follow[11]:

- *Ex Ante* – Forecasted savings used for program and portfolio planning purposes (from the Latin for "beforehand")
- *Ex Post* – Savings estimates reported by an evaluator after the energy impact evaluation has been completed (From the Latin for "From something done afterward")
- *Deemed Savings* – An estimate of an energy savings or demand savings outcome (gross savings) for a single unit of an installed energy efficiency measure. This estimate (a) has been developed from data sources and analytical methods that are widely accepted for the measure and purpose and (b) is applicable to the situation being evaluated (e.g., assuming 17.36 Therms savings for a low-flow showerhead)
- *Gross Savings* – The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an efficiency program, regardless of why they participated
- *Gross Realization Rate* – Ratio of Ex Post Savings / Ex Ante Savings (e.g., if ADM verifies 15 Therms per showerhead, Gross Realization Rate = 15/17.36 = 86%)
- *Free-Rider* – A program participant who *would have* implemented the program measure or practice in the absence of the program. Free riders can be total, partial, or deferred
- *Spillover* – Reductions in energy consumption and/or demand caused by the presence of the energy efficiency program that exceed the program-related gross savings of the

[11] Arkansas TRM V8.0, Volume 1, Pg. 89-95

participants. There can be participant and/or non-participant spillover rates depending on the rate at which participants (and non-participants) adopt energy efficiency measures or take other types of efficiency actions on their own (i.e., without an incentive being offered).

- *Net Savings* – The total change in load that is attributable to an energy efficiency program. This change in load may include, implicitly or explicitly, the effects of free drivers, free riders, energy efficiency standards, changes in the level of energy service, and other causes of changes in energy consumption or demand (e.g., if Free-Ridership for low-flow showerheads = 50%, net savings = 15 Therms x 50% = 7.5 Therms).
- *Net-to-Gross-Ratio (NTGR)* = (1 – Free-Ridership % + Spillover %), also defined as Net Savings / Gross Savings
- *Ex Ante Net Savings* = Ex Ante Gross Savings x Ex Ante Free-Ridership Rate
- *Ex Post Net Savings* = Ex Post Gross Savings x Ex Post Free-Ridership Rate
- *Net Realization Rate* = Ex Post Net Savings / Ex Ante Net Savings
- *Effective Useful Life (EUL)* – An estimate of the median number of years that the efficiency measures installed under a program are still in place and operable
- *Gross Lifetime Therms* = Ex Post Gross Savings x EUL

2.2 Overview of Methodology

The proposed methodology for the evaluation of the PY2019 BHE DSM Portfolio is intended to provide:

- Net impact results at the 90% confidence and +/-10% precision level; and
- Program feedback and recommendations via process evaluation

In doing so, this evaluation will provide the verified net savings results, provide the recommendations for program improvement, and ensure cost-effective use of ratepayer funds. By leveraging experience and lessons learned from prior program year evaluations, the PY2019 evaluation is expanded and can provide greater guidance as to methods by which program and portfolio performance could be improved.

2.2.1 Sampling

Sampling is necessary to evaluate savings for the BHE DSM portfolio insomuch as verification of a census of program participants is typically cost-prohibitive. As per evaluation requirements set forth by the Independent Evaluation Monitor (IEM), samples are drawn in order to ensure 90% confidence at the +/- 10% precision level. Programs are evaluated on one of three bases:

- Census of all participants
- Simple Random Sample
- Stratified Random Sample

2.2.1.1 *Census of Participants*

A census of participant data was used for programs where such review is feasible. Programs that received analysis of a census of participants include:

- Commercial & Industrial Solutions – Custom Component

2.2.1.2 *Simple Random Sampling*

For programs with relatively homogenous measures (largely in the residential portfolio), ADM conducted a simple random sample of participants. The sample size for verification surveys is calculated to meet 90% confidence and 10% precision (90/10). The sample size to meet 90/10 requirements is calculated based on the coefficient of variation (CV) of savings for program participants. CV is defined as:

$$CV(x) = \frac{Standard\ Deviation\ (x)}{Mean(x)}$$

Where x is the average Therms savings per participant. Without data to use as a basis for a higher value, it is typical to apply a CV of 0.5 in residential program evaluations. The resulting sample size is estimated at:

$$n_0 = \left(\frac{1.645 * CV}{RP}\right)^2$$

Where,

1.645 = Z score for 90% confidence interval in a normal distribution

CV = Coefficient of Variation

RP = Required Precision, 10% in this evaluation

With 10% required precision (RP), this calls for a sample of 68 for programs with a sufficiently large population. However, in some instances, programs did not have sufficient participation to make a sample of this size cost-effective. In instances of low participation, ADM then applied a finite population correction factor, defined as:

$$n = \frac{n_0}{1 + {n_0}/{N}}$$

Where

n_0 = Sample Required for Large Population

N = Size of Population

n = Corrected Sample

For example, if a program were to have only 100 participants, the finite population correction would result in a final required sample size of 41. The Evaluators applied finite population correction factors in instances of low participation in determining samples required for surveying or onsite verification. Programs subject to Simple Random Sampling included residential channels of the Equipment Rebates Program.

2.2.1.3 Stratified Random Sampling

For the BHE Commercial & Industrial programs, Simple Random Sampling is not an effective sampling methodology as the CV values observed in business programs are typically very high because the distributions of savings are generally positively skewed. Often, a relatively small number of projects account for a high percentage of the estimated savings for the program.

To address this situation, we use a sample design for selecting projects for the Measurement & Verification (M&V) sample that takes such skewness into account. With this approach, we select a number of sites with large savings for the sample with certainty and take a random sample of the remaining sites. To further improve the precision, non-certainty sites are selected for the sample through systematic random sampling. That is, a random sample of sites remaining after the certainty sites have been selected is selected by ordering them according to the magnitude of their savings and using systematic random sampling. Sampling systematically from a list that is ordered according to the magnitude of savings ensures that any sample selected will have some units with high savings, some with moderate savings, and some with low savings. Samples cannot result that have concentrations of sites with atypically high savings or atypically low savings. Programs that were evaluated using stratified random sampling include:

- Equipment Rebates – Non-Residential;
- Non-Residential;
- Commercial & Industrial Solutions – Direct Install (DI) Component.

2.2.2 Free-Ridership

In determining ex post net savings for the BHE DSM portfolio, the Evaluators provide estimates of free ridership for individual programs. Free riders are program participants that would have implemented the same energy efficiency measures at nearly the same time absent the program. As per TRM 8.0 guidelines, free riders are defined as:

> "…program participants who received an incentive but would have installed the same efficiency measure on their own had the program not been offered. This includes partial free-riders, defined

> as customers who, at some point, would have installed the measure anyway, but the program persuaded them to install it *sooner* or customers who would have installed the measure anyway, but the program persuaded them to install more efficient equipment and/or more equipment. For the purposes of EM&V activities, participants who would have installed the equipment within one year will be considered full free-riders; whereas participants who would have installed the equipment later than one year will not be considered to be free-riders (thus no partial free-riders will be allowed)."[12]

Given this definition, participants are defined as free riders through a binary scoring mechanism, in being either 0% or 100% free riders. Models of free ridership utilized in these EM&V efforts were aimed at providing a probability of free ridership; this probability value was then rounded to a whole-number free ridership value.

2.2.2.1 Residential Free-Ridership

The general methodology for evaluating free ridership among residential participants involved examination of four factors:

(1) Demonstrated financial ability to purchase high-efficiency equipment absent the rebate

(2) Importance of the rebate in the decision-making process

(3) Prior planning to purchase high-efficiency equipment

(4) Demonstrated behavior in purchasing similar equipment absent a rebate

In this methodology, Part (1) is essentially a gateway value, in that if a participant does not have the financial ability to purchase energy efficient equipment absent a rebate, the other components of free ridership become moot. As such, if they could not have afforded the high-efficiency equipment absent the rebate, free ridership is scored at 0%. If they did have the financial capability, the Evaluators then examine the other three components. The respondent is determined to be a free rider based upon a preponderance of evidence of these three factors; that is, if the respondent's answers indicate free ridership in two or more of these three components, they are considered free riders. Specific questions and modifications to this general methodology are presented in the appropriate program chapters.

For residential programs, free ridership is calculated as the average score determined for the sample of participants surveyed. For programs that are contractor-driven, the free rider score of a survey respondent incorporates the relative importance of advice from their contractor, provided that the contractor is a program trade ally that received training from the appropriate

[12] Arkansas TRM V8.0, Pg. 450.

program. This value is then applied to the program-level savings to discount savings attributable to free ridership.

2.2.2.2 *Prescriptive Non-Residential Free-Ridership*

The general methodology for evaluating free ridership among prescriptive program participants involved examination of four factors:

(1) Demonstrated financial ability to purchase high-efficiency equipment absent the rebate

(2) Importance of the rebate in the decision-making process

(3) Prior planning to purchase high-efficiency equipment

(4) Importance of the contractor in influencing the decision-making process[13]

In this methodology, Part (1) is essentially a gateway value, in that if a participant does not have the financial ability to purchase energy efficient equipment absent a rebate, the other components of free ridership become moot. As such, if they could not have afforded the high-efficiency equipment absent the rebate, free ridership is scored at 0%. If they did have the financial capability, the Evaluators then examine the other three components. The respondent is determined to be a free rider based upon a preponderance of evidence of these three factors; that is, if the respondent's answers indicate free ridership in two or more of these three components, they are considered free riders. Specific questions and modifications to this general methodology are presented in the appropriate program chapters.

For non-residential programs, free ridership is calculated as the average score determined for the sample of participants surveyed. This value is then applied to the program-level savings to discount savings attributable to free ridership.

2.2.2.3 *Custom Free-Ridership*

For custom projects from the C&I Solutions Program, free ridership is assessed on a case-study basis, through which the Evaluators conduct an in-depth interview that includes a battery of questions addressing:

- The timing of learning of the program relative to the timing of the planning of the retrofit;
- The impact the program incentive has on measure payback relative to the stated payback requirements by the respondent;

[13] Contractor recommendations were considered to be program-inducement in instances where findings from vendor interviews showed that the program changed the mix of products sold by the vendor and that the vendor responsible for the customers' installation was a program trade ally.

- Whether the respondent learned of the energy efficiency measure from a program-funded audit; and
- Whether any influence the program had in modifying the project affected savings by greater than 50%.

In the C&I Solutions chapter, the free rider "case studies" are provided for every custom project.

2.2.3 Impact Evaluation Activities by Program

The Evaluators used established, industry-standard approaches to estimate energy savings and demand reductions at the measure, program, and portfolio levels. We followed all applicable measure- and program-level guidelines and protocols from the AR TRM V8.0.

To evaluate program impacts, the Evaluators adjusted program-reported gross savings using the results of our research, relying primarily on engineering desk reviews, TRM deemed savings calculation, and onsite verification and metering for applicable programs. To calculate deemed savings, we verified the appropriateness of savings algorithms and values in program tracking data as compared to guidelines in the TRM V8.0. Where sampling was used (for surveys and site visits), we designed a sampling plan to achieve a minimum precision of ±10% of the gross realized savings estimate with 90% confidence at the program-level.

Impact evaluation activities by program are summarized in Table 2-1.

Table 2-1: PY2019 Impact Evaluation Activities by Program

Program	Equipment Rebates	C&I Solutions	Home Energy Savings
Database & Document Review	✓	✓	✓
Engineering Desk Review		✓	
TRM Deemed Savings Review	✓	✓	✓
On-site Verification / Metering		✓	✓
Simulation Modeling		✓	
Billing Analysis		✓	

2.2.3.1 Net-to-Gross Approach by Program

For the PY2019 evaluation, the evaluation team conducted data collection and analysis to support Net-to-Gross (NTG) calculations. Table 2-2 shows the NTG approach the Evaluators followed for each program based on our assessment of specific program needs and the availability of accurate, existing information. These data collection and analysis activities are in compliance with one of the five accepted approaches listed in the TRM V8.0, Protocol F.

Table 2-2 PY2019 NTG Approaches by Program

Program	Assigned PY2018 Value	Literature Review	BHE-specific Survey	Multi-utility Survey
Equipment Rebates				
▪ Residential furnace retrofit	✓			
▪ Residential DHW retrofit	✓			
▪ Residential smart thermostats	✓			
▪ Housing authority furnace & DHW	✓			
▪ Residential water conservation kits	✓			
▪ New construction – builders	✓			
▪ New construction – homeowner / custom				
▪ Commercial furnace & DHW				
C&I Solutions				
▪ Direct install	✓			
▪ Custom			✓	
▪ Prescriptive boilers	✓			
▪ Prescriptive food service	✓			
Home Energy Savings	✓			

2.2.4 Process Evaluation

The Evaluator's general approach to process evaluation begins with a review of the tests for timing and appropriateness of process evaluation as defined in Protocol C of the TRM V8.0. In this review, the Evaluators determine what aspects of the program warrant a process evaluation (due to issues identified in the PY2018 evaluations). Most BHE programs over-performed, and as such most of the PY2019 process evaluation activity was focused around identifying BHE and implementer response to PY2018 recommendations.

The PY2019 process overviews began with interviews of program staff. These interviews, along with guidance from IEM protocols, inform the establishment of goals for the process evaluation, provide background history of programs, and give an introduction to portfolio-level issues. From this, the Evaluators then develop a list of data collection activities. The data collection procedures for process evaluations typically included:

- *Participant Surveying*. The Evaluators surveyed statistically significant samples of participants in each program in order to provide feedback for the program and provide an assessment of participant satisfaction.
- *In-Depth Interviews*. The Evaluators conducted in-depth interviews with high-level program actors, including BHE program staff, third-party implementation staff, and program trade allies. These interviews are semi-structured, in having general topics to be covered, without fully prescribed question and answer frameworks.

3. Portfolio-Level Summary

This chapter provides a summary of the portfolio-level findings and any cross-cutting evaluation activities that occurred over the course of the PY2019 EM&V effort. Specifically, this chapter includes:

- A summary of program and portfolio performance in PY2019;
- A summary of EM&V activities and expenditures in PY2019;
- High-level findings that cut across programs.

3.1 Summary of EM&V Effort

All programs in the BHE DSM Portfolio received a formal process evaluation in PY2018. Table 3-1 summarizes the data collection efforts for the PY2018 EM&V effort. "Interviews" should be distinguished from "Surveys" in that "Interviews" reflect semi-structured, in-depth discussions with high-level program actors (such as utility staff and third-party implementation staff) whereas surveys are fully-structured and typically conducted with program participants.

Table 3-1: Summary of Data Collection Efforts

Program	# Site Visits	# Surveys	# Interviews
Equipment Rebates	0	0	2
C&I Solutions	7	17	2
Home Energy Savings	37	86	2
Total	44	103	6

3.2 Tests of Portfolio Comprehensiveness

The Arkansas Public Service Commission (APSC) has in place a set of criteria in order to determine whether a DSM portfolio qualifies as "Comprehensive". These criteria are:

- ***Factor 1:*** *Whether the programs and/or portfolio provide, either directly or through identification and coordination, the education,* ***training****, marketing, or outreach needed to address market barriers to the adoption of cost-effective energy efficiency measures;*
- ***Factor 2:*** *Whether the programs and/or portfolio, have adequate* ***budgetary****, management, and program delivery resources to plan, design, implement, oversee and evaluate energy efficiency programs;*
- ***Factor 3:*** *Whether the programs and/or portfolio, reasonably address all major* ***end-uses*** *of electricity or natural gas, or electricity and natural gas, as appropriate;*

- ***Factor 4:*** *Whether the programs and/or portfolio, to the maximum extent reasonable, comprehensively address the needs of customers at one time, in order to avoid* ***cream-skimming*** *and lost opportunities;*
- ***Factor 5:*** *Whether such programs take advantage of opportunities to address the comprehensive needs of* ***targeted customer sectors*** *(for example, schools, large retail stores, agricultural users, or restaurants) or to leverage non-utility program resources (for example, state or federal tax incentive, rebate, or lending programs);*
- ***Factor 6:*** *Whether the programs and/or portfolio enables the delivery of all achievable,* ***cost-effective*** *energy efficiency within a reasonable period of time and maximizes net benefits to customers and to the utility system;*
- ***Factor 7:*** *Whether the programs and/or portfolio, have evaluation, measurement, and verification "EM&V") procedures* ***adequate*** *to support program management and improvement, calculation of energy, demand and revenue impacts, and resource planning decisions.*

The Evaluators reviewed the BHE programs and portfolio in order to assess whether it complied with the APSC Comprehensiveness Goals. In assessing these metrics, the Evaluators score them on numerous subcomponents. The scoring methodology is as follows:

●: Meets all requirements and is in full compliance with this performance indicator

◒: Meets some requirements and is in partial compliance with this performance indicator

○: Is not in compliance with this performance indicator.

NA: Performance indicator is not applicable to this program.

3.2.1 Factor 1: Education, Training, Marketing, and Outreach

3.2.1.1 Assessment of Education

The Evaluators assessed the educational components of the BHE programs, in order to identify whether the programs were providing potential participants with the needed information to guide their decision-making, and whether the channels used to reach the target markets are appropriate. The Evaluators found that:

- BHE's programs used a range of channels to provide educational materials to their programs' target markets. The educational materials included brochures, case studies, and presentations to trade & industry groups.
- BHE program staff conducts outreach and education through a wide range of potential program partners, including contractors, retailers, home builders, and local governments.

The breadth of educational materials by program is summarized in Table 3-2.

Table 3-2: Assessment of Customer Education by Program

Program	*Provides Educational Materials*	*Outreach Through Multiple Channels*	*Education Targeted to Specific Market Barriers*	*Coordination of Education by Multiple Entities*
Equipment Rebates	●	●	●	●
C&I Solutions	●	●	●	●
Home Energy Savings Program	●	●	●	●

3.2.1.2 *Assessment of Training*

The Evaluators reviewed each BHE program to assess whether:

1) The program is trade ally-driven;
2) If not, could or should the program be trade ally-driven;
3) The program provides training classes to support their program offerings; and
4) The program needs trade ally certification.

A summary of the Evaluators' assessment of training for each BHE program is presented in Table 3-3.

Table 3-3: Assessment of Trade Ally Training by Program

Program	*Trade Ally Training Offered*	*Training Requirements Adhere to Best Practices*	*Trade Allies Participate in Training*
Equipment Rebates	●	●	●
C&I Solutions	●	●	●
Home Energy Savings Program	●	●	●

BHE does not require trade ally registration to participate for most programs. Their approach has been to allow all licensed dealers or contractors to apply for the appropriate equipment rebates. Trade ally training and registration is required for Home Energy Savings, however. Staff at BHE and CLEAResult came to this conclusion given the extent of service provided by the program, thus requiring trade ally training and registration as warranted.

3.2.1.3 *Marketing & Outreach*

The Evaluators reviewed the marketing and outreach strategies associated with each of the BHE programs. These strategies were reviewed to assess whether they adequately addressed the relevant participant barriers, the extent to which trade allies were actively marketing the program (where appropriate), and whether the materials were correctly targeted in marketing a comprehensive approach to energy efficiency.

A summary of the Evaluators' assessment of BHE marketing and outreach is presented in Table 3-4.

Table 3-4: Assessment of Marketing & Outreach by Program

Program	*Marketing Addresses Specific Barriers*	*Trade Allies Promote Program*	*Marketing Support Provided to Trade Allies*	*Marketing Performed Through Diverse Channels*
Equipment Rebates	●	●	●	●
C&I Solutions	●	●	●	●
Home Energy Savings Program	●	●	●	●

After reviewing the marketing and outreach materials, the Evaluators concluded that:

- Most programs have marketing materials that address specific barriers associated with the targeted segments or technologies.
- C&I Solutions has observed much higher participation from program trade allies and completed multiple projects originated by trade ally referral. More than half of custom project savings in PY2019 came from projects originated by program trade allies.
- The BHE programs are marketed through a diverse range of channels, including mass-media advertising, online advertising, meetings and training sessions with professional organizations and trade groups, and partnered marketing with municipal governments.
- The BHE programs for the non-residential sector all apply past participant case studies in their marketing.

3.2.2 Factor 2: Budgetary, Management, and Program Delivery Resources

Several performance indicators were assessed in reviewing the adequacy of budgetary, management, and program delivery resources presented in Table 3-6. This included:

- Self-reports from program management staff
- Cost per Therm saved
- Review of trade ally resources dedicated to program promotion

Table 3-5: Assessment of Budgetary, Management, and Program Delivery Resources by Program

Program	Budget is Sufficient to Support Program Goals	Cost per-Therm Aligns with Program Plan	Program Has Sufficient Staffing	Program Has Sufficient Trade Ally Support
Equipment Rebates	●	●	●	●
C&I Solutions	●	●	●	●
Home Energy Savings Program	●	●	●	●

From this review, the Evaluators concluded that the BHE portfolio overall has the adequate budget and staff allocations. Aggregated across all programs, actual cost per therm is significantly lower than planned. As demonstrated in Figure 3-1, in PY2019 the BHE portfolio had an acquisition cost of $2.69 per net therm, a slight increase from $2.54 per net therm in PY2018 but significantly lower than the program plan value of $3.03. At the individual program level, Equipment Rebates significantly outperformed relative to its planned acquisition cost, with acquisition costs at 59% of the program plan value. This is a notable achievement in that this was reached without the use of water conservation kits; in prior program years, kits had been a key driver of lower acquisition costs.

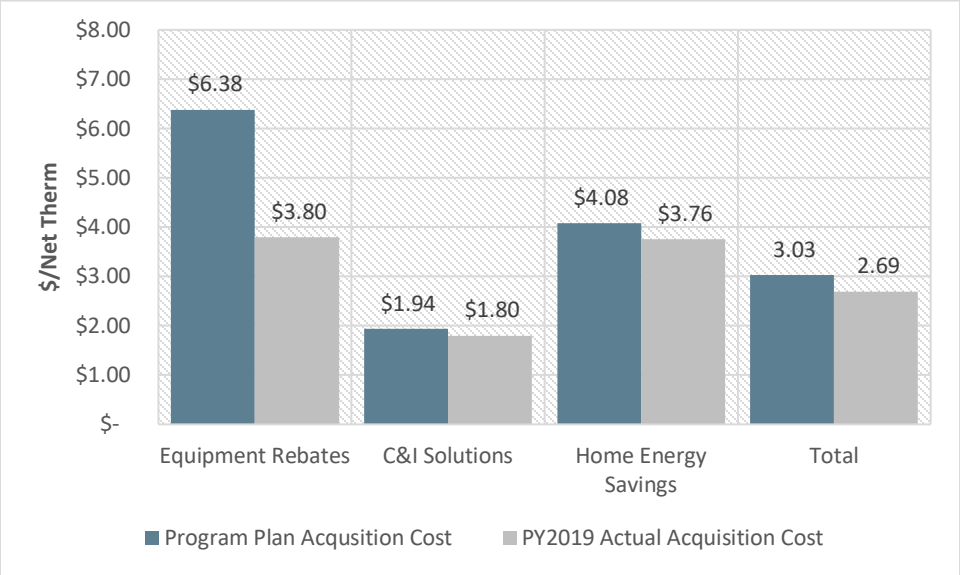


Figure 3-1: Comparison of Program Plan vs. Actual Acquisition Costs

Overall, the BHE portfolio had acquisition costs that were 11.3% lower than PY2019 plan values.

3.2.3 Factor 3: Addressing Major End-Uses

The Evaluators identified the end-uses served by each of the BHE programs. Most BHE programs are designed around a specific technology or end-use. Table 3-7 summarizes the end-uses addressed by each program.

Table 3-6: End-Uses Addressed by Program

Program	*HVAC*	*Hot Water*	*Appliances*	*Food Service*	*Building Envelope*	*Industrial Process*	*Behavioral*
Equipment Rebates	●	●	○	○	○	○	○
C&I Solutions	●	●	○	●	●	●	○
Home Energy Savings Program	●	●	○	○	●	○	○

● Measure targeted ◒ Measure offered ○ Measure not offered

Presently, the BHE portfolio covers most end-uses. The Evaluators found that sectors where the program offerings were not providing sufficient outreach and market transformation included:

- **Behavioral savings.** BHE cancelled their Home Energy Reports program to allow for the development of the Home Energy Savings weatherization program. This has had the tradeoff of filling residential building envelope but leaving a gap in behavioral savings. Given the program budget allotment, the Evaluators concluded that BHE was correct in prioritizing weatherization over behavioral savings.
- **Residential appliances.** The TRM V8.0 includes deemed savings for residential appliances, including dishwashers and clothes washers. These are not presently offered in any BHE programs. However, given the low unit energy savings of these measures, any offering for this end-use would need to be an upstream, multi-utility effort to be cost-effective.

Table 3-7 summarizes the percent of projects that are single- versus multiple-measure installations by program. The Evaluators define "multiple measures" as follows:

- **Equipment Rebates:** Completing more than one of the following four categories:
  - Furnace
  - Water Heater
  - Smart Thermostat
  - Water Conservation Kit
- **C&I Solutions:** Completing more than one of the following measures:
  - Custom
  - Prescriptive Boiler
  - Prescriptive Food Service
  - DrySmart Controls
  - Water Pump Controls
  - Direct Install Aerators
  - Direct Install Showerheads

- Direct Install PRSVs
- Direct Install Weather Stripping

Or having completed more than one custom measure, either as part of one application or multiple applications.

- **Home Energy Savings:** Completing more than of the energy-saving improvements as part of weatherization, excluding the Assessment incentive:
  - Duct Sealing
  - Air Sealing
  - Ceiling Insulation
  - Faucet Aerators
  - Showerheads

Table 3-7: Installation of Multiple Measures

Program	% Single-Measure	% Multi-Measure
Equipment Rebates	95.7%	4.3%
C&I Solutions	70.0%	30.0%
Home Energy Savings	11.1%	88.9%

3.2.4 Factor 4: Comprehensively Addressing Customer Needs

To assess Factor 4, the Evaluators reviewed BHE programs to discern the extent of:

- Program-provided technical assistance;
- Incentives of comprehensive projects/measure suites; and
- Tiered incentives for higher efficiency levels.

The BHE portfolio has no specific requirements for installation of multiple measures. Customers are able to participate to an extent of their choice. This is a program best-practice in enabling customers to engage in energy efficiency in a manner in accordance with their budget constraints. In addition, there is a bonus incentive offered for simultaneous installation of a 95% AFUE furnace and tankless water heater[14].

Table 3-8 summarizes the comprehensiveness of offerings for each program.

[14] Examples include Entergy Arkansas Inc.'s Commercial & Industrial Solutions Program, which escalates incentives based on multiple measure installations.

Table 3-8: Assessment of Project Comprehensiveness by Program

Program	*Technical Assistance and/or Audits*	*Information Provided for Comprehensive Efficiency*	*Bundled Incentives for Multiple Measures*	*Tiered Incentives for Premium Efficiency*	*Trade Ally Incentives for Premium Efficiency*
Equipment Rebates	●	●	●	N/A	●
C&I Solutions	●	●	●	●	○
Home Energy Savings Program	●	●	NA	●	●

Findings from the assessment of this factor included:

- Most BHE prescriptive programs offer incentives to trade allies for installation of top-tier efficiency measures. This has included incentives for condensing furnaces, and tankless water heaters.
- The BHE portfolio formerly offered tiered incentives for premium efficiency across all of their rebate programs. In some cases, this tiering has been removed in lieu of only including premium efficiency. Examples include:
  - The incentives for furnaces in the Equipment Rebates Program used to increase from $450 for units with 90-04.99 AFUE to $650 for units with 95 AFUE or greater. The program now only offers incentives for 95 or greater AFUE ($500 per unit). This decision was made due to low participation in this group; most program participants historically elected for the 95% AFUE model. The overall incentive was reduced in order to allow for greater total participation.
  - BHE has removed incentives for storage tank water heaters, opting to incentivize tankless units exclusively.
- Other retained tiered incentives include:
  - High efficiency boiler incentives are $1,400/MMBtuh for units < 94% efficient and $2,000/MMBtuh for units with 94% efficiency or greater.
  - The C&I Solutions program pays an incentive per verified therm, and as a result projects with higher savings are by design paid a higher incentive.
- The BHE portfolio has programs that bundle on-site technical assistance with direct installation.
- The range of technical assistance varies by program. The Equipment Rebates Program offers technical assistance through trade allies. C&I Solutions provides on-site technical assistance that is directly funded by the program.
- The programs have procedures for following up with customers after their participation (including thank-you calls or emails) and verification inspection.

- Marketing materials typically make attempts at cross-promotion of programs.

3.2.5 Factor 5: Targeting Market Sectors & Leveraging Opportunities

The Evaluators reviewed whether the BHE portfolio offered a comprehensive range of energy efficiency opportunities to all major customer sectors. Table 3-9 summarizes the market sectors and what programs target or allow each sector.

Table 3-9: Assessment of Targeted Customer Sectors by Program

Program	**Residential**	**Multifamily**	**Mobile Home**	**Small Commercial**	**Large Commercial**	**Industrial**	**Agricultural**	**Public Sector**
Equipment Rebates	●	◒	◒	●	◒	◒	◒	●
C&I Solutions	○	◒	○	●	●	●	●	●
Home Energy Savings Program	●	●	◒	○	○	○	○	●

● Program targets this sector
◒ Sector is eligible for this program
○ Sector is ineligible for this program

Each sector has several programs for which they are eligible, and at least one program that targets them. Segment-specific findings include:

- Agriculture and Industrial sectors are not specifically targeted by the Equipment Rebates Program as the equipment used by these facilities generally requires custom calculations.
- Public Sector facilities are targeted with a wide range of programs. This has included residential programs that reach out to public housing authorities.
- Home Energy Savings is a residential program and did not target any of the commercial sectors.

In addition, the Evaluators reviewed the extent of collaboration and leveraging of available partnership opportunities by BHE.

Examples of cross-utility coordination included:

- BHE has brought on a third-party implementer (CLEAResult) for their C&I Solutions Program. This implementer uses the same program design and similar incentive levels for CenterPoint and AOG. This has allowed for reduced program costs for C&I Solutions, which is the largest program in each of the three gas utility portfolios. Further, dual-fuel projects are coordinated with SWEPCO and EAI.
- In late PY2013, BHE established the Home Energy Savings Program. This weatherization program used a program model applied elsewhere in Arkansas by Entergy. Beginning in

PY2016, the program corresponded to the Consistent Weatherization Approach as designed by the Arkansas Parties Working Collaboratively (PWC). BHE has program partnering agreements with multiple electric utilities to leverage the effectiveness of program funds. In addition to multiple investor-owned utilities, BHE is developing partnerships with municipal utilities and rural cooperatives that have an interest in providing weatherization services to their residential customers.

Examples of coordination with non-utility partners included:

- BHE's programs are marketed through industry partners who include professional organizations, trade groups, universities, and homeowners' associations.
- BHE works with a local technical college to help provide training opportunities to trade allies and students interested in careers related to energy efficiency.

3.2.6 Factor 6: Cost-Effectiveness of Energy Efficiency

To assess this factor, the Evaluators reviewed whether:

- Programs met net savings goals;
- The NTG ratios were in line with industry norms; and
- Programs passed cost-effectiveness (TRC) testing.

A summary of Factor 6 findings is provided in Table 3-10.

Table 3-10: Assessment of Cost-Effectiveness

Program	*NTGR*	*NTGR Within Industry Norms*	*Met Net Savings Goal*	*Program TRC*
Equipment Rebates	81.1%	Yes	Yes	1.99
C&I Solutions	98.7%	Yes	Yes	3.28
Home Energy Savings Program	93.8%	Yes	Yes	4.31

All programs passed TRC in PY2019.

3.2.7 Factor 7: Adequacy of EM&V Procedures

The Evaluators conducted a review of EM&V procedures by program as implemented by several parties:

- QA/QC and EM&V procedures by BHE program staff;
- QA/QC and EM&V procedures by third-party implementation staff (where applicable)
- QA/QC and EM&V procedures by the Evaluators.

The EM&V of the BHE programs incorporated industry best practices and was conducted in an iterative process that incorporated feedback from BHE and implementation contractors as well as the Independent Evaluation Monitor (IEM).

Further, the Evaluators found that BHE has QA/QC procedures that align with industry best-practices, including randomized post-inspection to their programs and targeting of new trade allies for early feedback.

Finally, the Evaluators reviewed the quality of program tracking data in order to assess whether the data allowed for complete evaluation. Further, the Evaluators reviewed the extent to which individual savings calculations were performed using facility-specific inputs into the TRM V8.0 algorithms versus the use of simplifying assumptions[15]. The results of the review are summarized in Table 3-11.

Table 3-11: Assessment of Data & QA/QC Procedures by Program

Program	*Tracking Contains Necessary Fields*	*Savings Calculations Performed and Reported*	*Savings Calculations Based on Facility Data*	*QA/QC Inspections by Program Staff*
Equipment Rebates	●	●	●	●
C&I Solutions	●	●	●	●
Home Energy Savings Program	●	●	●	●

Findings of this review included:

- Home Energy Savings has a very robust QA/QC process which is well-defined in the program manual and executed by CLEAResult staff.
- Commercial water heater calculations were improved significantly in response to evaluation recommendations and were more transparent than in prior years.
- QA/QC inspections are in place for all programs.

3.2.8 Cost-Effectiveness Findings

3.2.8.1 Cost-Effectiveness Results

Table 3-12 summarizes the cost-effectiveness results by program.

[15] Examples of this could include assuming average facility square footage for commercial water heating and using that as an input to the savings calculation, as opposed to collecting facility-specific square footage.

Table 3-12: Cost-Effectiveness Summary

Program	TRC	UCT	RIM	PCT	TRC Net Benefits
Equipment Rebates	1.99	2.06	.52	3.37	$1,025,651
C&I Solutions	3.28	3.12	.73	8.56	$3,013,455
Home Energy Savings	4.31	2.53	.52	N/A [16]	$4,552,602
EEA	.00	.00	.00	N/A	($20,821)
Regulatory	.00	.00	.00	.00	(639)
Total	3.28	2.65	.59	6.65	$8,570,248

3.2.8.2 NEBs Summary

NEBs claimed by-program are as follows:

- **Equipment Rebates:** avoided replacement costs, deferred replacement costs, kWh, kW, and water;
- **C&I Solutions:** kWh, kW, and water; and
- **Home Energy Savings:** avoided replacement costs, kWh, kW, and water.

Table 3-13: Residential NEBs

Measure	Water	kWh / kW	ARC / DRC	AR TRM V8.0 Section
Furnace (early retirement only)			✓	2.1.3
Duct sealing		✓		2.1.11
Smart thermostats		✓		2.1.12
Ceiling insulation		✓		2.2.2
Air infiltration		✓		2.2.9
Tankless water heater			✓	2.3.1
Faucet aerators	✓	✓		2.3.4
Low-flow showerheads [17]	✓	✓		2.3.5
LEDs		✓	✓	2.5.1

[16] Program is provided free-of-charge, PCT is not calculable.

[17] When BHE administers mailer kits, there are claimable kWh / kW due to customers with electric water heating receiving kits. This does not occur in the Home Energy Savings Program; homes with electric water heating either have savings claimed by the IOU, or do not have low flow devices installed. No kits were administered in PY2019.

Table 3-14: Commercial NEBs

Measure	Water	kWh / kW	ARC / DRC	AR TRM V8.0 Section
Weather stripping		✓		3.2.11
Tankless water heater			✓	3.3.1
Faucet aerators	✓			3.3.2
Low-flow showerheads	✓			3.3.5
Pre-rinse spray valves	✓			3.8.11
Steam leak repair	✓			N/A - Custom
Condensate return	✓			N/A - Custom

NEBs were a significant contributor to program benefits in PY2019, accounting for 26.8% of total TRC benefits across the portfolio. Figure 3-3 summarizes the percent of total TRC benefits derived from NEBs. Equipment Rebates has a higher score than initially anticipated on this metric due to feedback from the IEM that Deferred Replacement Cost for early retirement of residential furnaces and Avoided Replacement Cost from tankless water heaters be treated as benefit-adders rather than cost-reducers. If these factors were instead treated as a cost-reducer, NEBs would account for 22.9% of TRC benefits for Equipment Rebates. The percent of net benefits from NEBs in Equipment Rebates declined from 48.1% to 35.1% from PY2018 to PY2019. The Evaluators attribute this to the increased share of total program savings from smart thermostats; though they produce kWh savings as a claimable NEB, this is lower in magnitude relative to their therms savings than ARC and DRC values are for water heaters and furnaces, respectively.

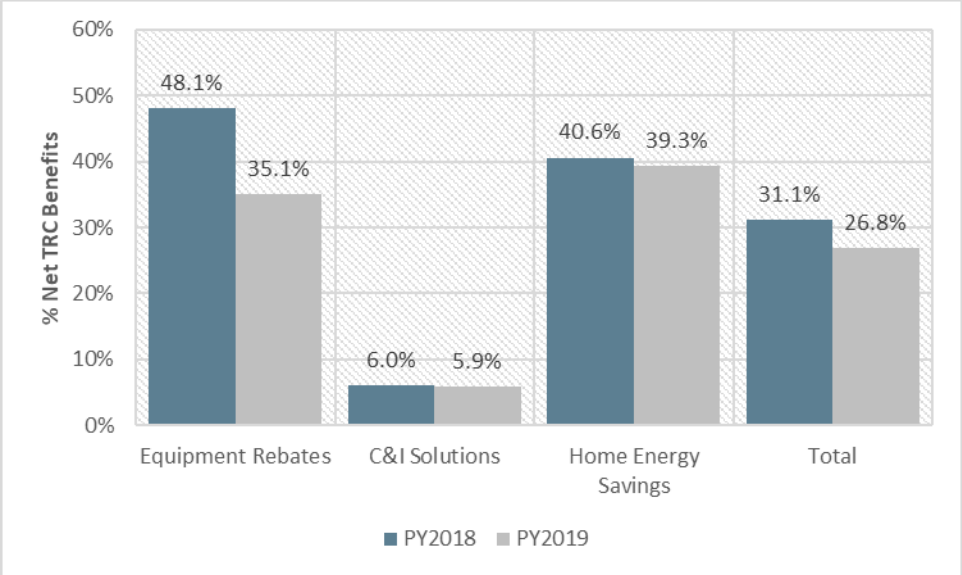


Figure 3-2: Percent of Total TRC Benefits Derived from NEBs

4. Equipment Rebates

The Equipment Rebates Program provides incentives to residential and business customers for high-efficiency space heating and water heating equipment. This program is an aggregated program combining the former Heating Equipment Rebates and Water Heating & Conservation Programs. Eligible measures for this program include:

- $500 for furnaces with 95% or higher AFUE;
- $300 for tankless water heaters with an EF of 0.90 or greater; and
- $100 for a smart thermostat.

Additionally, the program may provide self-install mailer kits with low flow devices. Further, a $50 trade ally incentive is provided for all qualifying furnace and water heating equipment. The Equipment Rebates Program is targeted at Residential and Small Commercial market sectors. Retrofit and New Construction applications are both allowed, utilizing the same baseline AFUE. The marketing efforts for the Equipment Rebates Program were largely directed at HVAC contractors; their involvement is seen as crucial, as they are generally a primary source of information for end-use customers when deciding upon a replacement system.

4.1 Program Overview

The Heating Equipment Rebates and Water Heating & Conservation programs began in 2010. The combined Equipment Rebates Program is designed to incentivize the purchase of high efficiency space heating and water heating equipment. Presently, the program incentivizes high efficiency furnaces and high efficiency water heaters. The program was internally implemented by BHE until September 2012, at which point CLEAResult was brought on board to implement BHE's prescriptive programs.

The history of program performance and expenditures is presented in Table 4-1.

Table 4-1: Equipment Rebates Historical Performance against Goals

Program Year	# Participants		Budget			Net Therms		
	Actual	Goal	Spent	Allocated	%	Achieved	Goal	%
2016	1,077	1,580	$704,718	$677,375	104.0%	114,778	91,911	124.9%
2017	692	1,456	$435,696	$558,217	78.1%	74,751	87,946	85.0%
2018	1,787	1,456	$421,688	$558,737	75.5%	110,102	87,946	125.2%
2019	1,987	1,456	$648,989	$561,264	115.6%	170,929	87,946	194.4%

4.1.1 Participation Summary

4.1.1.1 Residential Participation - Furnaces

The PY2019 residential heating component had a total of 460 processed rebates at 427 premises. Ninety-three percent of residential rebates issued were for retrofit projects. Seven percent were for new construction projects.

4.1.1.2 Residential Participation – Water Heaters

The residential component had a total of 185 tankless residential rebates at 185 premises. Seventy-nine percent of PY2019 residential participants were in retrofit applications, with 21% being new construction applications.

4.1.1.3 Residential Participation – Smart Thermostats

The program rebated 1,242 smart thermostats in PY2019, increasing significantly from PY2018 participation of 353 thermostats. BHE tracked the baseline thermostat type on the program application; 30% had a programmable thermostat and 70% had a manual thermostat.

4.1.1.4 Residential Participation – Water Conservation Kits

BHE did not distribute any water conservation kits in PY2019.

4.1.1.5 Commercial Participation - Furnaces

Commercial participation comprised of 86 95+AFUE furnaces, a notable increase from the 31 units rebated in PY2018. All commercial furnace rebates were for retrofit projects. Figure 4-1 summarizes the participation levels by facility type.

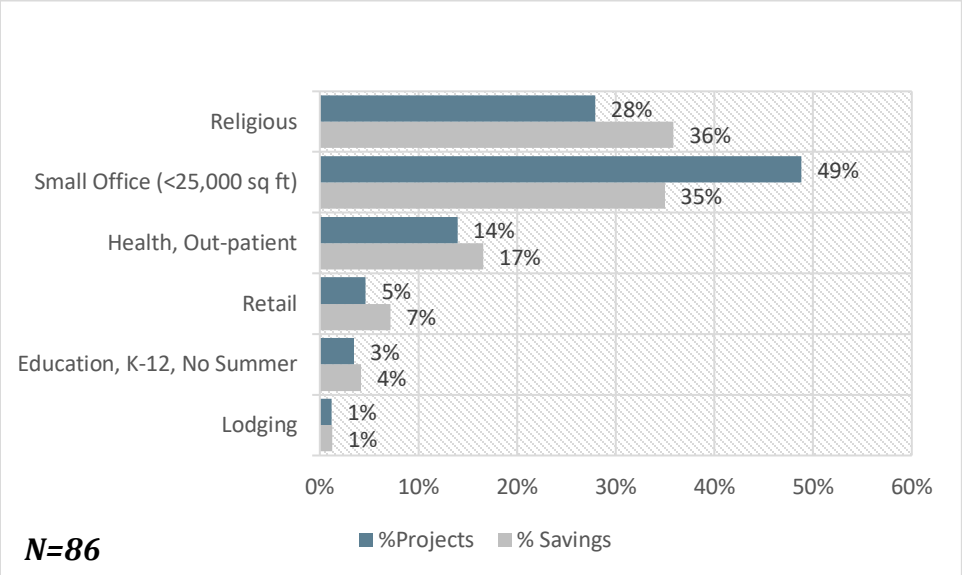


Figure 4-1: Heating Equipment Rebates Commercial Participation by Facility Type

Religious and small offices accounted for the majority of participation and savings in this channel in PY2019.

4.1.1.6 Commercial Participation – Water Heaters

The commercial component had a total of 14 rebates at 3 premises. All units were tankless units. Ten of the rebated units were in elementary schools. The remaining systems were in large offices and sit-down restaurants.

Figure 4-2 summarizes the share of rebates paid by facility type compared to the percent of program savings.

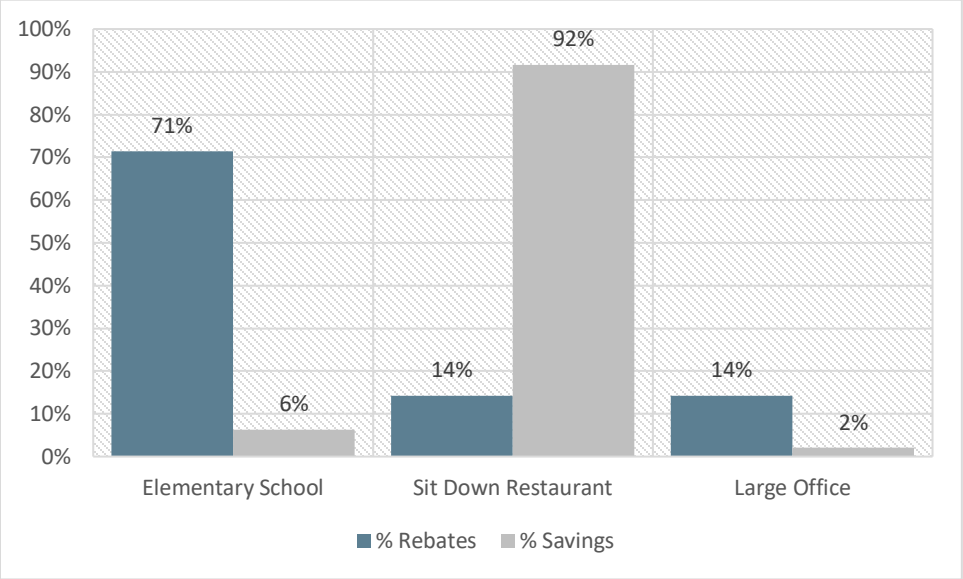


Figure 4-2: Rebate and Savings by Facility Type

4.2 Equipment Rebates Process Evaluation

The Evaluators conducted a formal process evaluation of the Equipment Rebates Program in PY2018 and found that the program was successful in meeting participation, savings, and satisfaction goals. Table 4-2 and Table 4-3 summarize the Evaluators' review of the Equipment Rebates Program in comparison to TRM V8.0 Protocol C for timing and conditions of conducting a process evaluation.

Table 4-2 Determining Appropriate Timing to Conduct a Process Evaluation

Component	Determination
New and Innovative Components	No. The program is unchanged from PY2018.
No Previous Process Evaluation	No. The program received a comprehensive process evaluation in PY2017.
New Vendor or Contractor	No. CLEAResult has implemented the program since 2012.

Table 4-3: Determining Appropriate Conditions to Conduct a Process Evaluation

Component	Determination
Are program impacts lower or slower than expected?	No. The program exceeded savings goals in all prior program years.
Are the educational or informational goals not meeting program goals?	No. The programs have had successful consumer and contractor outreach & education.
Are the participation rates lower or slower than expected?	No. The program met participant goals in all prior program years.
Are the program's operational or management structure slow to get up and running or not meeting program administrative needs?	No. The PY2017process evaluation found that operational and management structure to be up to speed and efficient in administering the program.
Is the program's cost-effectiveness less than expected?	No, the program's cost-effectiveness was within expected boundaries.
Do participants report problems with the programs or low rates of satisfaction?	No. PY2017 participant surveys found high satisfaction levels.
Is the program producing the intended market effects?	Yes. Interviews with participating contractors in PY2017 found significant market transformation occurring.

Due to these factors, no process evaluation was required for PY2018. Process evaluation activities were limited to staff interviews and addressing response to prior recommendations.

4.2.1 Data Collection Activities

The evaluation of the Equipment Rebates Program included the following activities:

- *Program Actor In-Depth Interviews*. The Evaluators conducted in-depth interviews with a series of program actors. These interviews covered a range of topics, including marketing efforts, feedback on program delivery, an assessment of barriers to program implementation and success, and recommendations for program improvement. Program Actors interviewed include:
  - *BHE Program Staff*. The Evaluators interviewed staff at BHE involved in the administration of the Equipment Rebates Program.
  - *Third Party Implementation Staff Interviews.* The Evaluators conducted interviews with CLEAResult personnel involved with the program.
- *Participant Surveying*. The Evaluators surveyed separate samples of residential and non-residential participants in the Equipment Rebates Program. In addition to their use in developing free ridership and spillover estimates, these surveys informed the process evaluation of the Equipment Rebates Program. These surveys addressed issues including participant satisfaction with the program offerings, demographics, and other contextual issues regarding the participation process. Further, the data from these surveys served to quantify the extent of early replacement.

Table 4-4 summarizes the data collection for this process evaluation effort. This includes the titles, role, and sample sizes for data collection.

Table 4-4: BHE Equipment Rebate Data Collection Summary

Target	Component	Activity	n	Sample Precision	Role
BHE Program Staff	Manager of Energy Efficiency	Interview	1	N/A	Overall administration of BHE DSM programs. This manager is involved in the larger strategic decisions associated with the DSM portfolio, and is involved with the Equipment Rebates Program and in the overall coordination of utility resources.
CLEAResult Staff	Program Manager	Interview	1	N/A	Handles day-to-day operations, including mass market outreach, application review, billing, and logistics

4.2.2 Process Results & Findings

This section will present the results and key findings from the data collection activities. These findings are based upon interviews with utility staff, implementation staff and surveys with participants.

4.2.2.1 Response to Program Recommendations

In PY2018, the Evaluators made three recommendations across the three program channels.

Table 4-5: Equipment Rebates Response to PY2018 Recommendations

Recommendation	BHE Response	Status of Issue
Review the issue pertaining to dual program participation with smart thermostats and assess appropriateness of rebate levels. If a customer receives rebates from BHE and an overlapping electric utility, then a total of $200 is paid towards the thermostat. BHE should assess whether it is feasible to share application and participation information with overlapping electric utilities to address this. This is acutely difficult for BHE in particular because they overlap with all four electric investor-owned utilities in Arkansas	For 2020, the rebate has been reduced to $75.	Recommendation Adopted

4.2.2.2 Participant Detailed Review

The Evaluators completed a detailed participant review, incorporating equipment cost and housing characteristics.

4.2.2.3 Residential Furnaces

Cost for furnace replacement was characterized in four categories:

- Replace on Burnout;
- Early Retirement;

- New Construction; and
- Housing Authority.

Housing Authority was an aggregate category and was separated in the analysis due to significantly smaller average residence size as well as cost differences due to the potential for bulk purchasing.

Table 4-6: Residential Furnace Participant Cost Metrics

Participant Type	Median Sq. Ft.	Median Home Age	Average Input BTU	Median $/unit	Median $/Input BTU	Median $/Sq. Ft.
Replace on Burnout (N=58)	2,016	39	71,419	$5,423	$0.070	$2.26
Early Retirement (N=69)	2,062	29	74,699	$5,787	$0.075	$2.82
New Construction (N=67)	2,800	0	81,242	$6,450	$0.078	$2.60
Housing Authority (N=65)	936	52	57,508	$4,630	$0.102	$5.29

4.2.2.4 Residential Water Heaters

Cost for water heater replacement was characterized in four categories:

- Replace on Burnout;
- Early Retirement;
- New Construction; and
- Housing Authority.

Housing Authority was an aggregate category and was separated in the analysis due to significantly smaller average residence size as well as cost differences due to the potential for bulk purchasing.

Table 4-7: Residential Water Heater Participant Cost Metrics

Participant Type	Median Sq. Ft.	Median Home Age	Median Input BTU	Median $/unit	Median $/Input BTU	Median $/Sq. Ft.
Retrofit (N=146)	2,402	19	199,000	$3,225	$0.012	$1.21
New Construction (N=39)	2,593	0	199,000	$1,631	$0.013	$.63

New construction projects had 51% lower total cost than retrofits.

Residential water heaters must have an input BTU lower than 200,000 to be tested under the Uniform Energy Factor procedure. Median sizing was 199,000 BTU for all categories. Among all program participants, a total of 54% of rebates were for 199,000 BTU systems. Excluding Housing Authority projects, 85% of all projects were 199,000 BTU systems. A total of 27 participants installed systems lower than 199,000 BTU (ranging from 130,000 to 180,000). Median costs for these systems were 47% lower than that of the 199,000 BTU systems for homes 16% lower in median square feet.

4.2.2.5 Smart Thermostats

There were 29 HVAC contractors listed as having installed smart thermostats. For projects that did not include a contractor, the line items are marked as "Self-Install" and do not include tracking of the retailer from which the customer purchased the thermostat. Ninety-one percent of participants installed their thermostat themselves. Figure 4-4 summarizes the installer type by brand. Ecobee models were more than twice as likely to be installed by an HVAC contractor than Nest thermostats.

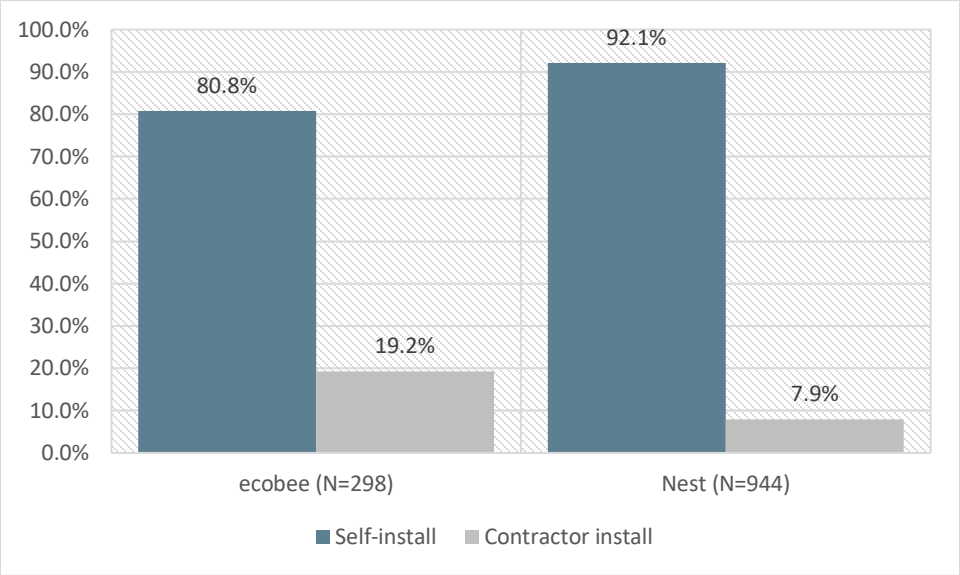


Figure 4-3: Installer Type by Brand

Sales rates were similar across brands in Hardware stores, online retailers, and manufacturer-direct sales. Statistically significant differences were identified among household products / electronics retailers (favoring Nest) and HVAC contractors (favoring ecobee).

The Evaluators then cross-referenced participant tracking between the thermostat and furnace replacement tracking datafiles. In total, 4.1% of thermostat participants had also received a rebate for a high efficiency furnace.

4.2.3 Other Heating Products

The Evaluators conducted a high-level review of program offerings in other states to identify potential new measures for the BHE portfolio. The products identified that may warrant inclusion in the Equipment Rebates Program are as follows.

4.2.3.1 *Gravity Wall Furnaces*

Gravity wall furnaces are self-contained vented heaters that are permanently incorporated into or attached to a wall. They range from 25,000 – 50,000 BTU in capacity, with the larger systems being dual-sided, through-wall systems that heat two spaces of a residence. Efficiency gains are achieved through improved heat exchanging surfaces.

Federal cod requirements for gravity wall furnaces range from 60% to 65% AFUE depending upon system capacity.

Savings for these units have been established in CA DEER via workpapers submitted by SoCal Gas[18].

Linearly interpolation of HDDs from California Climate Zones to Arkansas zones results in savings estimates as follows:

Table 4-8: Gravity Wall Furnace Savings – Linearly Interpolated

Zone	25 Kbtuh	35 Kbtuh	50 Kbtuh
9	20.49	21.22	26.22
8	25.71	26.63	32.91
7	19.30	19.99	24.70
6	18.20	18.86	23.30

Efficient options are relatively low-cost compared to baseline equipment, with an incremental cost of $38. If this equipment category has prevalence in older housing stock in Arkansas, efficient options are likely cost-effective.

Savings would require a more refined estimate based on simulation modeling to fully account for climate zone differences.

In researching example incentives, the Evaluators found that this measure is currently explicitly targeted primarily by natural gas IOUs in California, at incentives of $50 for Tier I and $75 for Tier II units.

[18] SWHC001-01 Gravity Wall Furnace, submitted by SoCal Gas 4/19/2019. Updated 1/1/2020.

4.2.3.2 *Efficient Fireplaces*

Fireplace inserts that work as self-contained vented heaters can be integrated with thermostat controls and produce viable natural gas savings. Efficiency gains are possible through addition of an indoor air circulation blower, power venting, flue dampers, and condensing technology. Tier 1 units are defined as 70%-75% AFUE, with Tier 2 units (condensing units) being greater than 75% AFUE.

Savings for these units have been established in CA DEER via workpapers submitted by SoCal Gas[19].

Linearly interpolation of HDDs from California Climate Zones to Arkansas zones results in savings estimates as follows:

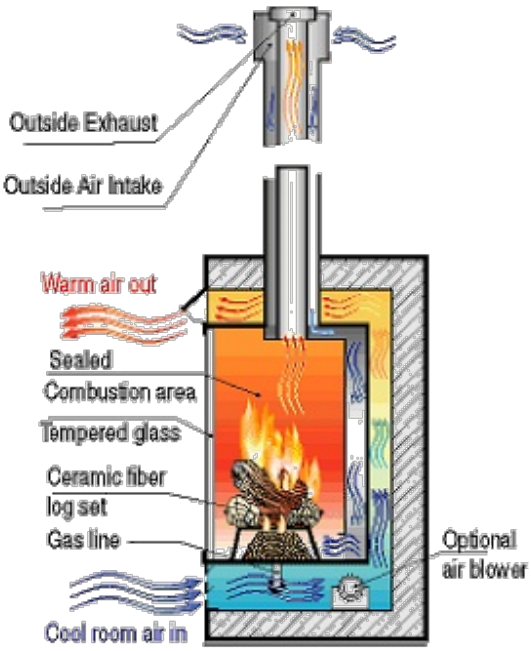


Table 4-9: Efficient Fireplace – Linearly Interpolated

Zone	Tier 1	Tier 2
9	18.55	32.71
8	16.51	29.12
7	12.41	21.89
6	9.88	17.42
Incremental Cost	$82.00	$158.00

Savings would require a more refined estimate based on simulation modeling to fully account for climate zone differences.

Table 4-10: Efficient Fireplace – Example Incentives

Program Administrator	Tier 1	Tier 2
SoCalGas	$300	$500
Energy Trust of Oregon	$150	$250
Northwest Natural Gas	$150	$250
CenterPoint (Minnesota)	$75	$75

4.3 Equipment Rebates Program Impact Evaluation

The evaluation effort of the Equipment Rebates Program included the following:

- *Desk Review of Residential Calculations.* The Evaluators utilized TRM V8.0 values in assessing savings from residential furnaces and water heaters.

[19] SWHC047-01 Residential Gas Fireplace, submitted by SoCal Gas 1/11/2019. Updated 1/1/2020.

- *Calculation of Deferred Replacement Costs.* The Evaluators used the calculation tool developed by the IEM to assess deferred replacement cost for residential and commercial water heaters.
- *Commercial Verification*. The Evaluators applied TRM V8.0 deemed savings parameters in assessing savings of the commercial component.
- *Free-Ridership Rates.* Free ridership rates were developed from current-year survey efforts.

4.3.1 Summary of Non-Energy Benefits

Table 4-8 summarizes the non-energy benefits by measure that will be credited to the Equipment Rebates Program.

Table 4-11: Equipment Rebates Non-Energy Benefits

Measure	Electric Savings	Water Savings	Propane Savings	Deferred Replacement Cost
Residential Furnace Early Retirement				✓
Residential Tankless WH				✓
Commercial Tankless WH				✓
Smart Thermostat	✓			
Low Flow Showerhead	✓	✓		
Low Flow Faucet Aerator	✓	✓		

4.3.2 Residential Impact Evaluation

4.3.2.1 Residential Free-Ridership

Table 4-9 summarizes the approaches taken for assessment of free ridership by measure category. Due to primary data having been collected in the PY2018 evaluation, no new NTG assessments were performed for PY2019. .

Table 4-12: Summary of Free-Ridership Approaches

Measure	Cite PY2018 Value	BHE-Specific Survey	Multi-utility Survey	Stipulated from Prior Evaluation
Residential Furnace Retrofits	✓			
Residential Furnace NC - Builders	✓			
Residential Furnace NC - Custom	✓			
Residential WH Retrofit	✓			
Residential WH NC - Builders	✓			
Residential WH NC - Custom	✓			
Housing Authority Furnace & WH	✓			
Residential Smart Thermostats	✓			
Residential Water Conservation Kits	✓			
C&I Furnaces	✓			
C&I Water Heaters	✓			

Figure 4-22 details the scoring mechanism for residential free ridership in the Equipment Rebates Program.

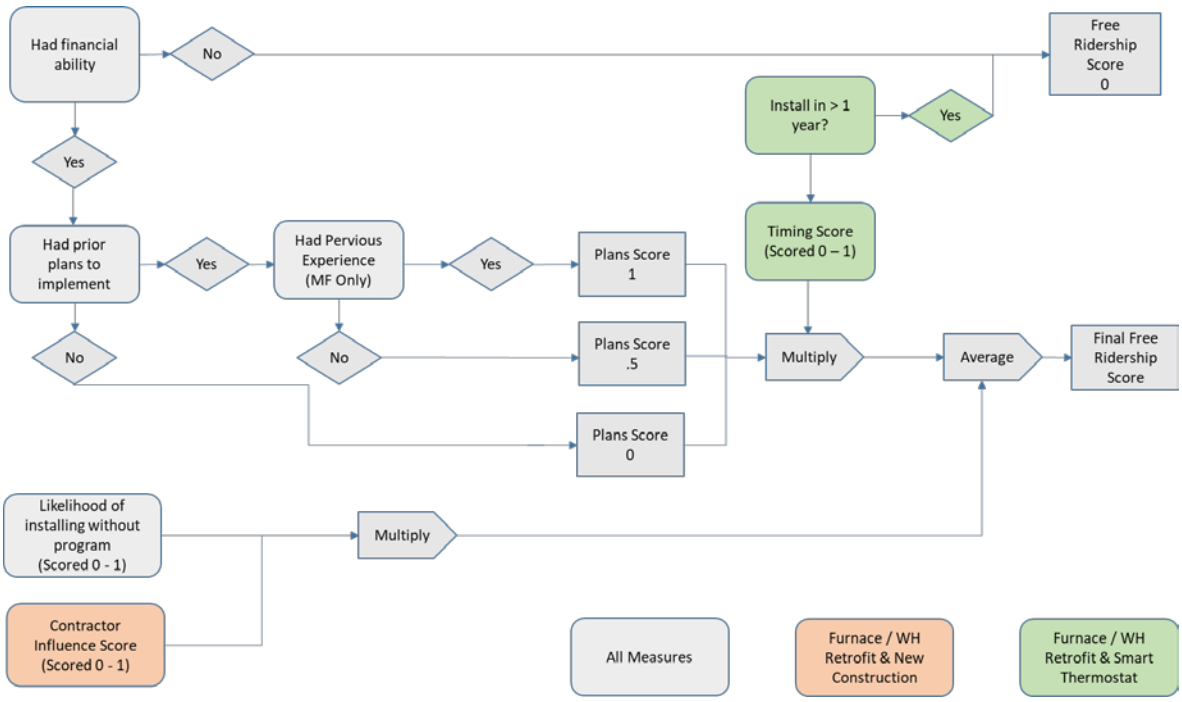


Figure 4-4: Residential Equipment Rebates FR Diagram

The approach was based on survey self-reports, using the following questions:

Q15. Prior to learning about the [PROGRAM], did you have plans to install a [MEASURE]?

1. Yes
2. No
98. DON'T KNOW
99. REFUSED

Q16. Just to be clear, did you have plans to install a [MEASURE] as opposed to a standard efficiency [BASELINE]?

1. Yes
2. No
98. DON'T KNOW
99. REFUSED

Q17. Would you have been financially able to purchase the [MEASURE] if there was not a rebate available through the [UTILITY_SHORT] program?

1. Yes
2. No
98. DON'T KNOW
99. REFUSED

Q18. How likely is it that you would have purchased and installed the same [MEASURE] that you had rebated through the program if the rebate was not viable? Would you say [READ. MARK ONE.]

1. Very likely
2. Somewhat likely
3. Neither particularly likely nor unlikely
4. Somewhat unlikely
5. Very unlikely
98. DON'T KNOW
99. REFUSED

Q19. How influential was your contractor in helping you finalize the selection of your equipment? [READ. MARK ONE.]

1. Very influential
2. Somewhat influential
3. Neither particularly influential nor uninfluential
4. Somewhat uninfluential
5. Very uninfluential
98. DON'T KNOW
99. REFUSED

Q20. Did you install the [MEASURE] sooner than you otherwise would have because of the rebate available through the [UTILTIY_SHORT] program?

1. Yes
2. No
98. DON'T KNOW
99. REFUSED

Q21. When would you have installed the [MEASURE] if rebates through the [UTILITY_SHORT] program were not available?

1. Within 6 months of when you installed it
2. Between 6 months and one year
3. 1-2 years
4. 2-3 years
5. More than 3 years
98. DON'T KNOW
99. REFUSED

The plans score was factored by the programs impact on timing. Specifically,

- If the respondent stated that they would have installed the measure more than one year after the measure was installed, the prior plan score reduced to zero.
- If the respondent stated that they would have installed the measure in 6 months to one year, then the prior plans score was reduced by one-half.
- If the respondent stated that they would have installed the measure at the same time or within 6 months of when it was installed, the prior plans score was not adjusted.

A likelihood of installing the measure in the absence of the program was developed based on respondents stated likelihood of installing a measure. Specifically, responses to this question were scored as follows:

- Very likely: 1
- Somewhat likely: .75
- Neither particularly likely nor unlikely: .5
- Somewhat unlikely: .25
- Very unlikely: 0

Contractor Influence: This score is first determined via respondent answers to Question 18. The scores are as follows:

- Very influential: .5
- Somewhat influential: .25
- All other answers: .00

This value is then scaled by .667 due to contractor estimates that the rebate assisted them in upselling to a high efficiency model two-thirds of the time.

The resulting NTGRs are as follows:

- Residential Furnace Retrofit: 75.0%

- Residential Water Heating Retrofit: 75.0%
- Smart Thermostats – 88.7%

For new construction applications, we apply a similar scoring mechanism as-completed in the multi-utility survey effort for owner-built custom homes. For homes from production builders, we apply the PY2017 values developed as part of the new construction builder survey effort completed for CenterPoint Energy Arkansas. The values are:

- New Construction: Owner-built custom: 64.4%
- New Construction: Builder production homes: 91.0%.

4.3.2.2 Energy Savings Calculations - Furnaces

As per the TRM V8.0, and the procedures for calculating the impact of early replacement for residential furnaces, early retirement AFUE is calculated by a degradation factor of a 78 AFUE unit. This is calculated as: [20]

$$AFUE_{base\_early} = (Base\ AFUE) \times (1 - M)^{age}$$

Where:

$Base\ AFUE$ = efficiency of the existing equipment when new, 78% AFUE.
M [21] = maintenance factor, 0.01.
age = the age of the existing equipment, in years.

Following this, lifetime savings are determined based on the Remaining Useful Life (RUL) of the old equipment. The TRM V8.0 updated the RUL table, which has been reflected in Table 4-13. [22]

[20] Arkansas TRM V8.0 Volume 2, Pg. 44
[21] Maintenance factor of 0.01 is the average maintenance factor for gas furnaces taken from the October 2010 National Renewable Energy publication "Building America House Simulation Protocols", table 30.
[22] AR TRM V8.0, Volume 2, Pg. 46

Table 4-13: Residential Furnace RUL

Unit Age	RUL	Unit Age	RUL
5	14.7	**19**	3.6
6	13.7	**20**	3.2
7	12.7	**21**	2.9
8	11.8	**22**	2.6
9	10.9	**23**	2.4
10	10.0	**24**	2.1
11	9.1	**25+**	0.0
12	8.3		
13	7.5		
14	6.8		
15	6.2		
16	5.5		
17	4.5		
18	4.0		

To assess whether a unit qualified for early retirement, the Evaluators examined the following survey questions:

7. Was the replaced [BASELINE]….(READ LIST)?

1. Fully functional and not in need of repair?
2. Functional, but needed minor repairs?
3. Functional, but needed major repairs?
4. Not functional?

98. DON'T KNOW
99. REFUSED

8. How old was the [BASELINE] at the time you replaced it?

1. ___ # Years

98. DON'T KNOW
99. REFUSED

9. How long do you think your [BASELINE] would have lasted if you had not replaced it?

1. ___ # Years

98. DON'T KNOW

Figure 4-5 summarizes the scoring for early retirement based on these three questions

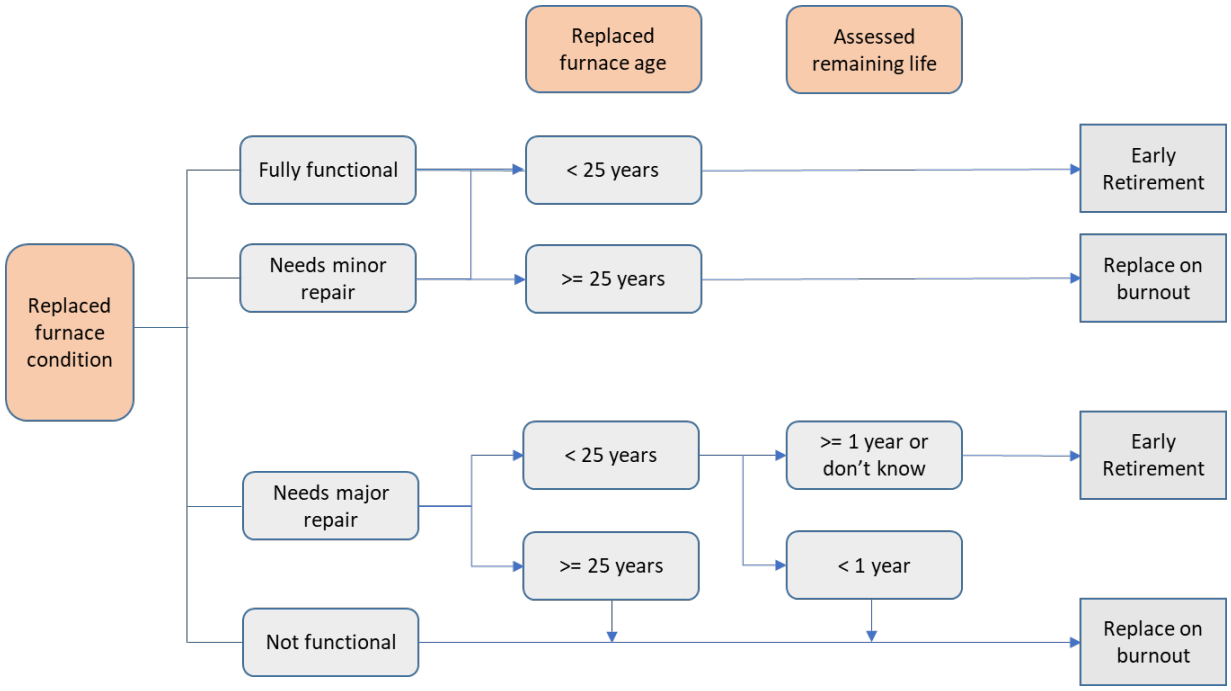


Figure 4-5: Residential Furnace Early Retirement Flowchart

In total, the Evaluators found that 66.67% of BHE furnace retrofits were early retirement.

The average age of functioning and failed units was as follows:

- 17.64 for functioning units
- 24.11 for failed units

Based on the degradation equation from TRM V8.0[23], this leads to an Early Retirement AFUE of:

$$AFUE_{base_{early}} = (.78) \times (1 - .01)^{17.64} = .6533$$

Further, based on the values in Table 4-18, the RUL of the early replacement units is four years. For years 5-20 of the unit EUL, the normal replacement baseline applies. The savings for each residential retrofit unit were calculated using both the normal and early replacement baselines, and final savings reflect a weighted average of these two values based on participant survey data findings. These values were then applied on a weighted basis to the residential retrofit units using

[23] TRM V8.0 Vol. 2 Pg. 44

weights of 66.67% early replacement and 33.33% normal replacement. The resulting weighted average baseline is:

$$AFUE_{base_{early\_weighted}} = 66.67\% \times .6533 + 33.33\% \times .80 = .7022$$

.

4.3.2.3 *Energy Savings Calculations – Water Heaters*

Savings from tankless water heaters were calculated using protocols from Arkansas TRM V8.0 Vol. 2 Section 2.3.1. For sample calculations, see Appendix C.

4.3.2.4 *Energy Savings Calculations – Smart Thermostats*

Gross savings were calculated for smart thermostats using protocols AR TRM V8.0 Vol 2 2.1.12. For sample calculations, see Appendix C.

BHE tracked the baseline thermostat on their program application. The Evaluators applied the appropriate baseline for each line item. There were 89 smart thermostats installed in new construction projects. Within this, program tracking data showed 69 using manual thermostat baseline and 20 using programmable thermostat. The Evaluators overwrote this and applied the programmable thermostat baseline to all new construction projects.

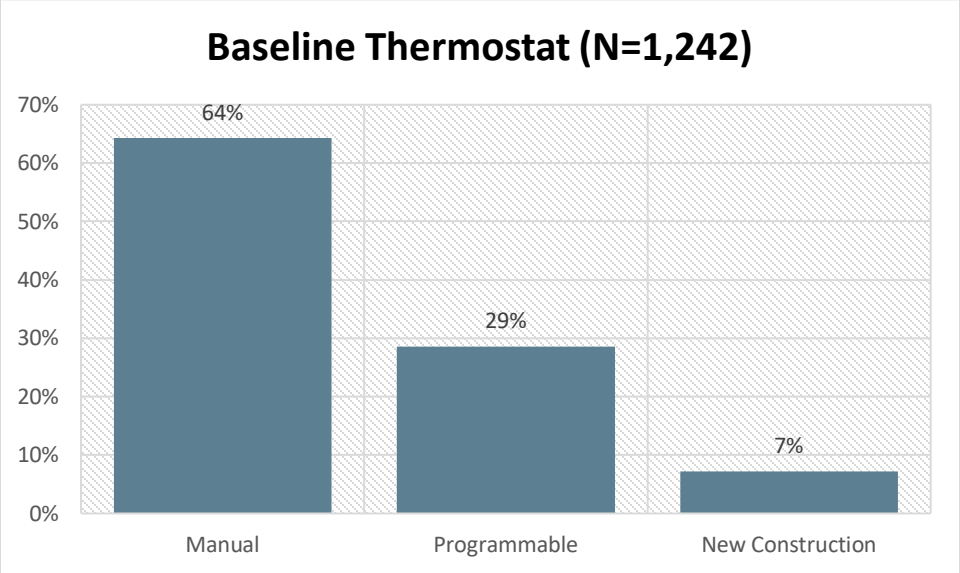


Figure 4-6: Baseline Thermostat for Smart Thermostat Rebates

To evaluate attributable energy savings for smart thermostats, the tracking data from the BJE program was compared to SWECPO and OG&E tracking data in order to identify premises that received rebates from both utilities. In total, 7.3% of BHE smart thermostat participants (26 out of 353) received rebates from SWEPCO. No overlap was found with OG&E. BHE was not credited with kWh savings from these projects.

4.3.3 Commercial Impact Evaluation

Several criteria determine which portion of a participant's savings should be attributed to free ridership. The first criterion comes from the response to:

- "Would you have been financially able to install the equipment or measures without the financial incentive from the Program?"

If a customer answered "No" a free ridership score of 0 was assigned to the project. That is, if a customer required financial assistance from the program to undertake a project, that customer was not deemed a free rider.

The second questions pertain to project timing. Respondents are asked "Did you purchase and install the [MEASURE] earlier than you otherwise would have without the program". If they indicate that they installed the measure more than one year earlier than they otherwise would have, they are not a free rider.

For decision makers who indicated they could undertake energy efficiency projects without financial assistance from the program, three additional factors determined what percentage of savings is attributable to free ridership. The three factors are:

- Plans and intentions of the firm to install a measure even without support from the program;
- Influence that the program had on the decision to install a measure; and
- A firm's previous experience with a measure installed under the program.

For each of these factors, rules were applied to develop binary variables indicating whether a participant showed free ridership behavior. Responses to the decision-maker questionnaire helped to develop the rules for the free ridership indicator variables

The first required step was to determine if a participant stated that his or her intention was to install an energy efficiency measure without the help of the program incentive. The survey respondents' answers to a combination of questions, then a set of rules determined whether a participant's behavior indicated likely free ridership. Two binary variables were constructed to account for customer plans and intentions: one, based on a more restrictive set of criteria that may describe a high likelihood of free ridership, and a second, based on a less restrictive set of criteria that may describe a relatively lower likelihood of free ridership.

The first, more restrictive criteria indicating customer plans and intentions that likely signify free ridership are as follows:

- The respondent answered "yes" to the following two questions: "Did you have plans to install the measure before participating in the program?" and "Would you have gone ahead with this planned installation of the measure even if you had not participated in the Program?"
- The respondent answered, "definitely would have installed" to the following question: "If the financial incentive from the Program had not been available, how likely is it that you would have installed [Equipment/Measure] anyway?"

The second, less restrictive criteria (Definition 2) indicating customer plans and intentions that likely signify free ridership are as follows:

- The respondent answered "yes" to the following two questions: "Did you have plans to install the measure before participating in the program?" and "Would you have gone ahead with this planned installation of the measure even if you had not participated in the Program?"
- Either the respondent answered, "definitely would have installed" or "probably would have installed" to the following question: "Would you have completed the [Equipment/Measure] project even if you had not participated in the program?"

The second required factor was determining if a customer reported that a recommendation from a program representative or experience with the program was influential in the decision to install a piece of equipment or measure. This criterion indicates that the program's influence may lower the likelihood of free ridership when any of the following conditions are true:

- The respondent answered "very important" to the following question: "How important was previous experience with the Program in making your decision to install [Equipment/Measure]?

The respondent answered, "definitely not would have" or "probably not would have" to the following question: "If the Program representative had not recommended implementing the [Equipment/Measure], how likely is it that you would have implemented it anyway?"

The third required factor is determining if a participant in the program indicated that he or she had previously installed an energy efficiency measure similar to one that they installed under the program without an energy efficiency program incentive during the last three years. A participant indicating that he or she had installed a similar measure considered to have a higher likelihood of free ridership. The criteria indicating that previous experience may signify a higher likelihood of free ridership are as follows:

- The respondent answered "yes" to the following question: "Thinking about all of the projects you completed in the last three years, did you implement any energy efficient

equipment or projects similar to the [Equipment/Measure] that you implemented at your facility located at [LOCATION] as part of any of those projects?

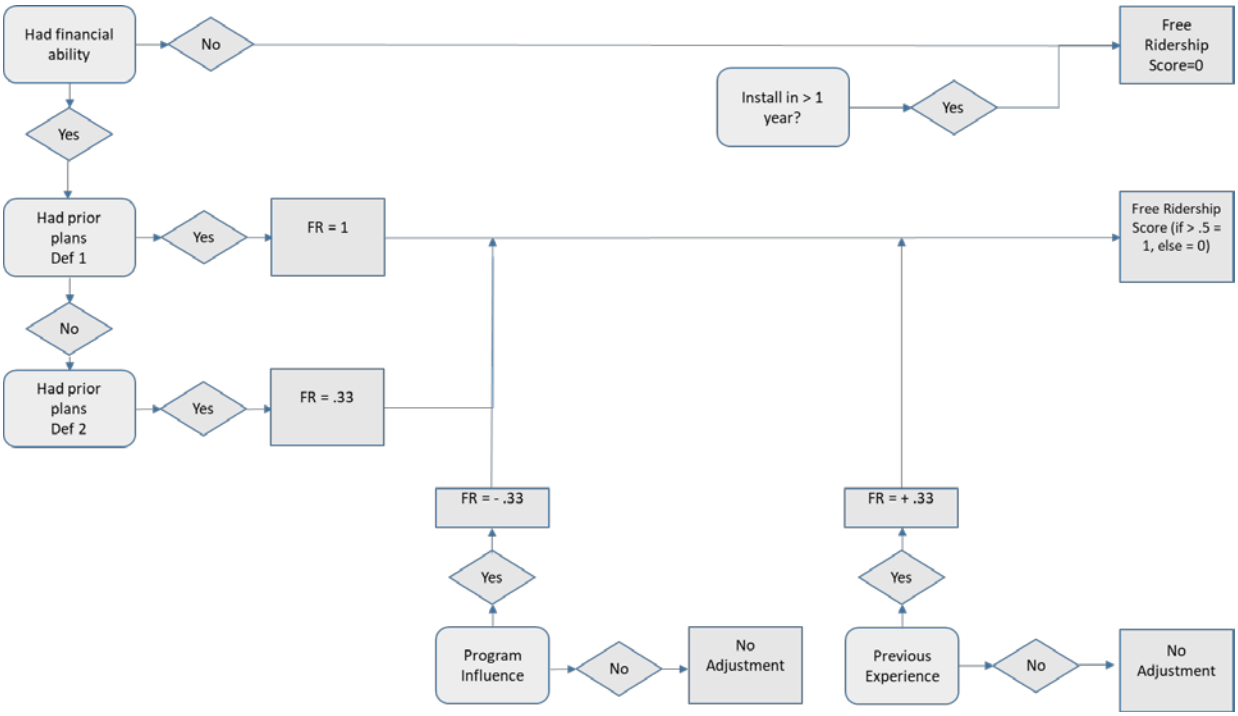


Figure 4-7: Nonresidential Free Ridership Scoring Flow Chart

The resulting NTGRs were:

- Furnaces: 84.36%
- Water Heaters: 88.51%

4.3.3.1 Energy Savings Calculations – Commercial Furnaces

Savings for commercial furnaces are calculated using protocols from AR TRM V8.0 Section 3.1.9. For sample calculations, see Appendix C.

4.3.3.2 Energy Savings Calculations – Water Heating

Savings for commercial furnaces are calculated using protocols from AR TRM V8.0 Section 3.3.1. For sample calculations, see Appendix C.

4.3.3.3 Commercial Desk Review Findings

The Evaluators conducted desk reviews for a census of the 14 water heaters installed at 3 premises in PY2019. In aggregate, the Evaluators found 113.7% gross realization from these desk

reviews. The basis for increased savings from this desk review is not known as the savings calculations are not shown in full detail in the program tracking database.

4.4 Ex Post Savings

Table 4-14 presents the gross savings results of the evaluation of the PY2019 Equipment Rebates Program. Total gross savings summarizes the savings calculations performed by TRM V8.0 protocols.

Table 4-14: Equipment Rebates Ex Post Gross Therms Savings

Measure Category	Ex Ante Therms Savings	Ex Post Therms Savings	Gross Realization Rate	EUL	Lifetime Therms Savings
Furnace Retrofit	91,182	112,587	123.48%	12.62	1,419,604
Furnace NC - Builders	280	225	80.31%	20	4,490
Furnace NC - Custom	1,941	1,765	90.93%	20	35,290
DHW Retrofit	6,450	7,480	115.98%	20	149,600
DHW NC - Builders	1,289	1,542	119.60%	20	30,840
DHW NC - Custom	336	409	121.85%	20	8,180
Smart Thermostat	69,034	68,210	98.81%	11	750,310
C&I Furnaces	14,709	14,718	100.06%	20	294,360
C&I Water Heaters	3,348	3,808	113.73%	20	76,160
Total Gross Savings	**188,568***	**210,743***	**112%**	**18.18**	**2,768,834**
***Sums differ due to rounding**					

The resulting net savings are presented in Table 4-15.

Table 4-15: Equipment Rebates Net Savings Summary

Project Category	Free-Ridership Rate		Net Annual Savings		Net Realization Rate	Net Lifetime Therms Savings
	Ex Ante	Ex Post	Ex Ante	Ex Post		
Furnace Retrofit	23.9%	23.9%	69,390	86,011	124.0%	1,082,162
Furnace NC - Builders	8.9%	8.9%	255	204	80.0%	4,086
Furnace NC - Custom	35.5%	35.5%	1,252	1,136	90.7%	22,727
DHW Retrofit	24.9%	24.9%	4,844	5,627	116.2%	112,200
DHW NC - Builders	8.4%	8.4%	1,181	1410	119.4%	28,066
DHW NC - Custom	35.3%	35.3%	217	264	121.4%	5,268
Smart Thermostat	11.4%	11.4%	61,164	60,493	98.9%	665,292
C&I Furnaces	15.7%	15.7%	12,400	12,414	100.1%	248,280
C&I Water Heaters	11.5%	11.5%	2,963	3,370	113.7%	67,412
Overall:	**18.9%**	**18.9%**	**153,665**	**170,929**	**111.2%**	**2,235,493**

4.4.1 Non-Energy Benefits Summary

4.4.1.1 Residential Tankless Water Heaters.

Residential tankless water heaters have an EUL of 20 years. The baseline system has an EUL of 11 years. This makes the systems eligible for the Deferred Replacement Cost Non-Energy Benefit. This NEB was calculated using the IEM calculation tool[24]. The input assumptions were as follows:

- Full installed cost of tankless system: $1,219
- Full installed cost of baseline storage tank system: $614
- Nominal Discount Rate: 5.66%
- Inflation Rate: 1.90%
- Real Discount Rate: 3.69%

The resulting gross deferred replacement cost is $348.90 per unit. The calculator for this is provided in Appendix B of this report. For individual line items in the BHE program, this value was scaled by the appropriate NTGR.

There were 185 residential tankless systems rebated in PY2019, and the resulting ARC value is $49,845.30.

4.4.1.2 Commercial Tankless Water Heaters.

Commercial tankless water heaters have an EUL of 20 years. The baseline system has an EUL of 15 years. This makes the systems eligible for the Deferred Replacement Cost Non-Energy Benefit. This NEB was calculated using the IEM calculation tool[25]. The input assumptions were as follows:

- Full installed cost of tankless system: $1,219
- Full installed cost of baseline storage tank system: $614
- Nominal Discount Rate: 5.66%
- Inflation Rate: 1.9%
- Real Discount Rate: 3.69%

The resulting gross deferred replacement cost is $140.91 per unit. The calculator for this is provided in Appendix B of this report. The Evaluators used the incremental costs associated with residential tankless systems as commercial costs are aligned with systems that are 200,000 BTU or greater in capacity (and therefore use the Combustion Efficiency baseline rather than the

[24] Protocol L Avoided & Deferred Replacement Cost_08_31_16.xlsx

[25] Ibid.

Energy Factor). All tankless systems rebated in commercial facilities in BHE's program were below 200,000 BTU and were units that are certified for residential applications. The values were then scaled by the commercial water heater NTGR factor (88.6%).

There were 14 commercial tankless systems rebated in PY2019, and the resulting DRC value is $1,746.22.

4.4.1.3 Residential Furnace Early Replacement

Early replacement of a residential furnace produces a Deferred Replacement Cost benefit from the delay of a purchase of new equipment in perpetuity.

The input assumptions were as follows:

- Full installed cost of efficient furnace: $2,548
- Full installed cost of baseline furnace: $2,011
- Nominal Discount Rate: 5.66%
- Inflation Rate: 1.9%
- Real Discount Rate: 3.69%

The resulting gross deferred replacement cost is $1,484.68 per unit. The calculator for this is provided in Appendix B of this report. The values were then scaled by the residential furnace NTGR factor (76.1%) and applied proportionally to each retrofit line item based on the percent of projects assumed to be early replacement (66.67%).

- There were 427 residential furnace retrofits in PY2019, and the resulting DRC value is $326,494.99.

4.4.1.4 Smart Thermostats

BHE did not have a savings sharing agreement with any electric utilities for this component of their portfolio. To ensure that savings are claimable by BHE, the Evaluators cross-referenced BHE smart thermostat tracking data with OG&E and SWEPCO tracking data. The Evaluators found that 26 of the 353 thermostats in BHE's program also received incentives from SWEPCO. There was no overlap identified with OG&E. For these projects, the kWh NEB was disallowed. The resulting kWh savings are in the table below. Savings were monetized using SWEPCO's filed avoided kWh and kW costs and associated line losses.

Table 4-16: Smart Thermostat kWh Savings Summary

Savings Type	Ex Post Annual kWh	Ex Post Lifetime kWh
Gross	831,296	9,144,256
Net	737,114	8,108,173

4.5 Conclusions & Program Recommendations

4.5.1 Equipment Rebates Program Conclusions

The Evaluators have found that:

1. **Savings increased dramatically.** After having increased by 39% in PY2018, they have increased again by 55% in PY2019. This is especially notable since no water conservation kits were provided in PY2019.
2. **Smart thermostats have increased as a share program savings.** In PY2019, smart thermostat accounted for 35.3% of program net annual therms**.**
3. **Tracking data for smart thermostats is missing some potentially useful elements.** Though program tracking contains all information needed to calculate savings per AR TRM 8.0 protocols, some additional tracking elements would be useful to help understand the market.

4.5.2 Equipment Rebates Program Recommendations

The Evaluators' recommendations for the Equipment Rebates Program are as follows:

1. **Collect additional tracking data elements for smart thermostats.** Customers that self-install their thermostat should indicate where they have purchased it and have it tracked (as seen in AOG's tracking data) and have the purchase price of the thermostat reported.
2. **Add an application check box for whether the preexisting water heater was functioning or failing, similar to how this data is collected for furnaces.** This is currently tracked by AOG, and in that analysis it was found that 80.3% of retrofit projects were of a functioning unit. This has not been vetted by the Evaluators in a primary data collection effort, but it is of a sufficiently high incidence to warrant further review.
3. **Consider research into viability of gravity wall furnaces and efficient fireplaces.** If the Northwest Arkansas region has reasonable prevalence of these measures, they could be cost-effective additions to the program

5. Commercial and Industrial (C&I) Solutions Program

The C&I Solutions Program is directed at developing and incenting energy efficiency measures for commercial and industrial customers. It is implemented by CLEAResult Consulting on behalf of BHE. CLEAResult handles program administration, marketing and outreach, direct install of energy savings measures, and technical review of custom efficiency projects. Program participants are provided:

(1) No-cost direct installation of low flow faucet aerators, showerheads, and pre-rinse spray valves (PRSVs), if they have gas water heating;

(2) No-cost direct installation of door air infiltration sealing if they have gas space heating;

(3) Prescriptive incentives for commercial boilers and controls (formerly rebated through the C&I Boiler Equipment Rebates Program);

(4) Prescriptive incentives for commercial kitchen equipment (formerly rebated through the Commercial Cooking Equipment Rebates Program);

(5) $.75 per therm for custom projects; and

(6) Incentives to trade allies for steam system surveys.

5.1 C&I Solutions Program Overview

The C&I Solutions Program had $1,380,696 in budget allocated for PY2019. The C&I Solutions Program's historical performance is summarized in Table 5-1.

Table 5-1: C&I Solutions Program Historical Performance against Goals

Program Year	# Participants		Budget			Net Therms		
	Actual	Goal	Spent	Allocated	%	Achieved	Goal	%
2011	404	790	$486,284	$637,926	76.2%	500,906	451,808	110.9%
2012	518	773	$836,388	$1,012,822	82.6%	560,574	536,810	104.4%
2013	417	723	$1,382,015	$1,410,997	97.9%	954,191	805,150	118.5%
2014	215	762	$1,331,924	$1,525,075	87.3%	789,523	694,577	113.7%
2015	385	800	$1,520,715	$1,698,848	89.5%	811,600	766,630	105.9%
2016	185	2,817	$1,638,167	$1,832,824	89.4%	851,581	798,455	106.7%
2017	157	2,344	$1,331,689	$1,374,482	96.9%	714,913	713,150	100.2%
2018	153	2,344	$1,247,349	$1,374,482	90.8%	713,833	713,150	100.0%
2019	42	2,344	$1,296,563	$1,380,696	93.6%	719,575	713,150	100.9%

The C&I Solutions Program participants fall into one of five categories:

- Direct install;
- Prescriptive boiler rebates;
- Prescriptive food service rebates;

- Custom audit recipients;[26] and
- Closed custom projects.

Total net Therms and share of program savings by channel are summarized in Figure 5-1.

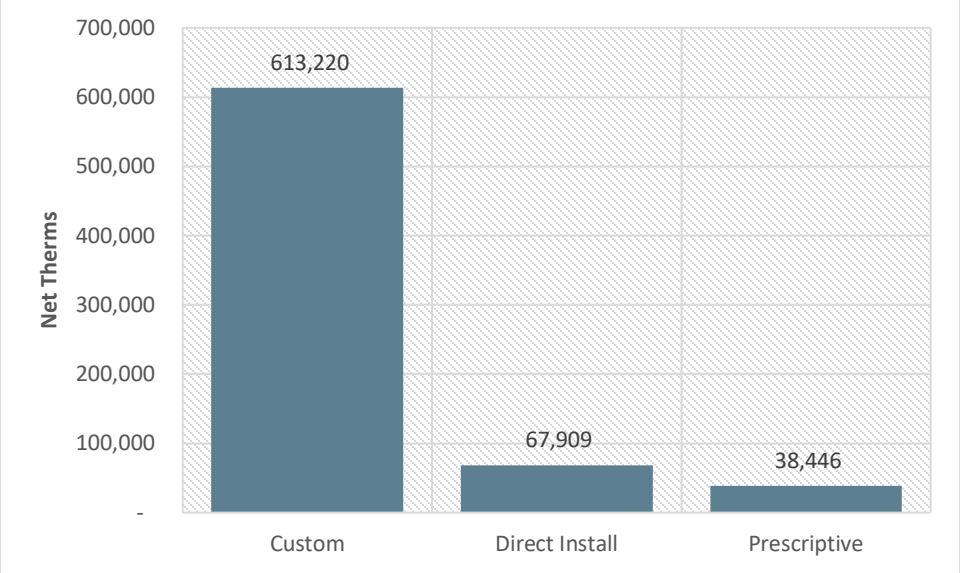


Figure 5-1: Total Net Therms by Program Channel

These participants are detailed in the subsections to follow.

5.1.1 Direct Install Participation Summary

In PY2019, there were 49 direct install measures[27] installed at 17 unique premises. The summary of participation by facility type and the relative share of program Therms savings are summarized in Figure 5-2.

[26] The Evaluators tally audit recipients but do not count them towards Black Hills Energy' participation goal.

[27] "Measure" in this context means "measure category"; i.e., if a facility received showerheads and aerators it is counted as two measures.

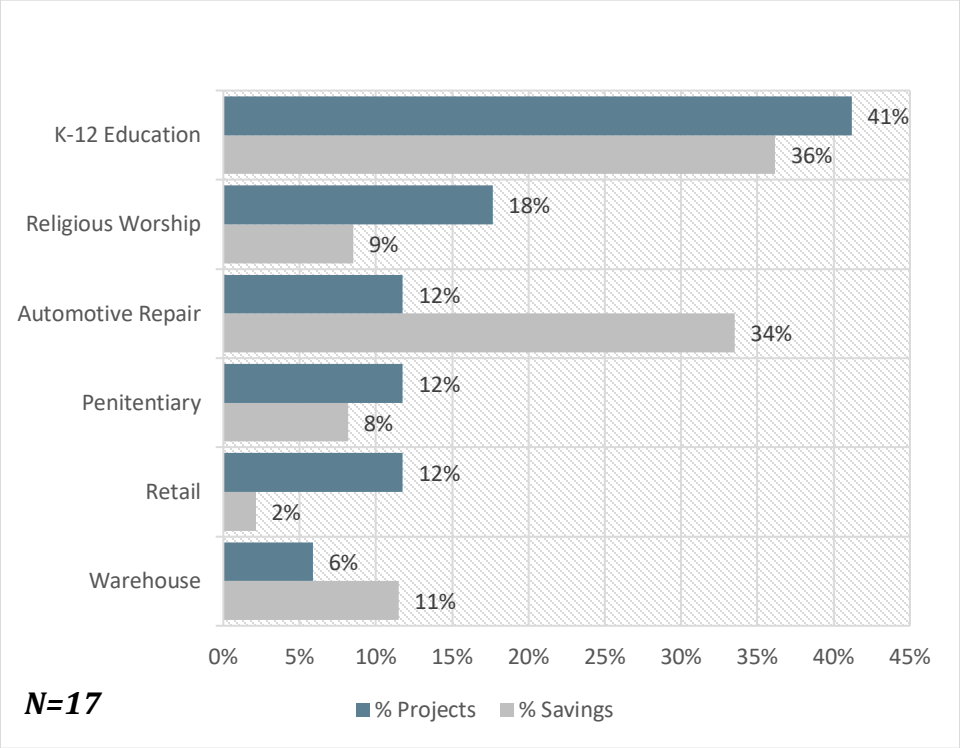


Figure 5-2: BHE Direct Install Participation Summary

Figure 5-3 summarizes the timing of direct install savings, listing the volume of Therms savings by month. This chart is reflective of the amount of annual savings from projects installed in each month. Direct install activity was highest in January.

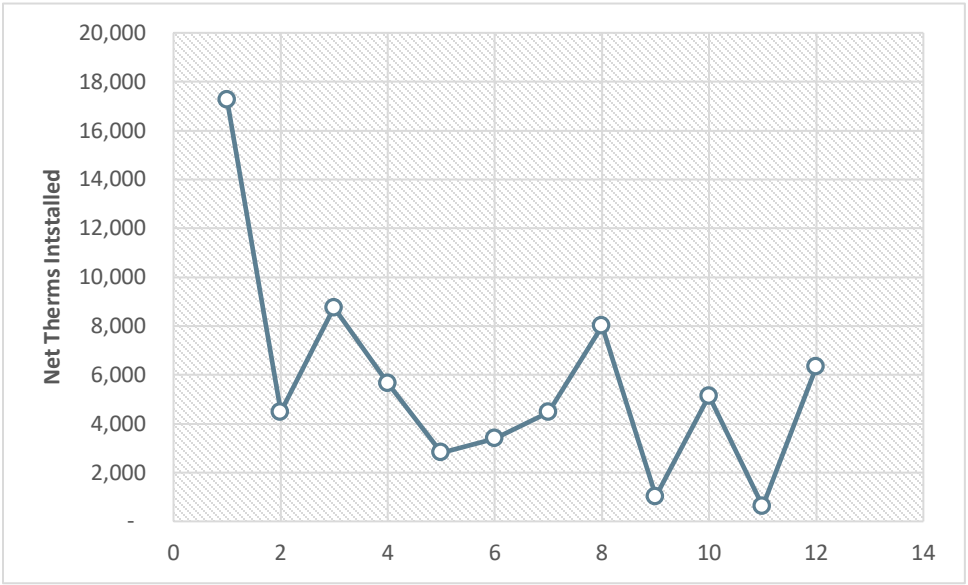


Figure 5-3: C&I Solutions Direct Install Monthly Therms Savings

5.1.2 Closed Custom Project Participation Summary

Table 5-2 summarizes the completed custom projects for the program. Closed custom projects are projects that have been verified by the evaluator and an incentive has been issued by BHEA.

Table 5-2: Custom Project Participation Summary

Facility Type	Project ID	Measure	Ex Post Savings
Industrial	PRJ-1794921	Economizer	82,200
K-12 Education	PRJ-1861832	Steam to Hot Water Retrofit	18,973
School/University	PRJ-2135401	Steam Trap Replacement	29,063
		Steam Leak Repair	4,782
		Insulation – Valves/Fittings	6,481
Assembly	PRJ-2135982	Smart Thermostat	1,940
Industrial	PRJ-2155782	Steam Leak Repair	5,490
		Steam Trap Replacement	63,210
Food Processing	PRJ-2174721	Steam Trap Replacement	11,335
		Steam Trap Replacement	36,893
		Insulation – Valves/Fittings	3,362
Food Processing	PRJ-2174811	Steam Trap Replacement	150,513
		Steam Leak Repair	6,329
		Insulation – Pipes	24,524
		Boiler	18,038
Hospital	PRJ-2176009	Steam Trap Replacement	2,783
		Steam Leak Repair	7,322
		Insulation – Pipes	7,942
Hospital	PRJ-2176549	Steam Trap Replacement	11,576
		Steam Leak Repair	26,312
		Insulation – Pipes	1,657
Industrial	PRJ-2176730	Steam Trap Replacement	56,343
		Steam Leak Repair	3,243
		Condensate Return	14,990
Multifamily	PRJ-2178782	Excess Air/ Outside Air Reduction	17,919

5.1.3 Prescriptive Rebate Summary

In PY2019, the program rebated six HVAC boilers at six facilities and 13 pieces of cooking equipment at 8 facilities. There were 4 convection ovens and 4 fryers rebated. The total savings from these projects was 46,219 net therms.

5.2 C&I Solutions Process Evaluation

The Evaluators conducted a formal process evaluation of the C&I Solutions Program in PY2017 and found that the program was successful in meeting participation, savings, and satisfaction goals. Table 5-3 and Table 5-4 summarize the Evaluators' review of the C&I Solutions Program in comparison to TRM V8.0 Protocol C for timing and conditions of conducting a process evaluation.

Table 5-3: Determining Appropriate Timing to Conduct a Process Evaluation

Component	Determination
New and Innovative Components	Yes. The program introduction steam system survey incentives.
No Previous Process Evaluation	No. The program received a comprehensive process evaluation in PY2017.
New Vendor or Contractor	No. The program has been implemented by CLEAResult since PY2011.

Table 5-4: Determining Appropriate Conditions to Conduct a Process Evaluation

Component	Determination
Are program impacts lower or slower than expected?	No. The program met savings goals in PY2018.
Are the educational or informational goals not meeting program goals?	No. The program has an established trade ally network.
Are the participation rates lower or slower than expected?	No. The program met participant goals in PY2018.
Are the program's operational or management structure slow to get up and running or not meeting program administrative needs?	No. The PY2018 process evaluation found that operational and management structure to be up to speed and efficient in administering the program.
Is the program's cost-effectiveness less than expected?	No, the program's cost-effectiveness vastly exceeded expectations.
Do participants report problems with the programs or low rates of satisfaction?	No. Participant surveys found exceedingly high satisfaction levels.
Is the program producing the intended market effects?	Yes. Interviews with participants and trade allies have shown market transformation is occurring.

Based on these findings, process evaluation activities were limited to a review of the new steam system study incentive required for PY2019.

5.2.1 Data Collection Activities

The process evaluation of the C&I Solutions Program included the following data collection activities:

- *Program Actor In-Depth Interviews*. The Evaluators conducted in-depth interviews with a series of program actors. These interviews covered a range of topics, including marketing efforts, feedback on program delivery, an assessment of barriers to program implementation and success, and recommendations for program improvement. Program Actors interviewed include:
  - *BHE Program Staff*. The Evaluators interviewed staff at BHE involved in the administration of the C&I Solutions Program. These interviews built upon interviews conducted in PY2018, keeping apprised of BHE's involvement as the C&I Solutions Program develops.

- *Third Party Implementation Staff Interviews.* The Evaluators conducted interviews with CLEAResult involved with the C&I Solutions Program. These interviews addressed the development of the program over the PY201 program year as well as CLEAResult's perspective on a variety of implementation issues, including conversion of audits to completed projects and the process flow for direct install and custom projects.

- *Participant Surveying*. A census of custom participants was surveyed for this evaluation effort. These surveys included net-to-gross and process issues. The surveys provided valuable data for this process evaluation effort, providing participant feedback as to their program participation, recommendations for program improvement, and insight into the decision-making process.

Table 5-5 summarizes the data collection for this process evaluation effort. This includes the titles, roles, and sample sizes for data collection.

Table 5-5: BHE C&I Solutions Data Collection Summary

Target	Component	Activity	n	Precision	Role
BHE Program Staff	Manager, Energy Efficiency	Interview	1	N/A	Overall administration of BHE the larger strategic decisions associated with the DSM portfolio, and is involved with the C&I Solutions Program in the overall coordination of utility resources.
CLEAResult Staff	Program Manager	Interview	1	N/A	The Program Manager handles day-to-day operations, including tracking of outreach and implementation activities, payments for direct installation, and interfacing with Evaluation staff.
Program Participants	Custom Participants	Survey	7	±0%	Custom participants received a semi-structured interview at the beginning of a project and a structured survey at the close. The Evaluators interviewed a census of participants
	Partial		10	±22%	Surveys with partial participants to address reasons for not installing recommended projects. Sample was cross cutting with 1 AOG, 7 CNP, 2 BHE customers.

5.2.2 Process Results & Findings

This section will present the results and key findings from the data collection activities. These findings are based upon interviews with utility staff, implementation staff, surveys with participants, and thorough and in-depth literature review.

5.2.2.1 Response to Program Recommendations

Table 5-6 summarizes PY2018 recommendations and BHE responses.

Table 5-6: C&I Solutions Response to PY2018 Recommendations

Recommendation	BHE Response	Status of Issue
In planning for the next triennial, add prescriptive measures that have been added to the TRM. This would include new food service equipment (under-fire boilers, conveyor broilers), HVAC (demand control ventilation)	These measures have not been added at this time.	Under consideration.

5.2.2.2 Program Theory & Design

The C&I Solutions Program was designed to provide outreach in hard-to-reach sectors of the C&I markets. The main bullets below list program activities and their expected outcomes as determined through the PY2018 process evaluation. The secondary bullets indicate new program enhancements.

- **Direct installation of high-return measures.** The C&I Solutions program provides no-cost direct installation of weather stripping, low flow faucet aerators, pre-rinse spray valves, and showerheads. These measures have a high return of savings relative to their cost and as such can be provided free-of-charge and remain cost-effective. The provided savings are unlikely to occur absent the program; generally, if a respondent does not already have the equipment in place, the direct install activities induce an action that was not planned. It is also the intention that these activities will serve as an introductory teaser to energy efficiency for the recipients, and that they will then be further interested in participating in the custom component of the program.
- **Energy audits to medium and large customers.** These audits are conducted by CLEAResult staff, providing recommendations for energy efficiency improvements and an audit report. These audits are intended to generate the bulk of the program savings, yielding high-return custom projects.
    - **Steam system survey incentives.** These incentives defray the cost of steam system surveys for participating trade allies, allowing them to provide detailed project scoping at no upfront cost to them or to the customer.
- **Incentives for custom measures.** The C&I Solutions Program provides $0.75 per Therm for verified savings from custom projects. These projects may be driven by a program-funded audit, generated by a trade ally, or be customer-directed.
- **Incentives for prescriptive measures in C&I Solutions.** This includes boiler and food service equipment at fixed incentive rates.
- **Referral to Equipment Rebates Program.** There are instances where the CLEAResult audit identifies energy savings opportunities that qualify for a prescriptive incentive from the

above-mentioned program. In these instances, the project is referred to the program and savings are not credited to the C&I Solutions Program.

5.2.2.3 Program Administration

The C&I Solutions Program is overseen by the Manager of Energy Efficiency at BHE. This manager's responsibilities primarily include interfacing with CLEAResult, who directly implements the program. Other activities by this manager include providing updated customer lists to CLEAResult to better facilitate their implementation, review of custom applications, and at times assisting CLEAResult in customer interactions.

For CLEAResult, the program overall is led by the Program Manager, who oversees the implementation of the C&I Solutions Program from CLEAResult's Fayetteville, AR office. This manager handles high-level issues across the programs, including regulatory compliance and reporting, as well as some level of intervention on the larger projects.

Much of the day-to-day activity is handled by the Program Manager. The Program Manager reviews direct install and audit activity, and coordinates with the Evaluators in facilitating EM&V activities.

Audit activities are run by Energy Engineers and Field Engineers. These engineers conduct the energy audits. Additionally, their responsibilities include development of the audit report and recommendations. The Direct Install Program Manager oversees crews that perform direct installation. Further, the Associate Account Manager follows up with customers to gauge interest in completing a project.

5.2.2.4 Program Implementation and Delivery

Throughout the program year, CLEAResult would provide the Evaluators with updates regarding their pipeline of custom projects. The Evaluators were provided with monthly updates, listing the full scope of facility audits, expected savings with associated recommended measures, and what stage the project was in. These stages are:

- *Pipeline*. Projects listed as Pipeline are in the first phase of involvement in the Commercial & Industrial Solutions Program. These participants are customers that have discussed the possibility of a facility audit and indicated interest to CLEAResult. These facilities will receive a Pre-Inspection at a later date and have not signed a project application.
- *Pre-Inspected*. Projects listed as Pre-Inspected are in the phase where CLEAResult has completed a facility audit. During these audits, CLEAResult conducts a comprehensive review of the facility's systems and operational practices. On this basis, CLEAResult then formulates initial recommendations for energy efficiency improvements. These are

discussed with facility staff during the audit in order to address the feasibility of recommended measures.

- *Pre-Installation Calculation*. At this phase, CLEAResult is compiling high-level data needed to provide an initial estimate of energy savings. This step of the process compiles the information collected in the site audit, which are then used in the development of an Audit Report.
- *Audit Report Complete*. In this phase, feasible measures from the Pre-Inspection are compiled into a formal audit report, providing the participant with further detail as to the scope of the project, initial savings estimates, associated incentives, expected project costs, and the payback period of the measure. Additionally, should the measure provide operational benefits to the facility (such as improved comfort or product reliability), these are included as well to provide the customer with a full scope of the benefits of the project. This report is provided at no cost to the participant.
- *Project Agreement*. At this point, the customer has informed CLEAResult and BHE that they intend to install a program-recommended measure. When this occurs, CLEAResult then involves the evaluators. CLEAResult provides the evaluators with an M&V plan for the facility, detailing the project scope and proposed data collection and analysis. The evaluators' engineering staff then reviews the M&V plan and makes recommendations for any changes needed. If this revises the savings amount, the reserved incentive amount in the application is revised. A project agreement is then signed, in which the reserved incentive amount is detailed and reflects edits made by the evaluators.
- *Post-Inspection*. This phase marks the completion of post-inspection for an installed measure. CLEAResult has, at this point, post-inspected a measure and revised savings accordingly if the installed project differs from the proposed project. At this point, 60% of the reserved incentive is paid to the customer.
- *M&V*. M&V marks the phase when post-installation data is collected for an installed project to allow for calculation of a final savings estimate, from which the remaining incentive to the customer is determined. There are some measures that do not require post-retrofit data; for such measures, the M&V phase is short and requires completion of calculations based upon inputs verified during the Post-Inspection. For facilities that require post-installation data, the data collection period can range from 30 days to 6 months.
- *Complete*. Facilities marked as Complete have received their full incentive. As stated prior, 40% of the reserved funds for the incentive are available to pay the remaining incentive amount owed to the customer. If the verified savings are below the Project Agreement savings, the customer's incentive is reduced accordingly, so as to keep incentive levels at

$.75/Therm. If the verified savings are higher than the Project Agreement amount, CLEAResult and BHE determine if there are available incentive funds left for the program year. If the program has remaining funds, the customer receives a total incentive higher than the initial agreement. If no remaining funds are available, the customer's incentive is capped at the Project Agreement amount.

The process flow for the C&I Solutions Program is displayed in the figure below.

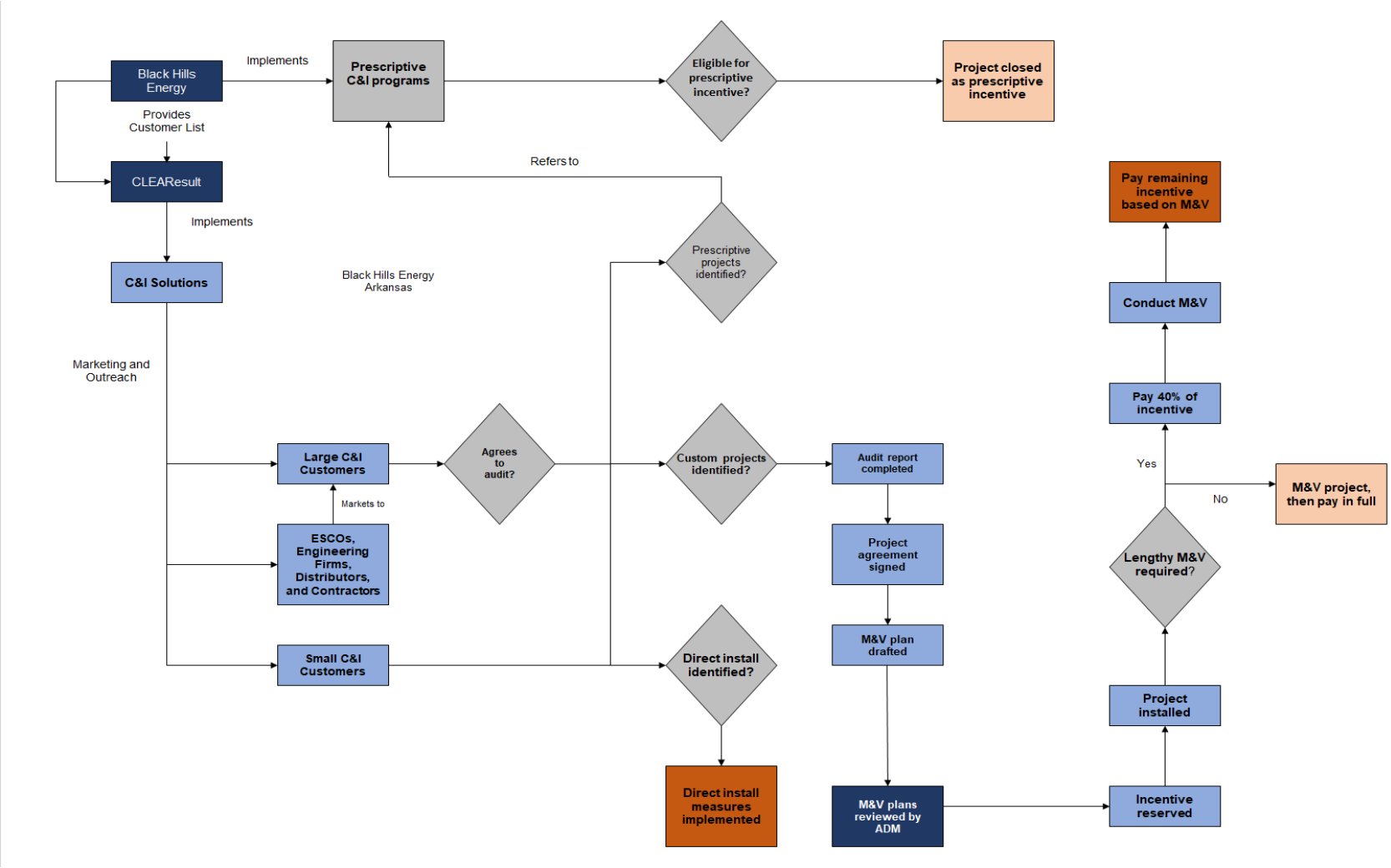


Figure 5-4: C&I Solutions Process Flow

5.2.3 Adherence to Protocol A

The CLEAResult tracking system contained full detail with project addresses, contact information, and measure inputs. Further, the tracking system provided the Therms savings for each line item.

During PY2019, the Evaluators received monthly tracking data updates as well as final tracking exports. The tracking system was updated to include necessary inputs as per AR TRM V8.0. Other than these updates, there were no major updates to the structure or content of program tracking data. The Evaluators previously reviewed program tracking data in PY2018 to assess its compliance with Protocol A of the AR TRM which specifies that tracking data should be checked for:

- Participating Customer Information;
- Measure Specific Information;
- Vendor Specific Information;
- Program Tracking Information;
- Program Costs; and
- Marketing & Outreach Activities.

The Evaluators conducted a review of each of the above factors within PY2019 tracking data except for marketing and outreach activities as these are outside the scope of the tracking system's reporting.

Customer, Premise, Cost, and Vendor Information

Each of these factors was assessed individually based on the guidelines stated in AR TRM V8.0. Overall, the Evaluators conclude the following regarding tracking data completeness:

- Participating customer information was complete for nearly all participants.
- Custom and prescriptive projects contained complete information on the contractor that completed the installation. This was not needed for direct install as this is done in-house with CLEAResult staff.
- Tracking data included the measure and project costs for each project.
- Weather zones were provided in the tracking data.
- All inputs needed to re-calculate savings according to TRM V8.0 protocols were present in the direct install database.

Measure Specific Information

The content of tracking data was found to include sufficient information for all measures in PY2019.

5.2.4 Custom Project Survey Response

The Evaluators conducted interviews with the seven decision-makers responsible for the completed custom projects in the C&I Solutions Program in PY2019. Given the small number of interviews, reporting data in terms of percent response by question does not adequately present the participant response to the program. The Evaluators opted to present the results in terms of individual case studies, rather than aggregated survey responses.

PRJ-1794921, PRJ-2155782: The participant is an industrial facility that received incentives for steam trap replacement, steam leak repair, and a boiler economizer. The facility staff have an energy consultancy developing projects in coordination with CLEAResult under the restriction of a maximum payback period of two years. The program incentives were necessary to bring the steam trap replacement within their allowed payback criterion. The trap replacements and leak repairs completed here are part of an ongoing retrofit of the facility, who completed prior projects in PY2017 and PY2018. The economizer component is claiming 60% of savings in PY2019, with the remaining 40% to be trued-up in PY2020.

PRJ-1861832: The participant is boarding school that received incentives for converting from two steam boilers to two hot water boilers and two water heaters. This retrofit disaggregated space heating and DHW loads to two separate boilers rather than using a combined steam system. The project received a 40% incentive in PY2018 and the results in PY2019 trued up the remaining savings and incentive amount.

PRJ-2174721: The participant is a food processing facility that received incentives for steam trap replacement and insulation. The participant received an incentive for a steam system survey in Q1 of 2019 that identified the projects. The respondent noted the difficulty they have completing projects, even when presented with good opportunities: “We dragged our feet as a company. At that time, we had to put up the investment cost on the front end for reimbursement, and my company wasn’t comfortable putting it up front. But we don’t have to do that any longer, now we don’t have to put the upfront cost and have that reimbursed down the road”.

PRJ-213501: The participant is a university which received incentives for steam trap replacement, steam leak repair, and insulation of valves and fittings. The participant received a steam system survey incentive in Q1 of 2019, identifying the savings opportunities. In past discussions with this participant, they have made it known that while they have sustainability goals, the goals are in part functionally unattainable without assistance because of a lack of in-house expertise in identifying and completing projects.

PRJ-2174811: The participant is a food processing facility that received incentives for steam trap replacement, steam leak repair, pipe insulation, and a boiler replacement. This participant completed a pipe and valve insulation in PY2018, and a steam trap retrofit in PY2017. The participant received an incentive for a steam system survey, completed in Q1 of 2019 which

identified this round of projects. The boiler retrofit component is claiming 60% of savings in PY2019, with the remaining 40% to be trued-up in PY2020.

PRJ-2176009, PRJ-2176549: The participant is a chain of hospitals that received incentives for steam trap replacement, steam leak repair, and pipe insulation at two separate premises. They received a steam system survey from the program in Q1 of 2019. They were first referred to the program by a mechanical contractor engaged for repair work. The respondent noted that they had made no steam system improvements at either location in their 10 years of employment with the hospital system, and that the projects proposed would not have met financial criteria for payback without incentives nor would have been known to the facility without the steam system survey.

PRJ-2176730: The participant is an industrial facility that received incentives for steam trap replacement, steam leak repair, and condensate return. The participant received an incentive for a steam system survey, completed in Q1 of 2019 which identified this round of projects. The respondent noted that though they had ideas surrounding these projects, incentive funds advanced the timeline significantly. They stated that the projects ”would be at least two years out; I’m not allocated the money”. The condensate return component is claiming 40% of savings in PY2019, with the remaining 60% to be trued-up in PY2020

5.3 C&I Solutions Impact Evaluation

The impact evaluation of the C&I Solutions Program included the following:

- *Custom Project M&V.* The Evaluators conducted project-specific M&V on a census of custom projects completed through the C&I Solutions Program. Each project included an M&V plan and a project-specific report. The reports are provided in Appendix A.
- *Free-Ridership Estimation.* A free ridership rate for DI participants was estimated through participant surveying. Respondents were asked a series of questions related to their past experience with the appropriate measures, whether they had ever installed similar equipment at the participating premise or at other premises within their organization, and whether they knew of the potential savings from the DI measures prior to participating. Given the types of measures covered by the DI component, the free ridership rate is essentially focused on to what extent participating organizations had policies in place to install such equipment anyway. If such policies were not in place, then the installation of the equipment is generally considered to be program-induced.
- *Participant Spillover.* Spillover was addressed for two customer classes: Participants and Partial Participants. Participants were surveyed for free ridership and process evaluation, and over the course of that survey are asked a series of questions addressing whether the C&I Solutions Program induced them to install other energy efficient equipment without

program incentive. Additionally, the Evaluators asked these customers for an estimate of savings that they expect from these measures. This was supplemented with Partial Participant Surveying. Partial Participants are defined as those which received a facility audit and measure recommendations (with associated savings estimates). Samples of these participants were interviewed, and over the course of these interviews were asked if they installed any measures recommended through the program without having signed a Project Application or receiving an incentive.

5.3.1 Summary of Non-Energy Benefits

Table 5-7 summarizes the non-energy benefits by measure that will be credited to the C&I Solutions Program.

Table 5-7: C&I Solutions Non-Energy Benefits

Measure	Electric Savings	Water Savings	Propane Savings	Deferred Replacement Cost
Steam Leak Repair		✓		
Condensate Return		✓		
Faucet Aerators		✓		
Low Flow Showerheads		✓		
Low Flow PRSVs		✓		
Weather Stripping	✓			

5.3.1.1 Water Savings Calculation Procedure

The TRM V8.0 provides detail for calculation of water savings for the following measures:

- Faucet Aerators (3.3.2);
- PRSVs (3.8.11); and
- Low Flow Showerheads (3.3.5).

The deemed savings procedures for these measures require calculation of water savings, and the water savings claims comply with TRM protocols.

5.3.2 C&I Solutions Direct Install Impact Evaluation

5.3.2.1 Deemed savings calculations

For sample TRM calculations, see Appendix C.

5.3.2.2 Direct Install Free-Ridership

In prior evaluations, the methodology for DI Free-Ridership was focused on the participants' past experiences with the appropriate equipment and whether they had organizational policies in place to install such equipment. Respondents were asked:

Q22. Before to participating in the C&I Solutions Program, did you have plans to install [LIST MEASURE]?

Q23 Would you have gone ahead with this planned project even if you had not participated in the program?

Twenty percent of respondents stated that they were aware of the savings potential from such equipment.

Q27 If the [PROGRAM] program representative had not recommended installing the [PROJECT_DESCRIPTION], how likely is it that you would have installed it anyway?

1. Definitely would have installed
2. Probably would have installed
3. Probably would not have installed
4. Definitely would not have installed
98. Don't know

These are combined into the following factors:

A. **Prior Plans:** If the respondent indicated plans to install prior to participation, they receive a "1" for this metric.

B. **Installation counterfactual:** If they respondent states that they would have gone ahead with this project without the program, they receive a "1" for this factor.

C. **Program Influence:** If a respondent states that they "Definitely would have" or "probably would have" installed this equipment without the program, they receive a "1" for this factor.

To be found a free rider, a respondent must receive a "1" score for all three factors. The direct install channel was found to have 100% NTGR.

5.3.2.3 Direct Install Spillover

No instances of spillover were identified among the C&I Solutions DI survey respondents.

5.3.3 C&I Solutions Prescriptive Projects Impact Evaluation

The C&I Solutions Program processed 19 prescriptive rebates in PY2019. These projects included:

- 7 fryers;

- 6 Convection Ovens
- 6 HVAC boiler replacements

The Evaluators found that savings calculations corresponded to TRM V8.0 specifications (see TRM V8.0 Vol. 2 Sections 3.1.8, 3.1.17 and 3.8.6). No errors were identified, and corresponding realization rates were 100%

Table 5-8: BHE C&I Solutions Prescriptive Project Summary

Measure	Ex Ante Gross Savings	Ex Post Gross Savings	Gross Realization Rate	Gross Lifetime Savings
HVAC Boilers	31,203	38,207	122.4%	764,141
Food Service	7,081	10,069	142.2%	120,828
Total	38,284	48,276	126.1%	884,969

5.3.4 Prescriptive Program Free-Ridership

Due to low participation volume, the Evaluators applied NTGR estimates from prior CenterPoint evaluations. These NTGRs are as follows:

- Boiler Replacement: 80.28%
- Food Service: 77.20%

5.3.5 Steam System Surveys

In PY2019, the program began providing incentives for steam system surveys. These incentives are provided to program trade allies that conduct detailed steam system assessments intended to identify energy savings opportunities: steam trap replacement, steam leak repair, and insulation, as well as potential higher-value projects. This incentive is intended to overcome a common first-cost barrier identified by program participants in that there was a lack of willingness to fund a steam system survey when there was not the guarantee of a viable project resulting from it. In past evaluations, it was found that at times program trade allies were completing costly surveys free-of-charge in an effort to develop projects. This steam system survey incentive is intended to encourage trade allies to complete these activities at a greater number of facilities; when left to make the decision on their own, the concern was that studies would not be conducted on facilities thought to have just a low to moderate probability of viable projects.

In PY2019, incentives were provided for 10 surveys to eight customers (two customers had separate surveys completed at multiple locations, totaling $29,113 in incentive spend. Of these 10 surveys, seven resulted in PY2019 projects.

The seven project conversions produced custom projects totaling 423,488 net therms, 69% of custom channel total savings. These results are encouraging and should be expanded upon in future program years.

The Evaluators do note that these were tracked separately from the rest of program tracking, without a project ID. Program staff should assign a project ID (PRJ-######) to surveys as incentives are paid out.

5.4 C&I Solutions Custom Project Impact Evaluation

The Evaluators opted for a census of custom projects in order to capture the full variability associated with these projects; the measures are often unique with idiosyncratic issues, and as such extrapolation from the M&V of other projects would be inappropriate. Table 5-9 summarizes the custom projects completed and evaluated in PY2019. In this table, "Reserved Savings" are the savings used to determine the amount of incentive funds reserved for the project at the time of signing a Project Agreement. This is essentially an initial ex ante value which determines the maximum possible incentive a project can receive following M&V. Forty percent of this amount is paid at the time of verification of installation, with the remaining held in reserve until the M&V of the project is complete. "Ex Ante Savings" is the value calculated by CLEAResult after M&V. "Ex Post Savings" is the savings calculation completed by the Evaluators.

Table 5-9: BHE C&I Solutions Custom Project Summary

Facility Type	Project ID	Measure	Reserved Savings	Ex Ante Savings	Ex Post Savings	M&V Protocol
Industrial	PRJ-1794921	Economizer	82,200	82,200	82,200	Option A
K-12 Education	PRJ-1861832	Steam to Hot Water Retrofit	18,973	18,973	18,973	Option C
University	PRJ-2135401	Steam Trap Replacement	29063	29,063	29,063	Option A
		Steam Leak Repair	4,782	4,782	4,782	
		Insulation – Valves/Fittings	6,481	6,481	6,481	
Town Hall	PRJ-2135982	Smart T-Stat (Pilot)	1,940	1,940	1,940	Option A
Industrial	PRJ-2155782	Steam Leak Repair	3,071	3,071	5,490	Option A
		Steam Trap Replacement	63,211	63,211	63,210	Deemed
Industrial	PRJ-2174721	Steam Trap Replacement	11,335	11,335	11,335	Option A
		Steam Trap Replacement	36,893	36,893	36,893	
		Insulation – Valves/Fittings	3,362	3,362	3,362	
Industrial	PRJ-2174811	Steam Trap Replacement	150,513	150,513	150,513	Option A
		Steam Leak Repair	6,329	6,329	6,329	
		Insulation – Pipes	24,524	24,524	24,524	
		Boiler	18,038	18,038	18,038	
Hospital	PRJ-2176009	Steam Trap Replacement	2,783	2,783	2,783	Option A
		Steam Leak Repair	7,322	7,322	7,322	
		Insulation – Pipes	7,942	7,942	7,942	
Hospital	PRJ-2176549	Steam Trap Replacement	11,576	11,576	11,576	Option A
		Steam Leak Repair	26,312	26,312	26,312	
		Insulation – Pipes	1,657	1,657	1,657	
Industrial	PRJ-2176730	Steam Trap Replacement	56,343	56,343	56,343	Option A
		Steam Leak Repair	3,243	3,243	3,243	
		Condensate Return	14,990	14,990	14,990	
Lodging	PRJ-2178782	Excess Air/ Outside Air Reduction	17,919	17,919	17,919	Deemed
		Total	**610,802**	**610,802**	**613,220**	

5.4.1.1 Custom Project Free-Ridership

The Evaluators conducted interviews with nine decision-makers responsible for the completed custom projects in the C&I Solutions program in PY2019. Given the small number of interviews, reporting data in terms of percent response by question does not adequately present the participant response to the program. The Evaluators opted to present the results in terms of individual case studies, rather than aggregated survey responses. The methodology used by the

Evaluators in determining the free ridership rates for custom projects examined the following factors:

- *Knowledge gained from program outreach*. If the project originated from program outreach (which may include program-sponsored training courses or facility audits), the respondent is asked if they had prior knowledge of the energy-saving opportunity recommended and eventually installed. If the respondent learned of the measure through the program audit or program–sponsored training, then they are considered to not have been free riders, in that in the absence of the program, the likelihood of the facility receiving a similarly detailed audit are low. Questions used in evaluating this criterion include:

FI-1 Prior to participating in the C&I Solutions Program, did your organization install any equipment similar to [EQUIPMENT/MEASURE] at your facility without financial incentives or rebates?

- ❑ Yes
- ❑ No

FI-1a Did you learn of this measure through your participation in the Commercial & Industrial Solutions Program?

- ❑ Yes [IF YES, ASK FI-1b] Do you recall how you learned of the measure?
- ❑ No

- *Prior plans for a similar measure*. This component is examined in instances where the respondent knew of the measure prior to receiving and technical assistance through the C&I Solutions Program. Respondents are asked a series of questions related to whether they had plans for installing this equipment prior to having learned of the available financial incentives from the C&I Solutions program. Questions used in this component include:

FI-1 Prior to participating in the C&I Solutions Program, did your organization install any equipment similar to [EQUIPMENT/MEASURE] at your facility without financial incentives or rebates?

- ❑ Yes
- ❑ No

FI-2 Did you have plans to install the [EQUIPMENT/MEASURE] that was upgrades through C&I Solutions before participating in the program?

- ❑ Yes
- ❑ No

If Yes: FI-2a Would you have gone ahead with this planned installation without the program rebates?

❑ Yes
❑ No

FI-2b Would this installation have included the same equipment without the program rebates?

❑ Yes
❑ No

- *Analysis of measure payback*. Respondents are asked to indicate what their required payback period is for energy efficiency improvements. This value is compared against the measure payback with and without the program incentive. If the financial incentive brings the project from over the threshold to under the threshold, then the project is considered to have been sufficiently influenced by the program incentive. This includes the following questions:

DM-5 Does your organization require a specific payback period in order to implement energy efficiency improvements?

❑ Yes [ASK DM-5A]
❑ No [SKIP TO DM-6]
❑ Don't know [DON'T READ]

DM-5a What **payback** *length of time* do you normally require in order to consider an energy investment cost effective?

____ Years

❑ Don't know

The stated payback requirement by the respondent is then compared against the payback of the recommended project with and without the program incentive.

- *Modification of the project*. Respondents are asked a series of questions addressing whether they modified the project as a result of their program participation. This includes changes in equipment quantity and/or efficiency level (where appropriate for the measure) and a change in project timing. Questions used to analyze this component include:

FI-5 If the C&I Solutions through C&I Solutions Program were not available, would you have installed the…

❑ Same quantity of energy efficient equipment,
❑ A lower quantity, or
❑ No energy efficient equipment at all?

[IF FI-5 = "Lower Quantity"]: FI-5a: By percentage, how much lower?

FI-6 If the C&I Solutions program were not available, would you have installed …

❑ The same equipment with the same efficiency level,

- ❑ The same equipment with a lower energy efficiency level, but still above minimum code, or
- ❑ standard efficiency equipment?

[IF FI-6 = "Lower efficiency level, but still above minimum code"]: FI-6a: By percentage, how much lower?

FI-7 Did the C&I Solutions rebate allow you to install [EQUIPMENT/MESURE] sooner than you otherwise would have?

- ❑ Yes

🡻

IF YES: FI-7a When would you otherwise have installed the equipment? (READ IF NEEDED)

- ❑ In less than 6 months later
- ❑ In 6-12 months later
- ❑ In 1-2 years later
- ❑ In 3-5 years later
- ❑ In more than 5 years later
- ❑ No, did not affect timing of purchase and installation

The scoring mechanism for custom projects is presented in Figure 5-5.

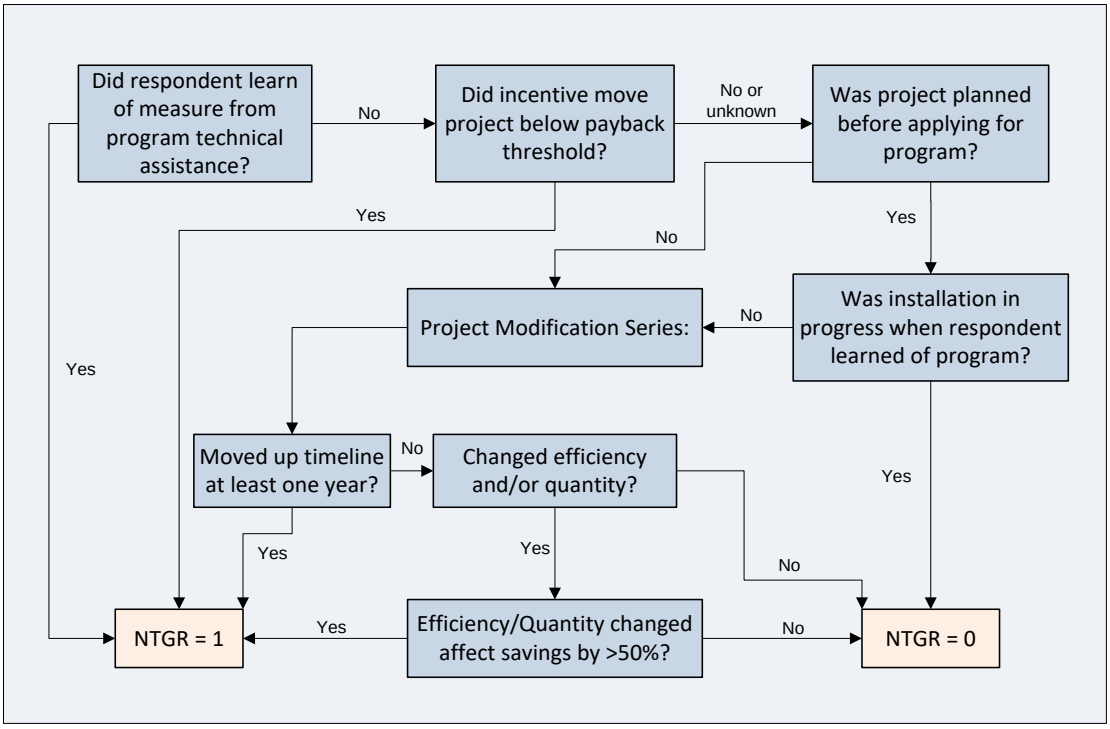


Figure 5-5: C&I Solutions Custom Project Free-Ridership Diagram

The resulting NTGRs by project are presented in Table 5-10.

Table 5-10: BHE C&I Solutions Custom Project Free-Ridership Results

Facility Type	Project ID	Measure	Gross Savings	Net to Gross Ratio
Industrial	PRJ-1794921	Economizer	82,200	100%
K-12 Education	PRJ-1861832	Steam to Hot Water Retrofit	18,973	100%
University	PRJ-2135401	Steam Trap Replacement	29,063	100%
		Steam Leak Repair	4,782	100%
		Insulation – Valves/Fittings	6,481	100%
Town Hall	PRJ-2135982	Smart T-Stat (Pilot)	1,940	100%
Industrial	PRJ-2155782	Steam Leak Repair	5,490	100%
		Steam Trap Replacement	63,210	100%
Industrial	PRJ-2174721	Steam Trap Replacement	11,335	100%
		Steam Trap Replacement	36,893	100%
		Insulation – Valves/Fittings	3,362	100%
Industrial	PRJ-2174811	Steam Trap Replacement	150,513	100%
		Steam Leak Repair	6,329	100%
		Insulation – Pipes	24,524	100%
		Boiler	18,038	100%
Hospital	PRJ-2176009	Steam Trap Replacement	2,783	100%
		Steam Leak Repair	7,322	100%
		Insulation – Pipes	7,942	100%
Hospital	PRJ-2176549	Steam Trap Replacement	11,576	100%
		Steam Leak Repair	26,312	100%
		Insulation – Pipes	1,657	100%
Industrial	PRJ-2176730	Steam Trap Replacement	56,343	100%
		Steam Leak Repair	3,243	100%
		Condensate Return	14,990	100%
Lodging	PRJ-2178782	Excess Air/ Outside Air Reduction	17,919	100%
		Overall Gross Savings:	613,220	100%
		Overall Net Savings:	613,220	100%

Given the small number of participants, the free rider assessments were a series of case studies as opposed to an extrapolated survey. The individual free rider assessments are contained within the survey narrative responses detailed in Section 5.2.3.

5.4.1.2 Participant Spillover

Participant spillover is defined as savings from program participants that was not incentivized by the BHE programs. During participant surveying, both DI and Custom participants are asked questions addressing whether their participation had led to the installation of equipment that was not rebated by BHE. The estimated savings from these projects are tallied and added to the program savings as Participant Spillover.

OS-3 Has your organization's participation in the C&I Solutions Program led you to buy any energy efficient equipment for which you did not apply for a financial incentive?

- ❑ Yes

  ⬇

  If Yes: OS-3a What type of equipment? _____

- ❑ No
- ❑ Don't know [DON'T READ]

The Evaluators did not identify any participant spillover.

5.4.1.3 Partial-Participant Spillover

Partial-participant spillover are savings resulting from projects that were recommended to recipients of audits through the C&I Solutions Program that were completed without filing for program incentives. Respondents are asked:

> Have you since implemented any of the recommendations from your facility audit?
>
> a. If Yes: Why didn't you install these measures through the available incentive program?

It is then clarified as to whether the respondent installed the project as specified in the audit or made modifications to the project. This is combined in providing an estimate of non-incentivized savings, which constitutes the Partial Participant Spillover. This year a survey was conducted to assess the partial participants.

5.4.1 Partial Participant Survey

Ten partial participants from the Commercial and Industrial Solutions program from CenterPoint Energy, Black Hills Energy, and Arkansas Oklahoma Gas were all surveyed. Partial participants are those customers that received a utility audit from CLEAResult but did not get a rebate. The survey was completed via email with telephone follow-up. All available respondents received three separate email attempts as well as three attempted phone contacts.

The purpose of this survey was to learn why participants did not complete a project after having received an audit report to provide feedback to the AR gas utilities. Due to the small pool of customers to survey the results have been aggregated in this report.

Those surveyed were asked if they recalled receiving an audit report with a recommendation to install a variety of energy efficient measures. The table below summarizes the number of respondents and the estimated gas savings (Therms/year), if they had installed the equipment recommended in the audit.

Table 5-11: Partial Participant Sample Summary

Utility	Respondents (n=10)	Estimated Gas Savings (CCF/year)
CenterPoint Energy	7	457,873
Black Hills Energy	2	8,051
Arkansas Oklahoma Gas	1	5,766
Total	**10**	**471,690**

Respondents were asked what motivated their organization to participate in the C&I Solutions Program. Most of the respondents (80%) stated they were motivated by the potential for operational cost reductions.

Respondents were asked what energy savings opportunities were discussed over the course of their facility audit. The savings opportunities include electrical upgrades, insulation, and HVAC improvements. Two out of ten respondents did not remember what had been discussed.

Respondents were asked about their awareness of the energy-savings potential from each of their recommendations shown in the audit before participating in the program per measure. Forty percent of respondents stated that the audit identified potential improvements that they had not been aware of in their facility. Examples of all measures recommended in the audit include boiler replacement (two respondents), steam trap replacement (two respondents), insulation, and infrared heaters.

Respondents were asked why their organization did not install the recommended improvements. Four out of the nine (44%) who answered this question did not recall the recommendations. Some other responses include recommendations not being a priority and the cost of the recommendations. They were further asked why the recommendations were not viable. A common response included that they did not have time to complete the work.

Lastly, respondents were asked if they had any final comments about the Commercial & Industrial Solutions program of their respective utilities. One stated that the program needs more visibility with industries since “the program is not well known”. Another respondent stated that they were not clear the that the recommendations were energy efficient.

5.5 Ex Post Savings

Table 5-12 presents the gross savings results of the evaluation of the PY2019 C&I Solutions Program. Total gross savings summarizes the savings calculations performed by TRM protocols for direct install measures as well as the project-specific M&V of custom measures.

Table 5-12: C&I Solutions Ex Post Therms Savings

Measure Category	Ex Ante Therms Savings	Ex Post Therms Savings	Gross Realization Rate	EUL	Lifetime Therms Savings
Direct Install	68,876	67,909	98.6%	11	744,401
Prescriptive	38,284	48,276	126.1%	16	884,969
Custom	610,802	613,220	100.4%	11	31,110,619
Total	717,962	729,405	108.37%	13	32,739,989

Net savings for the C&I Solutions Program were calculated using survey data of direct install and custom participants. The resulting net savings are presented in Table 5-13.

Table 5-13: C&I Solutions Net Savings Summary

Measure Category	Free-Ridership Rate		Net Annual Savings		Net Realization Rate	Net Lifetime Therms Savings
	Ex Ante	Ex Post	Ex Ante	Ex Post		
Direct Install	0.00%	0.00%	68,876	67,909	98.60%	744,401
Prescriptive	20.2%	20.3%	30,516	38,445	126.10%	706,732
Custom	0.00%	0.00%	610,802	613,220	100.40%	5,151,417
Total	**0.43%**	**0.46%**	**710,194**	**719,575***	**101.59%**	**6,602,550**
***Difference due to rounding**						

The Evaluators applied AR TRM v8.0 Volume 1, Section II, Protocol L1 to calculated water savings from faucet aerators and low-flow showerheads. Avoided costs for water savings is calculated using AR TRM v8.0 Volume 1, Section II, Protocol L2.[28] The Evaluators relied on the TRM-calculated marginal water rates. The corrected marginal water rates below are reported both for PY2019.

Table 5-14: Total Marginal Water Rates

	Original 2019 TRM V8.0 Values			Corrected: For use in 2019
Customer Class	Marginal Water Rates (per 1,000 gallons)	Marginal Sewage Rates (per 1,000 gallons)	Total Combined Marginal Water Rates (per 1,000 gallons)	Total Combined Marginal Water Rates (per 1,000 gallons)
Residential	$3.41	$4.61	$6.49	$8.03
Commercial	$2.76	$4.16	$7.25	$6.92
Average Cost $/Gallon	$3.12	$4.38	$6.87	$7.50

Table 5-15 summarizes water savings from the C&I Solutions Program.

[28] In PY2019, these avoided costs were updated through the 'TRM Clarification Memo' distributed by the IEM on July 22, 2019.

Table 5-15: Commercial & Industrial Solutions Ex Post Net Water Savings

Measure Category	Net Annual Water Saving (Gallons)	Lifetime Net Water Savings (Gallons)
Custom	3,110,691	31,110,619
Direct Install	421,301	4,021,384
Prescriptive	0	0
Total	3,531,992	35,132,003

Table 5-16 summarizes electric savings from the program. These savings were monetized using SWEPCO's avoided energy and capacity costs and associated line losses.

Table 5-16: Commercial & Industrial Solutions Ex Post Net Electric Savings

Measure Category	Net Annual kWh	Net Peak kW	Lifetime Net kWh
Direct Install	35,510	29.15	390,610
Custom	0	0	0
Prescriptive	0	0	0
Total	35,510	29.15	390,610

5.6 Conclusions & Recommendations

5.6.1 Conclusions

The Evaluators have found that:

1. **Custom projects are accounting for an increasing share of savings.** In PY2019, custom projects accounted for 85.2% of program savings.
2. **Program EUL has increased.** Due to lower reliance on steam trap replacement, the program EUL has increased from 5.79 to 9.17 from PY2017 to PY2019.

5.6.2 Recommendations

The Evaluators' recommendations for the C&I Solutions Program are as follows:

1. **Add PRJ numbers for steam system surveys and integrate them into the custom tracking sheet.** They were tracked separately; combining into the close project file would enable easier tracking of incentives.

6. Home Energy Savings Program

The Home Energy Savings Program is a weatherization program launched by BHE in late PY2013. The program is designed to train contractors and home energy consultants to analyze the energy use for single and multifamily homes and identify specific energy efficiency improvements which may be undertaken by the customer.

The program provides energy assessments, along with direct installation of low-cost measures and pre-qualification for building envelope improvements.

Direct install measures include:

- Faucet aerators; and
- Low flow showerheads.

Eligible coupon measures include:

- Air sealing;
- Duct sealing; and
- Ceiling insulation.

The program is implemented by CLEAResult. In 2016, the program was certified as meeting the requirements of Home Performance with Energy Star®. This is mentioned in program marketing but is not used as the program's name.

6.1 Program Overview

The Home Energy Savings Program (HESP) is intended to be primarily contractor-driven program, with the marketing targeted at contractors in the BHE service territory. In PY2019, the program had $1,549,329 in budget allocated. Table 6-1 summarizes the historical performance of the Home Energy Savings Program.

Table 6-1: HESP Historical Performance against Goals

Program Year	# Participants		Budget		Net Therms	
	Actual	Goal	Spent	Allocated	Achieved	Goal
2014	1,049	590	$709,875	$737,910	244,677	205,580
2015	1,476	1,027	$1,125,605	$1,256,736	487,668	342,239
2016	992	1,612	$1,474,417	$1,518,639	574,107	371,622
2017	821	3,031	$1,500,570	$1,502,615	474,684	379,880
2018	862	3,031	$1,479,201	$1,502,615	438,589	379,880
2019	771	3,031	$1,422,528	$1,549,329	378,410	379,880

6.1.1 Participation Summary

The HESP had 771 participants in PY2019. Of these, 99.6% installed energy efficiency improvements. Figure 6-1 summarizes the share of program savings contributed by each measure. Most savings came from duct sealing, air sealing, and ceiling insulation. The Evaluators found that 376 of the 771 participating residences were jointly rebated by an electric IOU. Among homes that were rebated solely by BHE, there were 12 different electric utilities. Their distribution among BHE-only homes is summarized below.

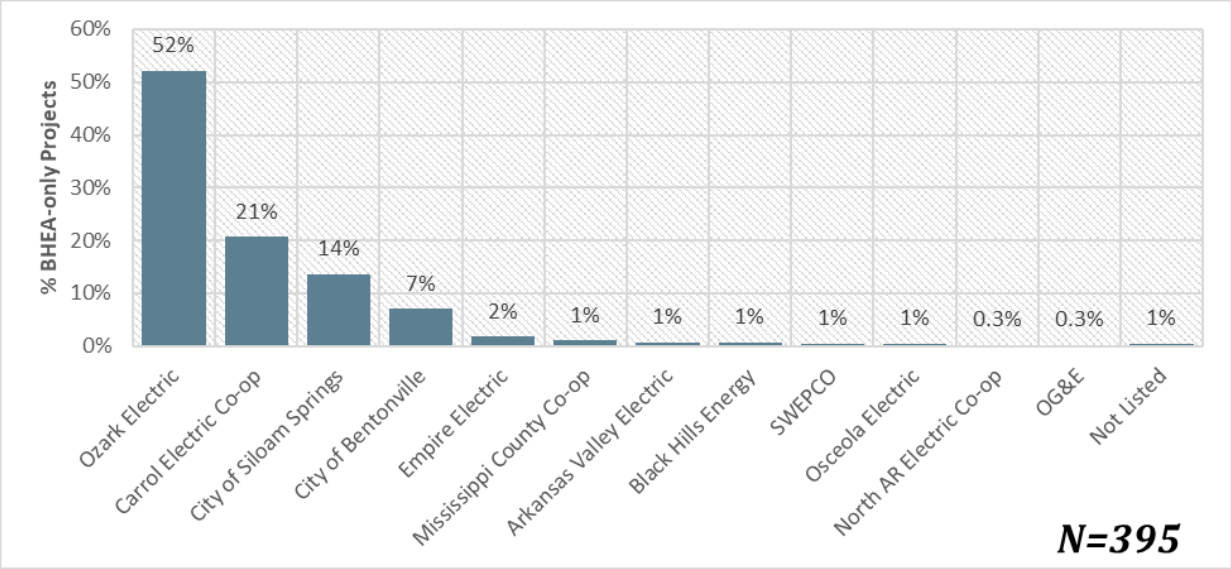


Figure 6-1: HESP BHE Sole-Rebate Summary

Figure 6-2 summarizes savings by measure for PY2019.

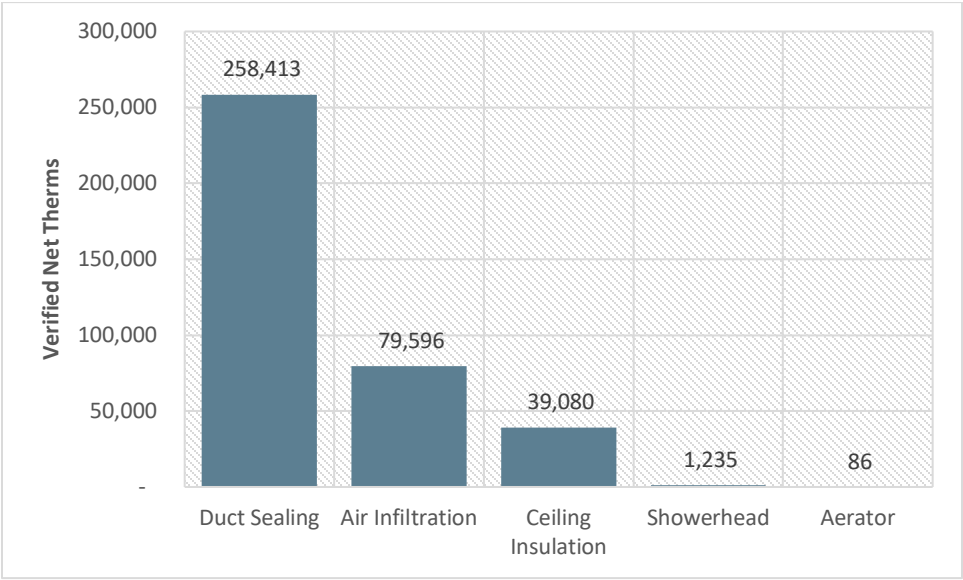


Figure 6-2: Program Savings Share by Measure

In addition, incentives were provided for 727 Assessments.

6.1.2 Contractor Participation

In PY2019, the HESP had four registered trade allies. All registered allies were active in the program in PY2019. As shown in Figure 6-4, most trade allies installed duct sealing and air sealing improvements at a large majority of their projects. In PY2018, the top-performing trade ally completed 49% total projects. This was spread to a greater extent among all trade allies in PY2019, with each trade ally completing between 16% and 36% of total projects.

The top-performing trade ally (who completed 49% of total projects) installed ceiling insulation at only 13% of their projects. In contrast, the second-highest performing trade ally (that provided 36% of total projects) installed insulation at 43% of their projects. It is possible that the areas where this trade ally works have newer housing stock with more preexisting insulation, but program staff should check to ensure that this trade ally is not overlooking ceiling insulation opportunities.

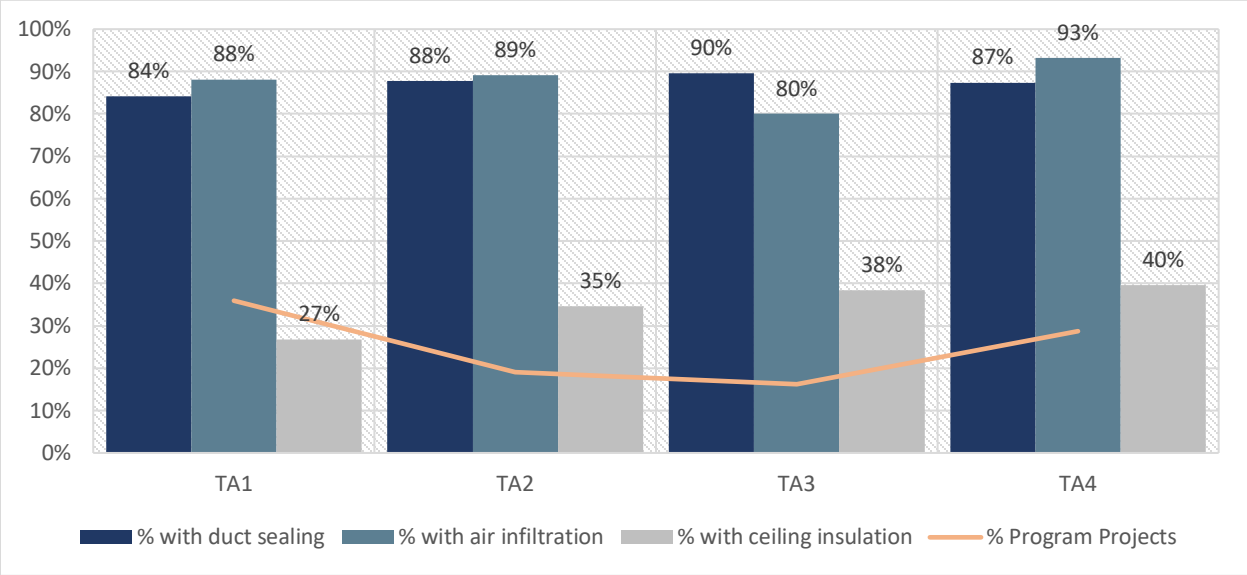


Figure 6-3: Trade Ally Participation Summary

6.1.3 Participation Timing

Figure 6-2 summarizes the net savings installed by month in PY2019.

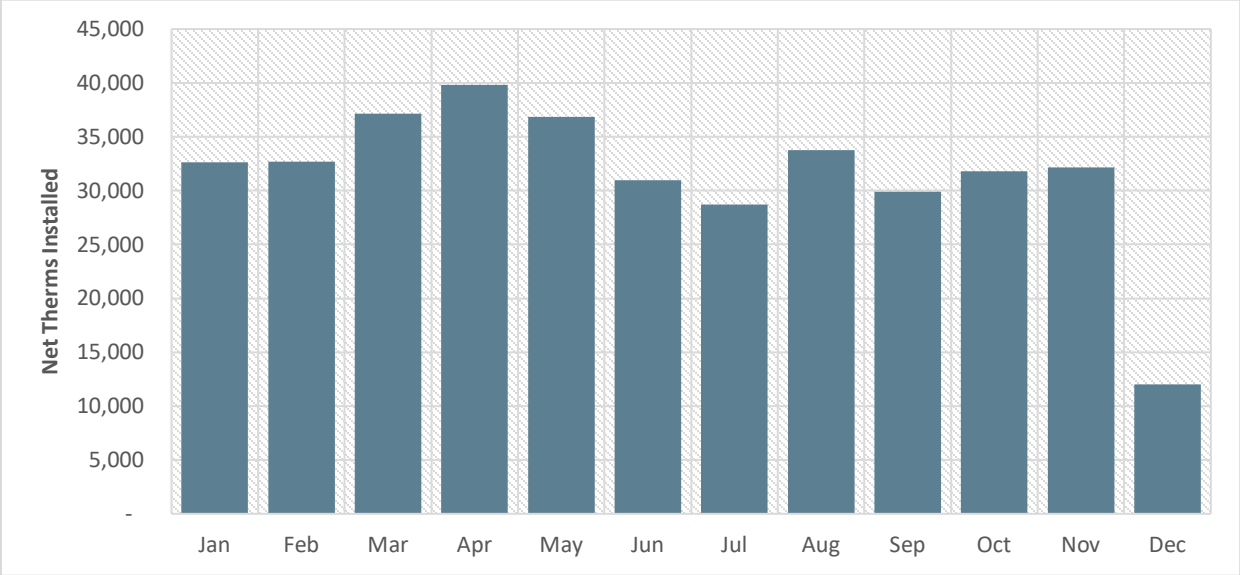


Figure 6-4: HESP Premises and Savings by Month

6.2 HESP Process Evaluation

The Evaluators conducted a formal process evaluation of the Home Energy Savings Program in PY2017 and found that the program was successful in meeting participation, savings, and satisfaction goals. Table 6-2 and Table 6-3 summarize the Evaluators' review of the Home Energy Savings Program in comparison to TRM V8.0 Protocol C for timing and conditions of conducting a process evaluation.

Table 6-2: Determining Appropriate Timing to Conduct a Process Evaluation

Component	Determination
New and Innovative Components	No. The program is designed in a manner consistent with similar programs elsewhere and applies deemed savings values from the TRM.
No Previous Process Evaluation	No. The program received a comprehensive process evaluation in PY2014 and a partial process evaluation in PY2017.
New Vendor or Contractor	No. CLEAResult has implemented the program since program inception.

Table 6-3: Determining Appropriate Conditions to Conduct a Process Evaluation

Component	Determination
Are program impacts lower or slower than expected?	No. The program exceeded savings goals in prior program years.
Are the educational or informational goals not meeting program goals?	No. The programs have had successful consumer and contractor outreach & education.
Are the participation rates lower or slower than expected?	No. The program met participant goals in prior program years.
Are the program's operational or management structure slow to get up and running or not meeting program administrative needs?	No. The prior process evaluations found that operational and management structure to be up to speed and efficient in administering the program.
Is the program's cost-effectiveness less than expected?	No, the program's cost-effectiveness was within expected boundaries.
Do participants report problems with the programs or low rates of satisfaction?	No. PY2017 participant surveys found high satisfaction levels.
Is the program producing the intended market effects?	Yes. Interviews with participating contractors in PY2018 found significant market transformation occurring.

Due to the need to collect data on participation rates of Act 1102-elligible customers, a limited evaluation was conducted to address this research question.

6.2.1 CWA Metrics Summary

They key CWA metrics are presented in Table 6-4.

Table 6-4: CWA Program Metrics Summary

Metric	Value
Program Name	Home Energy Savings Program
CWA Implementation	The CWA is implemented using a third-party contractor (CLEAResult) with a network of pre-approved trade allies that market the program. The program coordinates with SWEPCO, Entergy, and Empire Electric District
Total Audits Completed	771
Total Submitted Projects	768
Conversion Rate	99.6%
Measures installed per-project	2.26
Cost per participant	No customer co-pay. BHE paid $934/home
Percent of contractors promoting program	100%

6.2.2 Data Collection Activities

The process evaluation of Home Energy Savings Program included the following activities:

- *Program Actor In-Depth Interviews*. The Evaluators conducted in-depth interviews with a series of program actors. These interviews covered a range of topics, including marketing efforts, feedback on program delivery, an assessment of barriers to program

implementation and success, and recommendations for program improvement. Program Actors interviewed include:

- *BHE Program Staff*. The Evaluators interviewed staff at BHE involved in the administration of the Home Energy Savings Program.
- *Third Party Implementation Staff Interviews.* The Evaluators conducted interviews with CLEAResult involved with the Home Energy Savings Program.
- *Participant Surveying.* The Evaluators surveyed 80 owner-occupant participants in the HESP, collecting feedback on their experiences with the program.

Table 6-5 summarizes the data collection for this process evaluation effort. This includes the titles, role, and sample sizes for data collection.

Table 6-5: BHE HESP Data Collection Summary

Target	Component	Activity	n	Precision Met	Role
BHE Program Staff	Manager of Energy Efficiency	Interview	1	NA	Overall administration of BHE DSM programs. This manager is involved in the larger strategic decisions associated with the DSM portfolio, and is involved with the HESP Program and in the overall coordination of utility resources.
CLEAResult Staff	Program Manager	Interview	1	NA	Handles day-to-day operations, including mass market outreach, application review, billing, and logistics
Program Participants	All	Survey	86	±8.6%	This survey was conducted on a sample of single-family owner-occupants which participated in the program.
		On-site inspection	37	±8.7%	On-site testing for duct leakage, air infiltration, and inspection of ceiling insulation was completed at 37 residences, comprising 90 measures.

6.2.3 Response to PY2018 Recommendations

Responses by program staff to PY2018 evaluation recommendations are summarized in the table below.

Table 6-6: Home Energy Savings to PY2018 Recommendations

Recommendation	*BHE/CLEAResult Response*	*Status of Issue*
Investigate trade allies with low rates of installation of ceiling insulation.	This has been reviewed, and in PY2019 the rate of ceiling insulation conversions has increased.	Recommendation adopted

6.2.4 Program Theory & Design

The HESP was designed in order to fill a gap in BHE portfolio offerings. Prior to this program, building envelope improvements were only available through the Arkansas Weatherization Program. This was not providing adequate participation for BHE, with no BHE homes weatherized

through the AWP in PY2015. The program now aligns with the Consistent Weatherization Approach (CWA).

6.2.5 Program Administration

The HESP is overseen by the Manager of Energy Efficiency at BHE. This manager's responsibilities primarily include interfacing with CLEAResult, who directly implements the program. Other activities by this manager include providing updated customer lists to CLEAResult to better facilitate their implementation, participation in outreach events, and at times assisting CLEAResult in customer interactions.

For CLEAResult, the roles and responsibilities of program staff are as follows:

- **Program Manager.** The Program Manager oversees day-to-day activities, supervises program staff, and handles complaints from customers or contractors.
- **Program Coordinator/Specialist.** This staff member coordinates tracking data, develops samples for quality assurance inspection, and supports reporting and invoicing requirements.
- **QA Verification Specialist.** The QA Verification Specialist conducts post inspections and communicates inspection results to contractors.

6.2.6 Program Implementation & Delivery

There are two program channels for the HESP: Assessment and Install-only. Formerly, there was a Tier 1 Energy Survey but that has been removed from the program due to it being an unpopular offering that yielded no savings in prior program years.

The two channels are:

- **Assessment.** The Assessment is a comprehensive audit which includes conducting duct blast and blower door testing. This testing is needed to pre-qualify a home for duct sealing and air sealing improvements. Before a home may receive an Assessment, program trade allies are required to calculate the gas intensity of the residence. In this, the contractor must take the customer's highest winter natural gas bill and divide it by the heated square feet of the home. Figure 6-3 summarizes the calculation process.

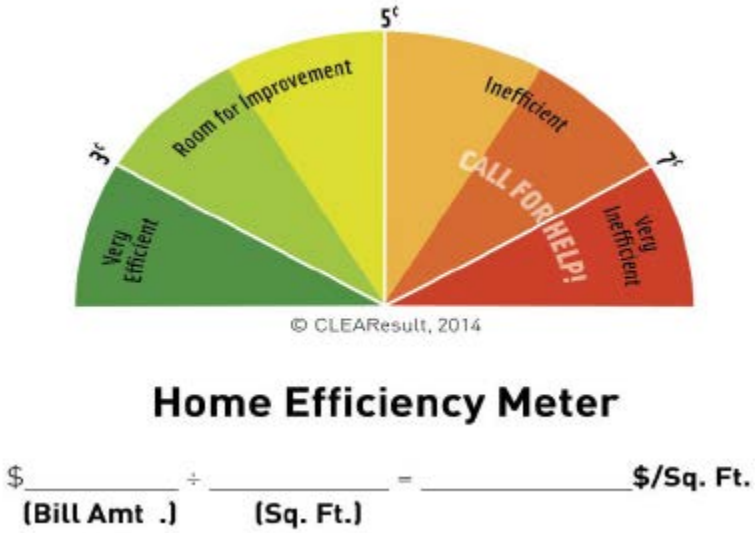


Figure 6-5: Home Efficiency Meter Graphic

A home must be at least 10 years old or have use above $0.05 per square foot during a winter season month to qualify for an Assessment.

- **Install-only.** Further, residential customers may opt to go directly through a contractor to install eligible measures without receiving an Assessment. This is allowed if the contractor is a registered trade ally with the program. Participation in this program channel has declined significantly in favor of more assessments; 99.6% of PY2019 projects had assessments.

The criteria of $0.05/square foot of use on a customer's highest bill is used to ensure that program funds go towards project which will produce enough savings to be cost-effective. Further, all participating residences are required to have central natural gas space heating to receive an assessment and rebates for building envelope measures and natural gas water heating to be eligible for direct install measures.

Residential customers may enter into the program either by contacting the Energy Efficiency Solutions Center (EESC) to request an assessment or by working through a participating contractor who initiates the assessment and coupon process.

6.2.7 Marketing

CLEAResult is the implementer for the HESP programs and oversees marketing efforts. A variety of marketing methods are used including radio ads and word of mouth.

6.2.8 Quality Assurance

Staff at CLEAResult conducts post inspections at a minimum of 10% of the projects completed by each trade ally. Post inspections are conducted by a Quality Assurance Specialist. The post-inspection procedure includes designations of Major Violations and Minor Violations for each measure.

- Major Violations require immediate resolution which may include charging the contractor back for the coupon amount.
- Minor Violations may be resolved without coupon chargeback.

The definition of Major and Minor violations by measure are summarized in Table 6-7.

Table 6-7: QA Violation Definitions by Measure

Measure	*Definitions*
Direct Install	Major violation examples: ■ Verified devices installed does not match claimed devices installed. ■ Device installed on an appliance of non-eligible fuel type ■ Installation of direct install equipment results in damage or inoperability of existing equipment Minor violation examples: ■ None
Insulation	Major violation examples: ■ Stated existing R-value: error > 1 step difference in R-value range chart on the coupon. ■ Stated finished R-value: error of > 10% in R-value ■ Stated square footage: error of >10% in square feet Minor violation examples: ■ Improper installation of new insulation (such as varying depths) ■ Bag count card not properly displayed ■ Depth markers not properly displayed
Duct Sealing/Air Sealing	Major violation examples: ■ Starting vs. finished air leakage rate: verification reveals discrepancy > 20% ■ Minimum Ventilation Requirement (MVR): failure to identify correct MVR or take proper action in the event of the MVR not being met ■ Duct sealing or air sealing materials: use of improper materials ■ Combustion Safety Test (CST): not performing the CST or failing to take proper action on the results. Minor violation examples: ■ None

6.2.9 Application Processing

Four milestone dates are included in program tracking:

1. Install date: when the project is installed

2. Application received date: when the project application is submitted by the trade ally to CLEAResult
3. Capture date: when the project receives final approval for savings and incentives
4. Submitted date: when the payment is submitted to the trade ally.

Figure 6-6 summarizes the median time elapsed for project application following installation. The median project application processing timeline was 29 calendar days.

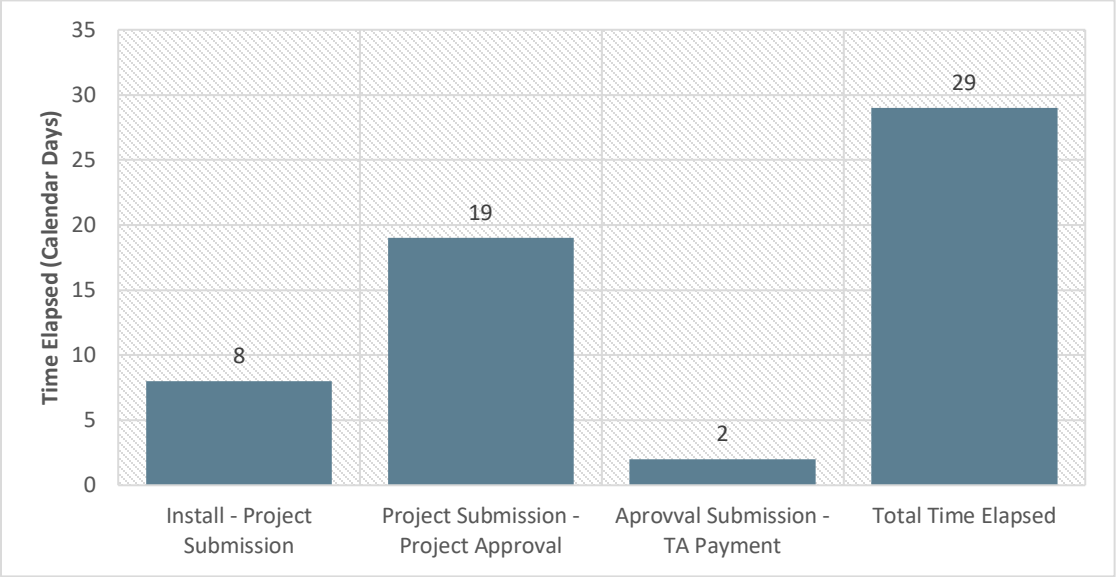


Figure 6-6: Application Processing Time

Figure 6-7 summarizes processing time by month. Application processing is notably quicker in the 4th quarter, with production ramping up for year-end close.

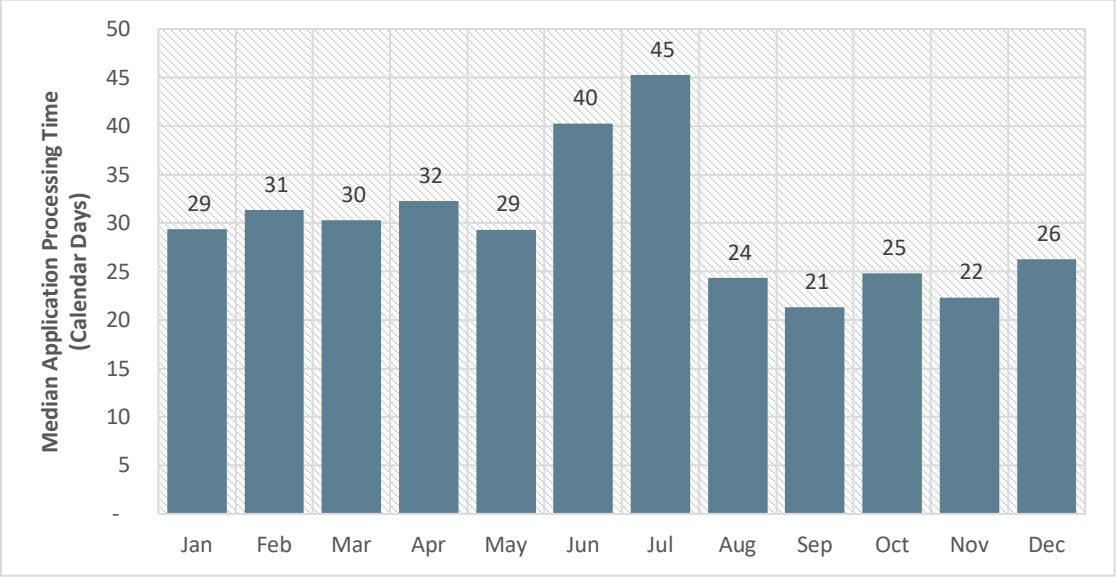


Figure 6-7: Median Application Processing Time by Month

6.2.10 Impact of Home Assessments

The Evaluators reviewed the measure installations energy savings for participants in the HESP. The Evaluators key findings from this review were:

- Conversion rates for Assessments are now at 99.6%.
- Similar to PY2018, Assessment homes had significantly higher savings than homes that install-only. It should be noted that in PY2019 there were only 44 install-only homes, however.

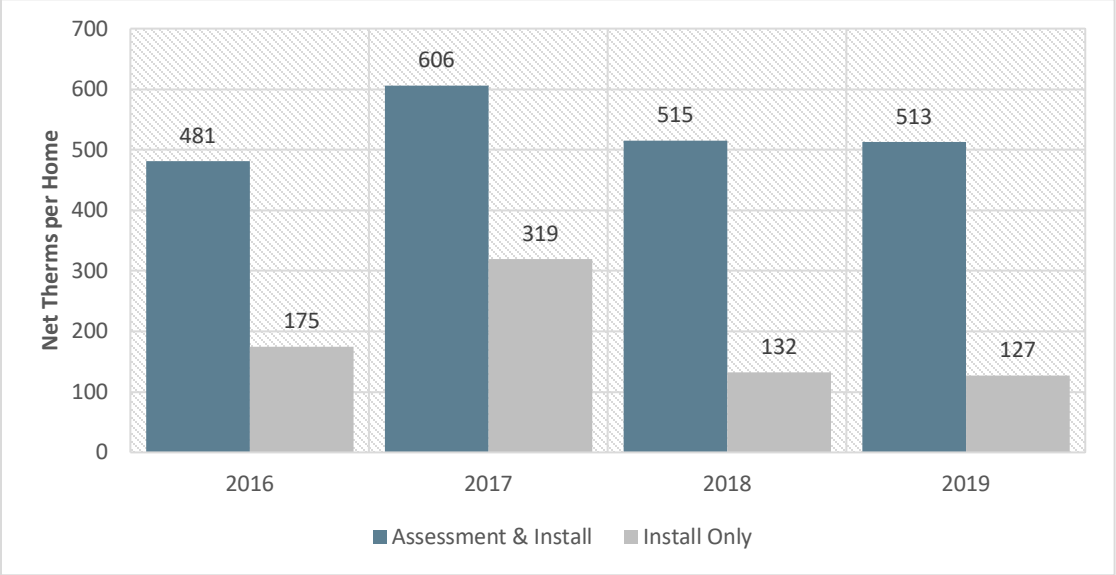


Figure 6-8: Per-Home Therms Savings: Assessment vs. Install-Only

As shown in Figure 6-9, the measure mixes changed significantly from PY2016 to PY2017, and then remained largely similar in PY2018 and PY2019.

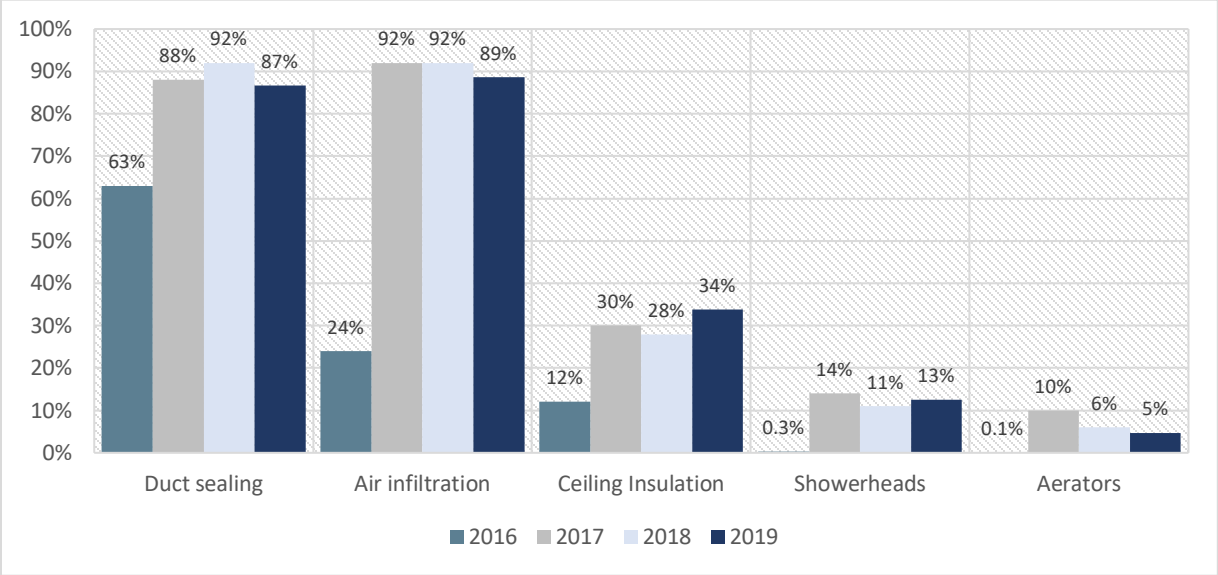


Figure 6-9: % Houses with Each Measure

6.2.11 Participant Survey Response

The Evaluators surveyed 86 single-family participants in Black Hill Energy's (BHE) Home Energy Savings (HES) Program. These surveys were to collect data on participants experience with the program including sources of program awareness, motivations for participating, and satisfaction with the program. Furthermore, the evaluators collected demographic information on the respondents during the survey.

6.2.11.1 Program Awareness

BHE's marketing is driven primarily by word of mouth (50%). Sixteen percent of respondents stated that they heard of the program through social media. Figure 6-10summarizes the sources of awareness by respondents.

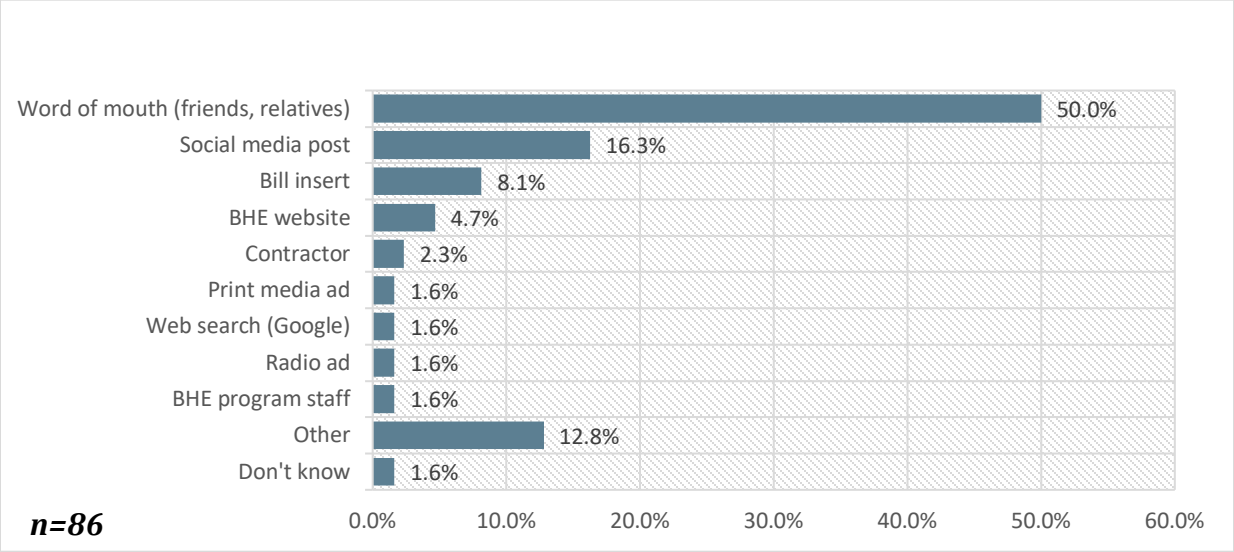


Figure 6-10: HES Source of Awareness

6.2.11.2 Reasons for Participation

Respondents were asked about their primary motivations for becoming involved with this program. Fifty percent of those interviewed stated that their main reason for participating was to reduce their monthly bill. The second most common response was that respondents wanted to save energy (40%). Some respondents noted that there were multiple reasons for their involvement in the program. All responses are summarized in the figure below.

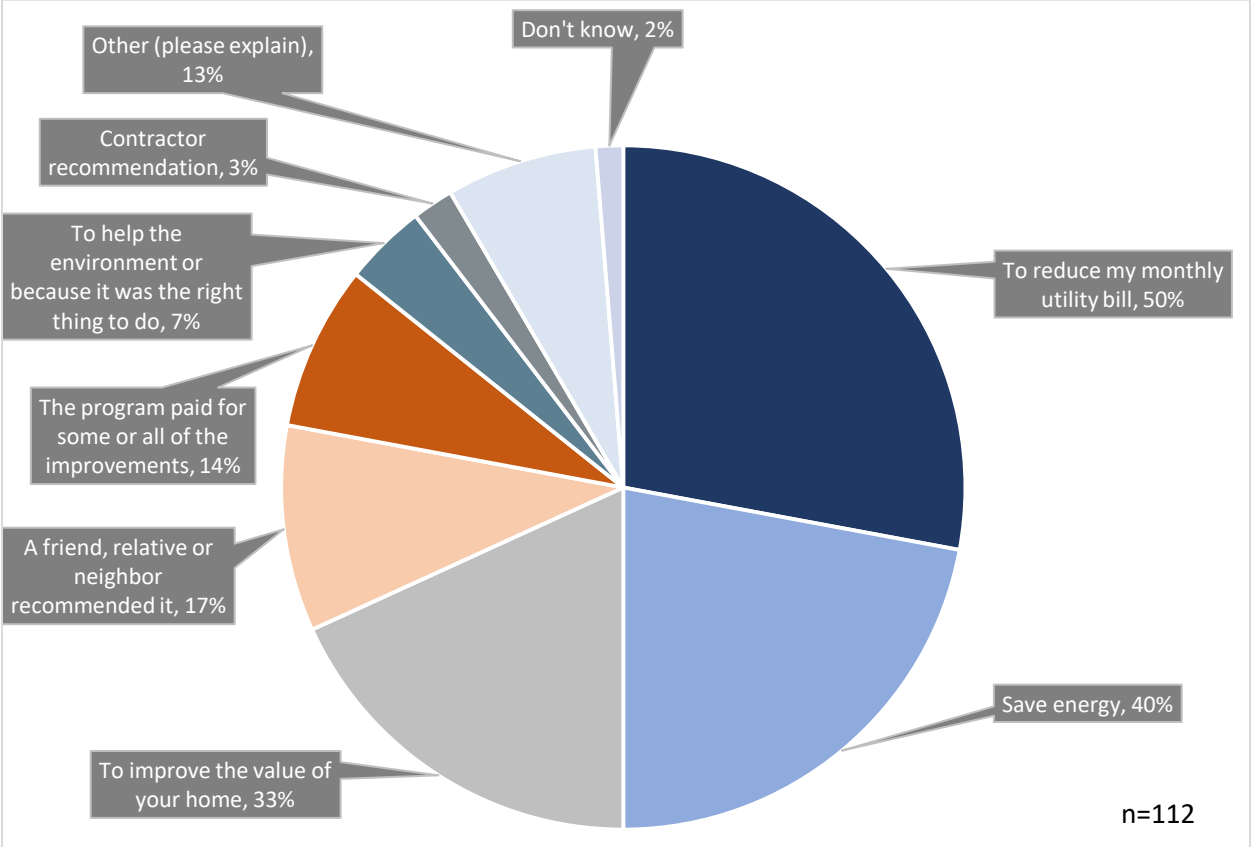


Figure 6-11: Reasons for Participation

6.2.11.3 Home Energy Assessment

Part of the HES involves the option to receive a home energy assessment from a BHE assessor. A series of questions were asked of respondents to determine their experience and satisfaction with the energy assessment received. Figure 6-12 shows the percentage of respondents who scheduled the home energy assessment that they received through the program. Eighty-six percent of respondents scheduled the home energy assessment themselves, and 10% had the assessment scheduled by another person in the household. A few respondents (3%) were not aware that a home energy assessment was performed.

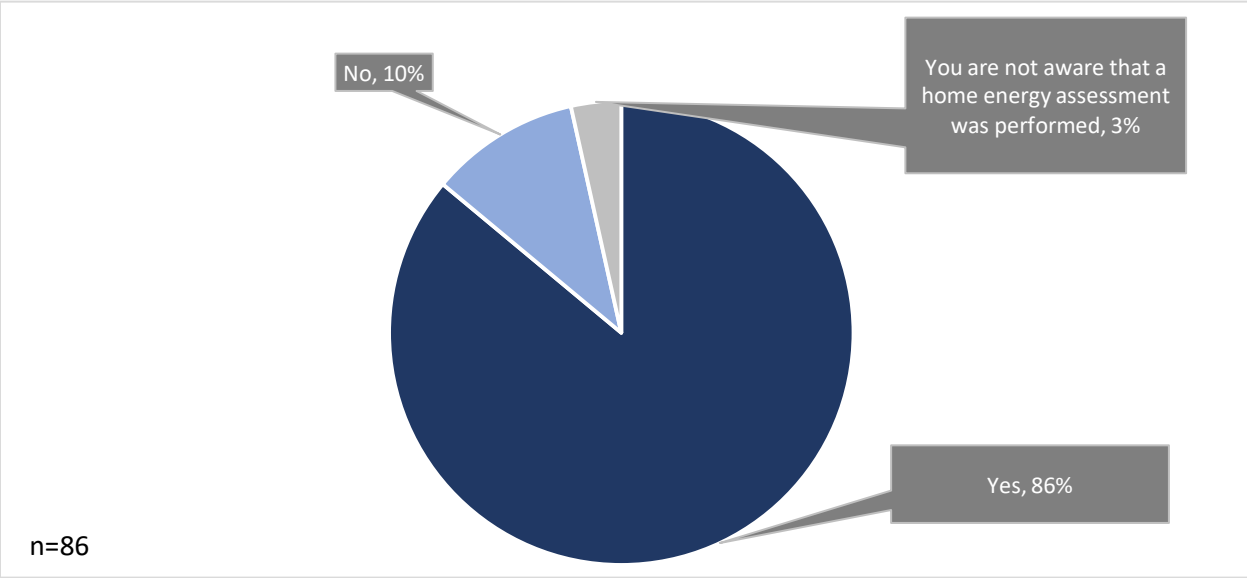


Figure 6-12 Recipients of Assessment

Eighty-six percent of respondents who received a home energy assessment were not planning on having an assessment of their home before learning about the program. Respondents were then asked about the scheduling process, interaction with the assessor, and what happened during the assessment. Ninety-nine of respondents who received an assessment found that the scheduling process was "easy" or "very easy." Results are summarized in the figure below.

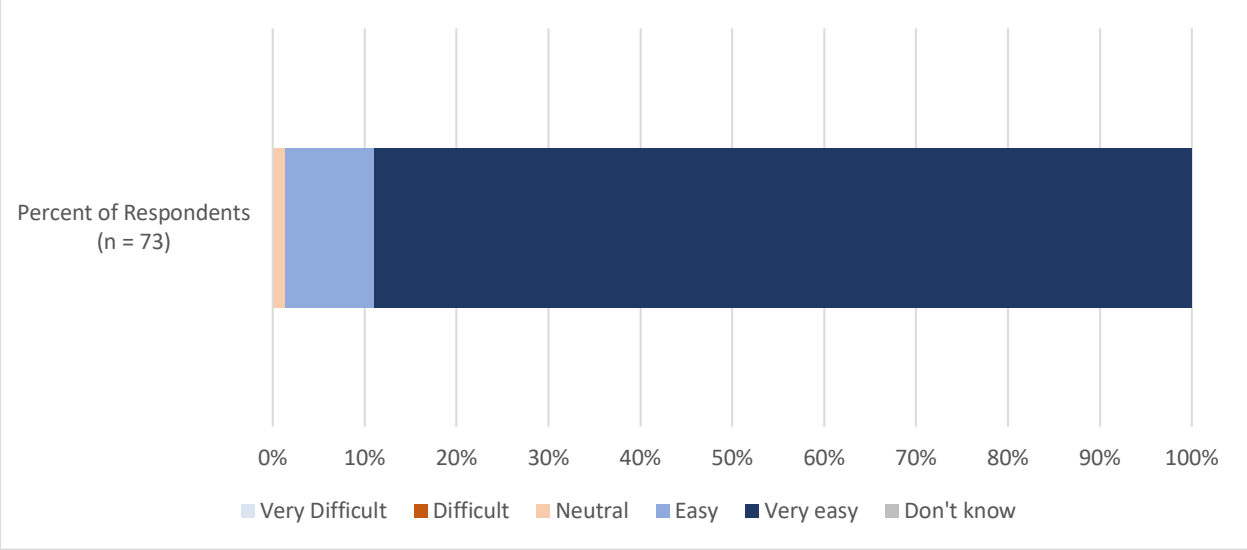


Figure 6-13: Home Energy Assessment Scheduling

Respondents were asked about the experience during their home assessment. When asked about if the assessor addressed any specific issues, 68% stated yes. Additionally, 71% stated

that the assessor provided an energy assessment report with energy efficiency recommendations, and 68% discussed potential energy savings based on recommendations. Respondents' experiences are summarized in Figure 6-14.

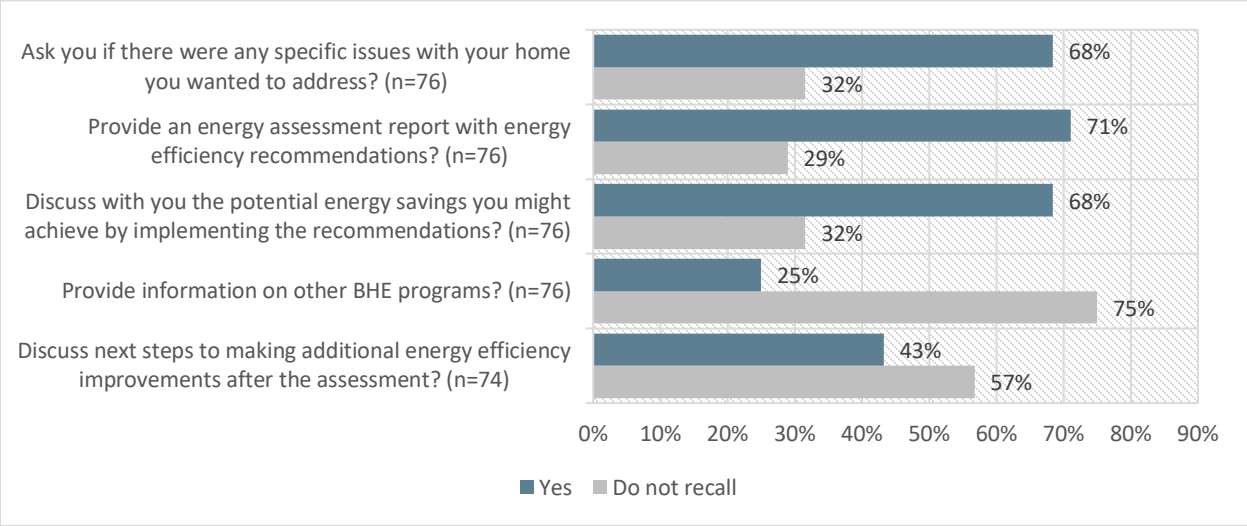


Figure 6-14: Home Energy Assessment Customer Experience

Those interviewed were asked a series of questions if they made the energy efficient improvements recommended in the home energy assessment. Fifty-seven percent of respondents made all the energy efficiency improvements that were recommended throughout the program. Forty-three percent either did not make the recommended energy efficiency improvements or did not remember if they did.

Surveyed respondents were asked about the energy savings that they noticed from participating. Thirty-seven percent of respondents stated that the energy savings are what they expected. Twenty percent stated that they energy savings are more than what was expected, but 34% could not tell if there were any energy savings. The results are summarized in Figure 6-15 below.

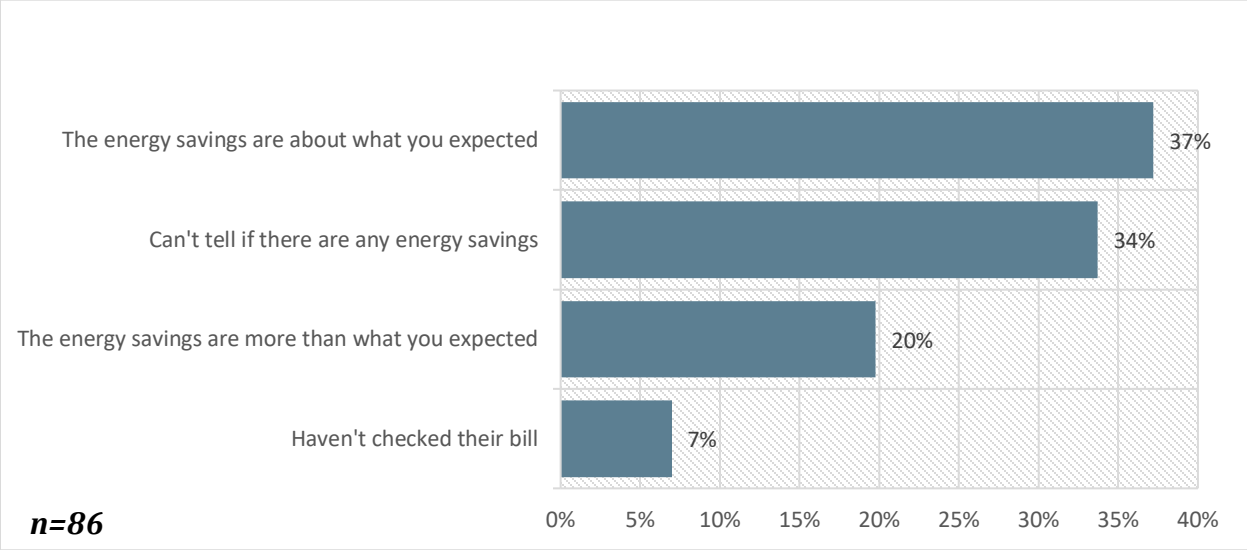


Figure 6-15: Perception of Energy Savings

6.2.11.4 Satisfaction

Customer feedback was generally positive about a variety of aspects of the program. Respondents were asked to use a scale of 1 to 5, where 1 is "very dissatisfied" and 5 is "very satisfied. Ninety-nine percent reported that they were “very satisfied” or “satisfied” with their overall program experience. Figure 6-10 summarizes responses about overall program experience. No respondents indicated dissatisfaction.

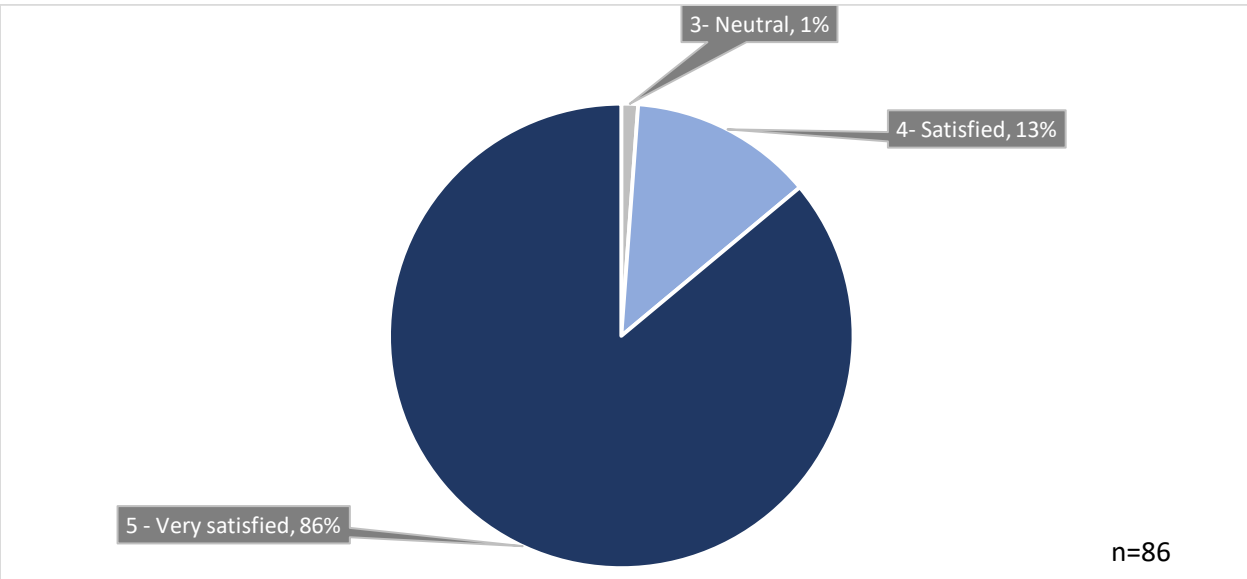


Figure 6-16: HES Program Satisfaction

Those surveyed were also asked general satisfaction questions about BHE and its programs on a scale of 1 to 5 where 1 is “completely disagree” and 5 is “completely agree.” Ninety-three percent

of respondents completely agreed or agreed that participating in BHE's weatherization program increased their satisfaction with the utility. Ninety-seven percent of respondents completely agreed or agreed that they would recommend BHE's program and other services to customers who want to save energy. Eighty-six percent of respondents completely agreed or agreed that BHE is a trusted resource for information on saving energy. Although customers expressed satisfaction with the utility and the programs, 22% of the customers did not take additional steps to save energy since participating in the program. See the results in Figure 6-17 below.

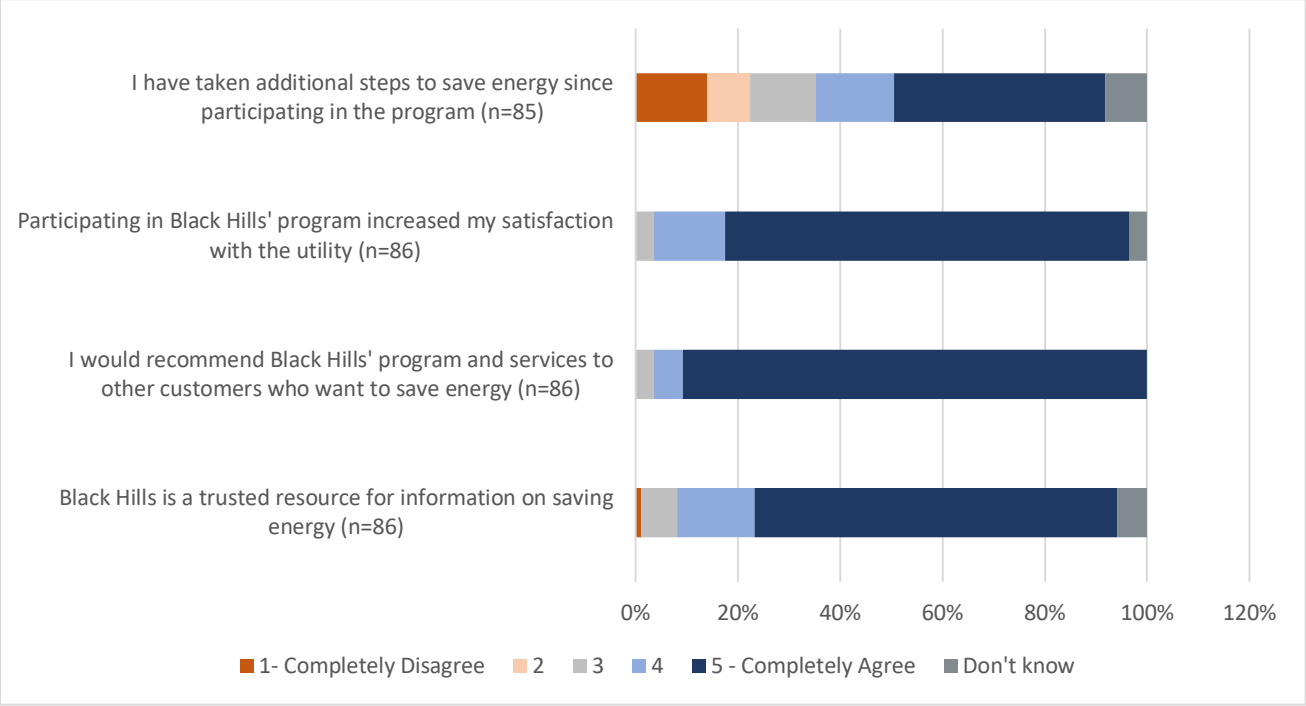


Figure 6-17: HES Satisfaction

Those surveyed were also asked about their experience with the contractor who performed the work on their home. Overall the respondents had positive experiences with their contractors with 95% completely agreeing or agreeing that the contractor was on time to all service appointments. Ninety-nine percent of respondents agreed that the contractor was courteous and professional, and 88% agreed that the contractor's work was high quality.

Lastly, respondents also asked their satisfaction levels about BHE as their gas service provider. Seventy-nine percent were very satisfied with BHE, but 16% of respondents did not know how they felt.

6.2.11.5 Demographics

Respondents were additionally asked a series of questions related to demographic information. Eighty-five percent of respondents own the property where the weatherization took place, with 12% renting, as seen in Figure 6-17 below.

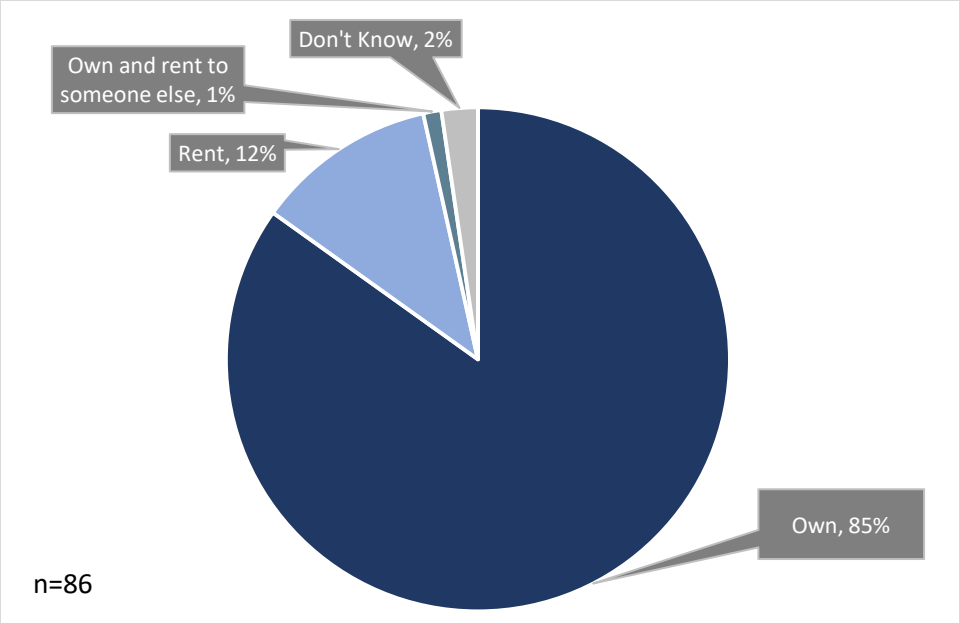


Figure 6-18: Home Ownership

Six percent of those interviewed stated that electricity was the main fuel used for heating their home while 90% stated that natural gas was the main fuel that heated their home. Eight percent of respondents stated that their main water heater used natural gas as fuel while 87% stated that electricity was the main fuel that their water heater used. Table 6-9 summarizes the age brackets of survey respondents.

Table 6-8: Age of Respondents

What is your age?	*Percent of Respondents (n =86)*
18-24	2%
25-34	14%
35-44	23%
45-54	15%
55-64	13%
65-74	20%
75+	10%
Prefer not to answer	2%

If a respondent stated an age grouping less than 65, they were then asked if there were any occupants in their home older that are age 65 or older. An additional 60 respondents that were themselves below 65 years old were asked if they had a household member that was 65 or older.

In aggregate, a total of 2 out of 60 respondents (3%) had at least one occupant age 65 or older in their home.

Table 6-9: Household Member Age

Is any member of your household age 65 or older?	Percent of Respondents (n =60)
Yes	3%
No	93%
Don't know	0%
Prefer not to answer	3%

Respondents were asked to identify the total number of occupants in their home. Based on this response, respondents were then asked a "yes or no" question addressing whether their income level was above or below a pre-specified value that maps to 150% of the Federal Poverty Line (FPL).[29] given their number of occupants. This survey approach was taken with the intent of mitigating refusal rates from survey respondents to income questions (which in past evaluations have been as high as in excess of 90%). The occupancy level, income cut-off, and percent indicating below this cutoff are summarized in Table 6-11.

Table 6-10: Household Size & Income Grouping

How many occupants live in your home?	Percent of Respondents (n = 85)	Income Cut-off (150% of FPL)	Percent of Respondents Below Threshold
1 person	19%	$18,735	38% (n=16)
2 people	33%	$25,365	8% (n=26)
3 people	20%	$31,995	18% (n=17)
4 people	15%	$38,625	31% (n=13)
5 people	8%	$45,225	14% (n=7)
6 people	2%	$51,885	50% (n=2)
7 people	0%	$58,515	N/A (n=0)
8 or more people	0%	$65,145	N/A (n=0)
Don't know	1%	N/A	N/A
Prefer not to answer	1%	N/A	N/A

Fifty-five percent of respondents believe that they are not eligible for the Low- Income Home Energy Assistance program (LIHEAP), and 38% did not know if they were eligible or not. Results are summarized in Table 6-12.

[29] https://aspe.hhs.gov/poverty-guidelines

Table 6-11: LIHEAP Eligibility

Is your household eligible for the Low-Income Home Energy Assistance program (LIHEAP)?	Percent of Respondents (n = 85)
Yes	4%
No	55%
Don't Know	38%
Prefer not to answer	4%

To determine if respondents were Act 1102 eligible, we examine the combined responses of age and income level. Twenty-eight respondents were age- eligible. Seventeen respondents were income-eligible, and eight respondents were both age and income eligible. We have concluded that 43% of respondents would be eligible for weatherization programs under Act 1102. Results are summarized in Table 6-13.

Table 6-12: Act 1102 Program Eligibility

Eligibility Criterion	*Percent of Respondents*
Age-eligible (n=86)	33%
Income-eligible (n=81)	21%
Age- & Income-eligible (n=45)	18%
Total eligible by any criteria* (n=86)	43%
Ineligible (n=86)	57%

*Does not equal sum of (3) eligibility groups; eligibility groups include overlapping customers.

6.3 HESP Impact Evaluation

The evaluation effort of the HESP included the following:

- *Desk Review of Residential Calculations.* The Evaluators utilized TRM V8.0 values in assessing savings from measures included in the program.
- *Field Verification.* Field inspections were completed at a sample of 37 residences. Field inspections included duct blast and blower door testing when participants received duct sealing or air sealing (respectively).

6.3.1 Tracking Review

The impact evaluation began with a review of program tracking data. The tracking data included a separate row for each measure installed. Every premise in the program had a unique rebate identifier, and thus one premise would have multiple rows to reflect the different measures completed. Table 6-14 summarizes ex ante savings by measure for the HESP.

Table 6-13: HESP Ex Ante Summary

Measure	Ex Ante Therms
Duct Sealing	276,272
Air Sealing	80,203
Ceiling Insulation	42,125
Showerhead	1,183
Aerator	92
Total	**399,876**

The tracking data provided measured values for duct pressurization testing and blower door tests, allowing for the recreation of ex ante calculations based on leakage reduction. Ceiling insulation included an indicator for baseline R-value. Program specifications are to bring the home's insulation level up to R-38. The maximum allowed baseline insulation in the program is R-14. The TRM V8.0 allows for up to a minimum of R-22 but the program allows a max of R-14 due to cost-effectiveness issues with preexisting insulation above that level.

6.3.2 Field Verification Procedures

The Evaluators conducted field verifications at 37 premises. The field verification sample included the following measures:

- 8 ceiling insulation retrofits;
- 39 duct sealings;
- 36 air sealings.

For all measure types requiring on-site measurements, the square footage and heating and cooling types were verified. To verify ceiling insulation, the insulation type and measured depth were recorded.

To measure duct leakage, the Evaluators' field staff performed duct pressurization testing (using Duct Blasters®) on the ducting for central heating systems. System static pressure (SSP) on the duct system was first measured, where SSP is a measurement of static pressure at the supply side plenum of the duct system when the supply fan is on and operating with registers in their normal position. This pressure is unique for each system. The ducts were then pressurized by means of a Duct Blaster® connected to the return side of the system. Total duct leakage was measured with the registers sealed and the Duct Blaster® pressurizing the duct system. Total Duct leakage was then recorded.

Finally, total home infiltration, measured in CFM, was calculated. One-time measurements of pressure differential between the conditioned and unconditioned space were taken to calculate a snapshot of total home infiltration, in CFM.

6.3.2.1 *Duct Sealing Field Results*

The Evaluators found that 11 of the 37 tested sites had post-retrofit leakage which differed from values listed in program tracking data by more than 20%. Figure 6-18 summarizes the differences in field test values. The line in this figure presents the Evaluators' tested post-retrofit CFM leakage minus the trade allies' post-retrofit CFM leakage. The data is presented in ascending order, based on lowest ex ante post-retrofit CFM to highest ex ante post-retrofit CFM.

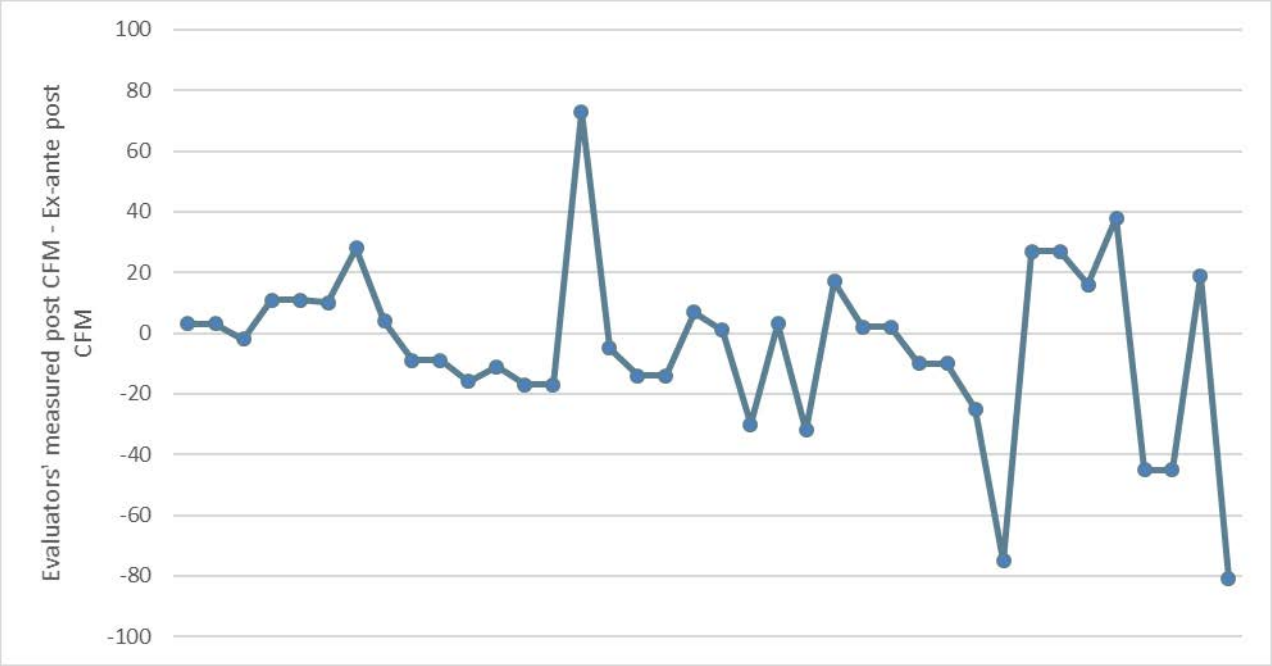


Figure 6-19: Difference in Ex Ante and Ex-Post Duct Sealing CFM

In aggregate, the Evaluators found that ex ante test values aligned almost perfectly with ex post measurements, with overall realization of 99.7% for this measure.

6.3.2.2 *Air Sealing Field Results*

The Evaluators found that 16 of the 47 tested homes had post-retrofit air leakage values that differed from program tracking data more than 20%. Two of these values over state savings and 14 understate savings. The field test differences are summarized in Figure 6-19.

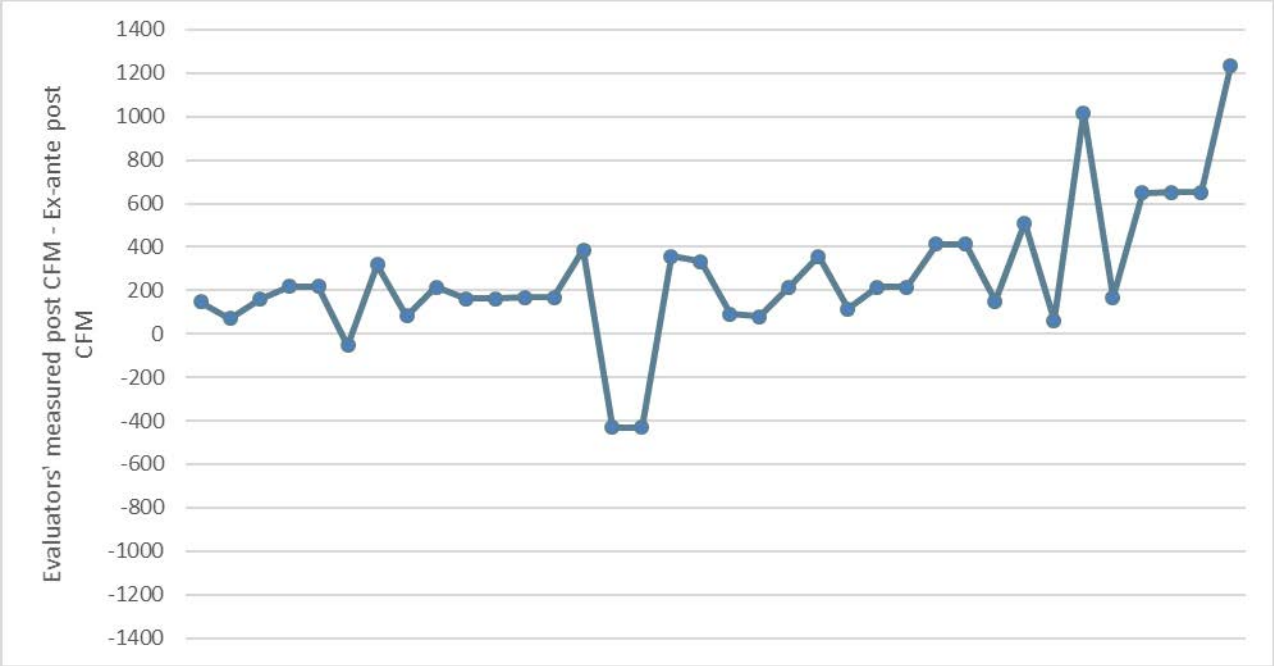


Figure 6-20: Difference in Ex Ante and Ex-Post Air Sealing CFM

In aggregate, the Evaluators found that ex ante test values underestimated program savings. Based on the field results, the Evaluators found 105.6% realization.

6.3.3 Net Savings Estimates

The Evaluators applied NTG estimates developed in the PY2018 evaluation. The approach for those estimates is summarized here. To assess the program's influence on major measures (i.e., duct sealing, air sealing, and insulation), program participants were asked questions regarding:

- If they could afford to install the equipment if it had not been provided for free through the program;
- If they had plans to complete the project;
- The likelihood of installing the equipment if it had not been provided for free; AND
- The timing of the project in the absence of the program.

The procedures for developing a free ridership score based on the survey responses are summarized below.

In this methodology, financial ability is essentially a gateway value, in that if a participant does not have the financial ability to purchase energy efficient equipment absent a rebate, the other components of free ridership become moot. Respondents that reported they could have afforded to implement the improvements were assigned an overall free ridership score based on a prior plans score, a likelihood of installing the measure in the absence of the program, and a timing score.

Prior Plans and Deferred Free Ridership

The prior plans score was based on a response to a question regarding the presence of plans. Specifically, respondents were considered to have had prior plans if they answered "Yes" to the following question:

- Prior to learning about the program, did you have plans to implement the [Measure]?

The program influence on the timing of the project was incorporated into the estimation of free ridership in one of two ways. First, consistent with the Arkansas TRM definition of free ridership, respondents who indicated that the project would have been completed in more than one year if the program was not available were assigned a free ridership score of 0. For all other respondents, the plans score was factored by the program impact on timing. Specifically,

- If the respondent stated that they would have installed the measure in 6 months to one year, then the prior plans score was reduced by one-half.
- If the respondent stated that they would have installed the measure at the same time or within 6 months of when it was installed, the prior plans score was not adjusted.

Likelihood of Implementing Measure without Program

A likelihood of installing the measure in the absence of the program was developed based on respondents stated likelihood of installing a measure if the financial support was not provided or if the measure had not been recommended through the energy assessment. Specifically, responses to this question were scored as follows:

- Very likely: 1
- Somewhat likely: .75
- Neither particularly likely nor unlikely: .5
- Somewhat unlikely: .25
- Very unlikely: 0

The likelihood score was based on the lower value of the likelihood of installing the measure if the program financial support was not available or if the measure was not recommended through the energy assessment.

The overall free ridership score for participants with the financial ability to install the measures was based on the average of the prior plans and the likelihood scores. The free ridership scoring is summarized in Figure 6-16.

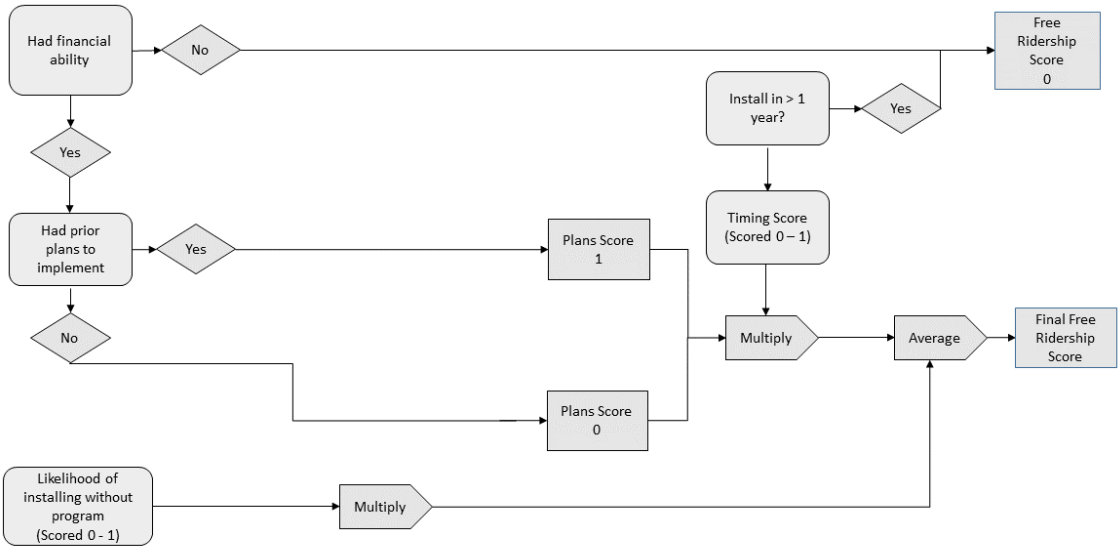


Figure 6-21: Major Measure Free Ridership

In total, 5 of the 80 survey respondents provided answers that fully aligned with the free rider indicators on all questions. The resulting free ridership rate is (5/80) = 6.25%, with a NTGR of 100% - 6.25% = 93.75%.

6.3.3.1 Direct Install Measures Free Ridership Methodology

Due to the low volume of direct install measures (which accounted for .3% of verified savings) the Evaluators did not develop a separate NTGR. DI measures received the 93.75% NTGR developed for the weatherization measures.

6.4 Ex Post Savings

Table 6-15 presents the gross savings results of the evaluation of the PY2019 Home Energy Savings Program. Total Gross Savings summarizes the savings calculations performed by TRM protocols for program measures.

Table 6-14: HESP Ex Post Savings Summary

Measure	*Ex Ante Therms*	*Ex Post Therms*	*Gross Realization Rate*	*EUL*	*Lifetime Therms*
Duct Sealing	276,272	275,640	99.8%	18	4,961,525
Air Sealing	80,203	84,902	105.9%	11	933,922
Ceiling Insulation	42,125	41,686	99.0%	20	833,714
Showerhead	1,183	1,317	111.3%	10	13,168
Aerator	92	92	100.0%	10	920
Total	**399,876**	**403,637**	**100.9%**	**17.0**	**6,743,249**

Table 6-15: HESP Net Savings Summary

Free-Ridership Rate		Net Annual Savings		Net Realization Rate	EUL	Net Lifetime Therms Savings
Ex Ante	Ex Post	Ex Ante	Ex Post			
6.25%	6.25%	374,884	378,410	100.9%	16.50	6,321,797

6.4.1 Water & Electric NEBs

Table 6-16: HESP Ex Post Net Water Savings

Measure Category	Net Annual Water Saving (Gallons)	Lifetime Net Water Savings (Gallons)
Aerators	22,503	225,028
Showerheads	307,356	3,073,556
Total	**329,859**	**3,298,585***
***Difference due to rounding**		

Table 6-17: HESP Ex Post Net Electric Savings

Measure Category	Net Annual kWh	Net Peak kW	Lifetime Net kWh
Duct Sealing	604,143	282.37	10,874,565
Air Sealing	74,875	44.57	823,623
Ceiling Insulation	89,733	74.91	1,794,661
Total	**768,751**	**401.85**	**13,492,849**

6.5 Conclusions & Recommendations

The Evaluators' conclusions and recommendations are as follows.

6.5.1 Conclusions

- **High prevalence of Act 1102-eligible customers:** The Evaluators found that 33% of survey respondents have a household member at least 65 years of age and that 21% of survey respondents had household income lower than 150% of the federal poverty line. In total, 43% of survey respondents were eligible for Act 1102 programs under at least one criterion (lower than the sum of the two criteria as some respondents are both age- and income-eligible).

6.5.2 Recommendations

- **Research viability of other insulation measures.** Wall insulation and floor insulation should be cost-effectiveness screened to see if they warrant inclusion in the program. The last time these measures were screened was prior to the introduction of NEBs.

7. Recommendations for TRM Updates

The Evaluators have the following recommendations for updates to the TRM.

7.1 Correction of the Preheat Savings Formula

The formula for preheating savings in food service measures is shown as:

$$BTU_{Preheat} = PreheatEnergy \times Days$$

The tables subsequent to this formula indicate preheat time of 15 minutes, but this is not reflected in the formula. The Evaluators recommend revising the formula as follows:

$$BTU_{Preheat} = PreheatEnergy \times Minutes_{Day}/60 \times Days$$

This revision affects the following measure sections:

- 3.8.3 Commercial Griddles
- 3.8.4 Commercial Ovens
- 3.8.5 Combi Ovens
- 3.8.6 Commercial Fryers
- 3.8.7 Commercial Steam Cookers
- 3.8.9 Commercial Conveyor Broilers

The formula is currently correctly shown in:

- 3.8.8 Commercial Underfired Broilers

It would suffice to copy the formula from Section 3.8.8 into other food service measure sections.

7.2 Addition of Gravity Wall Furnaces

Gravity wall furnaces have savings developed in CA DEER via workpapers submitted from SoCal Gas. These units have savings in these workpapers on a basis of an improvement from 65% baseline AFUE to 70% AFUE, with the potential of additional savings from electronic ignition and an intermittent pilot light.

This heating system configuration is seen in older housing stock and may have increased potential in Arkansas due to the advent of Act 1102 programs.

7.3 Addition of High Efficiency Gas Fireplaces

Gravity wall furnaces have savings developed in CA DEER via workpapers submitted from SoCal Gas. These units have savings in these workpapers on a basis of an improvement from 64%

baseline AFUE to 70%-75% AFUE, with the potential of additional savings from electronic ignition and an intermittent pilot light.

7.4 Addition of Steam Leak Repair

The C&I Solutions Program has done a significant amount of steam leak repair projects in the past four program years. These projects have not had a realization rate below 90% as savings are readily predictable when the plume length, system pressure, and boiler efficiency are known. The Evaluators recommend that CLEAResult's workpaper for steam leak repair be included in a TRM update so as to remove the EM&V burden on a measure that does not warrant this level of review.

7.5 Addition of Water Savings for Food Service Measures

The Food Service Technology Center (FSTC) calculators cited by the TRM V8.0 have since been updated to include water savings where applicable. The Evaluators recommend that this be added to the TRM for:

1. Combi ovens
2. Steam cookers

8. Appendix A: Site Reports

This appendix contains the individual site reports for C&I Solutions.

Program	C&I Solutions
Project ID	PRJ-2155782
Measures	Steam Trap Replacement Steam Leak Repair

Project Background

The participant is an industrial facility that received incentives from Black Hills Energy for:

- ECM #1: Steam trap replacement
- ECM #2: Steam leak repairs

The site uses steam throughout the facility for various process needs. A condensate return system will take condensate from where steam cools and will use this hot water to produce more steam instead of using makeup water. Savings will come from requiring less energy to produce steam using the hot condensate water instead of the makeup water.

Steam Trap Replacement Parameters

Line Size (inches)	Orifice Size (inches)	Feedwater Temperature (°F)	Inlet Pressure (psig)	Outlet Pressure (psig)	Applied Discharge Rate (lb/hr)
1/2	1/8	210	200	6	90
1	1/8	210	110	6	52
1	1/8	210	200	6	90
1/2	1/8	210	200	6	90
3/4	1/8	210	50	6	27
1	3/16	210	275	6	231

The facility had 6 steam leaks in the system. This energy conservation measure (ECM) saved energy by repairing these leaks and improved the system efficiency by reducing steam loss in the plant. The key variables that affect the realization of energy savings include:

- Plume Length (ft)
- System Pressure (psig)
- Boiler Feed Water Temperature (°F)
- Makeup Water Temperature (°F)
- Combustion Efficiency of Boiler (%)
- Operating Hours (hrs./yr.)

Steam Leak Repair Parameters

Leak No.	System Pressure (psig)	Feedwater Temperature (°F)	Plume Length (ft)	Operating Hours (hr)	Combustion Efficiency
1	275	210	0.5	8,760	82.0%
2	275	210	1.5	4,380	82.0%
3	275	210	1.0	8,760	82.0%
4	275	210	1.5	8,760	82.0%
5	275	210	1.0	4,380	82.0%
6	50	210	1.0	8,760	82.0%

M&V Methodology

ECM#1: Steam Trap Replacement

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A- Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Steam trap orifice sizes (1/8'' for five steam traps, and 3/16'' for one)
- Annual Hours of Operation
    - 8,760 hours (drip)
    - 2,628 hours (Process 1)
    - 2,000 hours (Process 2)
    - 5,256 hours (Process 3)
- Inlet / outlet system pressures
- Boiler efficiency (82% estimated)

Calculations for annual therms savings use the following equation:

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)
OpHrs = annual hours the system is pressurized (hrs./yr.)
H_{fg} = latent heat of evaporation (BTU/lb) = 970.4 BTU/lb
EC_{Base} = combustion efficiency of boiler (%)
Therm Conversion Factor = 100,000 (BTU/therm)

The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here: https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

ECM #2: Steam Leak Repairs

An alternative method was used to calculate the steam loss before steam leak repairs. The more traditional method equates the orifice diameter flow rate, using the orifice diameter of the leak and the system's absolute pressure. Due to the difficulty in determining the exact diameter of an orifice leak, the alternate method was used.

Calculations follow the methods established by G.G. Rajan for a steam leak rate as a function of the length of an active steam plume.

$$Leak\ Rate\ \left(\frac{kg}{hr}\right) = 2.5678\ x \exp[1.845\ x\ Plume\ Length\ (m)]$$

$$Leak\ Rate\ \left(\frac{lb}{hr}\right) = 5.661\ x \exp\ [0.562\ x\ Plume\ Length\ (ft)]$$

$$Heat\ Loss\ \left(\frac{Btu}{hr}\right) = Leak\ Rate\ \left(\frac{lb}{hr}\right) x\ \left[Steam\ Enthalpy\ \left(\frac{Btu}{lb}\right) - FW\ Enthalpy\ \left(\frac{Btu}{lb}\right) - MW\ Enthalpy\ \left(\frac{Btu}{lb}\right)\right]$$

Where:

Leak Rate = calculated value using the Leak Rate equation
Steam Enthalpy = saturated steam region based on system steam pressure
FW Enthalpy = steam look up table based on feedwater temperature
MV Enthalpy = steam look up table based on makeup water temperature, derived from average temperature of water main in each zone

Energy Savings

The annual energy savings from repairing a steam leak is calculated with the following equation:

$$Annual\ Energy\ Savings\ (therms) = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right) x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Eff_{Boiler}\ (\%)\ x\ 100{,}000\ \frac{Btu}{therm}}$$

Where:

Annual Operating Hours = number of hours facility operates annually (obtained from facility representative)
Eff_{Boiler} = 81.3% (Note: only one boiler was tested)
100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Steam Leak Repairs	10 years
Steam Trap Replacement	5 years

Calculated Savings:

ECM #1: Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Discharge Rate (lb/hr)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	therms Savings
1	3/16	275	6	231	1,199.7	178.2	25,230
2	1/8	200	6	90	1,199.7	178.2	9,821
3	1/8	200	6	90	1,199.7	178.2	9,821
4	1/8	200	6	90	1,199.7	178.2	9,821
5	1/8	110	6	52	1,191.4	178.2	5,628
6	1/8	50	6	27	1,179.3	178.2	2,888
						Total	**63,210**

ECM #2: Steam Leak Repairs

Steam Leak Repairs Savings

Steam Leak #	Plume Length (ft)	Steam Pressure (psig)	Leak Rate (lbs./hr.)	System Enthalpy (BTU/lb)	Heat Loss (BTU/hr)	therms Savings
1	0.5	275	7.5	991.8	7,436.6	794
2	1.5	275	13.2	991.8	13,045.1	697
3	1.0	275	9.9	991.8	9,849.4	1,052
4	1.5	275	13.2	991.8	13,045.1	1,394
5	1.0	275	9.9	991.8	9,849.4	526
6	1.0	50	9.9	967.7	9,609.6	1,027
					Total	**5,490**

Overall project savings are as follows:

Overall Project Savings

Measure	Expected Annual therms Savings	Realized Annual therms Savings	Realization Rate	Lifetime therms Savings	Annual Water Gallons Savings	Lifetime Water Gallons Savings
Steam Leak Repair	5,492	5,490	100.0%	54,900	46,369	463,690
Steam Traps	63,212	63,211	100.0%	316,050	0	0
TOTAL	**67,794**	**68,741**	**101.4%**	**370,950**	**46,369**	**463,690**

Program C&I Solutions
Project ID PRJ-1861832
Measures Steam to Hot Water Boiler Retrofit

Project Background

The site is an educational facility that used a steam boiler and three heat exchanges to provide hot water. The hot water is used throughout the facility for space heating, domestic hot water, cooking and laundry. The participant is received incentives from Black Hills Energy for:

- ECM #1: Steam to Hot Water Boiler Retrofit

M&V Methodology

ECM #1: Steam to Hot Water Boiler Retrofit

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option C – Whole Facility.

Measurement and verification activities are based on the following assumptions:

- The facility load remained constant between the pre and post recording periods.
- The gas usage can be normalized based on the local weather HDD.
- A baseload of 60 degrees is used to calculate the HDD.

Calculations for annual Therms savings use a linear regression of the monthly billed CCF usage, normalized by HDD using local weather and then estimated using TMY 3 weather data. The formula is as follows:

$$Therm_{savings} = Therm_{pre} - Therm_{Post}$$

$$Therm_{Pre} = Slope_{Pre} * HDD + Intercept_{Pre}$$

$$Therm_{Post} = Slope_{Post} * HDD + Intercept_{Post}$$

Where:

$Slope$ *= Linear Regression Slope*
$Intercept$ *= Linear Regression Intercept*

Measure Life

The EUL of this measure is 15 years.

Calculated Savings:

ECM #1: Steam to Hot Water Boiler Retrofit

Pre and Post Billed Gas Usage

Pre Read Date	Pre CCF Usage	Pre HDD, 60	Post Read Date	Post CCF Usage	Post HDD, 60
5/7/2018	12,056	186	6/5/2019	2,089	11.4
4/3/2018	14,146	232	5/6/2019	3,607	55.8
3/2/2018	19,970	435	4/5/2019	12,498	221
2/1/2018	27,492	646	3/6/2019	19,778	554.2
1/2/2018	22,739	615	2/5/2019	19,887	554.8
12/1/2017	11,265	237	1/7/2019	19,832	514
11/1/2017	7,107	129	12/5/2018	15,998	487.9
10/2/2017	5,105	3	11/5/2018	6,189	160.6
9/1/2017	4,639	0			
8/2/2017	4,302	0			
7/3/2017	4,843	0			
6/1/2017	4,896	18			

	Slope	Intercept
Pre	33.2316	4,621.7536
Post	31.9563	2,259.9344

Month	TMY3 HDD	Pre CCF	Post CCF	Savings
Jan	764	30,007	26,671	3,336
Feb	644	26,015	22,832	3,183
Mar	346	16,133	13,329	2,804
Apr	124	8,759	6,238	2,521
May	36	5,829	3,421	2,408
Jun	1	4,659	2,296	2,363
Jul	0	4,622	2,260	2,362
Aug	1	4,641	2,279	2,363
Sep	12	5,019	2,642	2,377
Oct	138	9,216	6,678	2,538
Nov	284	14,059	11,335	2,724
Dec	658	26,502	23,300	3,202
Total	**3,009**	**155,461**	**123,282**	**32,179**

The calculated savings for ECM #1 is as follows:

- Annual Therms Savings: 32,179
- Lifetime Therms: 482,692

After adjusting for claims made in PY2018 for this project, total savings for PY2019 are:

- Annual Therms Savings: 18,973
- Lifetime Therms: 284,595

Program	C&I Solutions
Project ID	PRJ-2174811
	Steam Leak Repairs
Measures	Pipe Insulation
	Steam Trap Replacement

Project Background

The participant is a food processing plant that received incentives from Black Hills Energy for:

- ECM #1: Steam leak repairs
- ECM #2: Pipe Insulation
- ECM #3: Steam trap replacement

The site uses steam throughout the facility primarily for two process needs: space heating and in some cases, domestic water heating. Savings will come from steam leaks throughout the site's pipework, as well as properly insulating sections of pipe throughout the facility's pipework. There is an additional boiler replacement measure that is receiving a 40% claim under this project ID that is not included in this report.

M&V Methodology

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A - Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Supply water temperature is 65.6°F based on the AR TRM 8.0
- Combustion efficiency is 85.0% (for both pre-retrofit and post-retrofit condition)

Steam Leak Repairs

An alternative method was used to calculate the steam loss before steam leak repairs. The more traditional method equates the orifice diameter flow rate, using the orifice diameter of the leak and the system's absolute pressure. Due to the difficulty in determining the exact diameter of an orifice leak, the alternate method was used.

Calculations follow the methods established by G.G. Rajan for a steam leak rate as a function of the length of an active steam plume.

Equating Steam Plume Length to Flow Rate

$$Leak\ Rate\ \left(\frac{kg}{hr}\right) = 2.5678\ x \exp[1.845\ x\ Plume\ Length\ (m)]$$

$$Leak\ Rate\ \left(\frac{lb}{hr}\right) = 5.661\ x \exp\ [0.562\ x\ Plume\ Length\ (ft)]$$

Calculation for Heat Loss

$$Heat\ Loss\ \left(\frac{Btu}{hr}\right) = Leak\ Rate\ \left(\frac{lb}{hr}\right) x\ \left[Steam\ Enthalpy\ \left(\frac{Btu}{lb}\right) - FW\ Enthalpy\ \left(\frac{Btu}{lb}\right)\right]$$

Where:

Leak Rate = calculated value using *the Leak Rate equation*
Steam Enthalpy = saturated steam region based on system steam pressure
FW Enthalpy = steam look up table based on feedwater temperature,
derived from average temperature of water main in each zone (34.2 BTU/lb)

The following table shows relevant steam leak parameters required for annual energy savings calculations.

Steam Leak Parameters

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Pressure (psig)	Leak Rate (lbs./hr.)	Boiler Efficiency
1	Air Dry Roof East Side	1	3	125	30.56	85.0%
2	SK2 Kettle	1	1	125	9.93	85.0%
3	302 CIP	1	1	125	9.93	85.0%
4	Behind SK1 Kettle	1	1	125	9.93	85.0%
5	Air dryer on roof fitting	1	0.25	125	6.51	85.0%

Energy Savings

The annual energy savings from repairing a steam leak is calculated with the following equation:

Steam Leak Repair Annual Energy Savings

$$Annual\ Energy\ Savings\ (therms) = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right) x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Boiler\ Efficiency(\%)\ x\ 100{,}000\ \frac{Btu}{therm}}$$

Where:

Annual Operating Hours = 8,000 hours

Boiler Efficiency = 85.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Pipe Insulation

For this measure, energy savings are calculated using key data and through the North American Insulation Manufacturers Association's 3E Plus software:

(http://www.pipeinsulation.org/).

Measurement and verification activities are based on the following assumptions:

- Hours of operation are 8,760
- Insulation thickness: 1.50 in
- Insulation material type: 850°F Min. Fiber Pipe and Tank, Type IIIB, C1393-14
- Boiler Efficiency: 85.0%
- Process temperatures: between 189°F and 384°F
- The average ambient air temperature: 82.4°F

The 3E Plus software was used to calculate heat loss (btu/hr/ft) for bare piping (pre-retrofit) and piping with 1.5-inch insulation (post-retrofit). The software required these inputs: process temperature, ambient temperature, pipe size, base metal, insulation, and jacket material. Annual therms savings was calculated using the following equation:

Pipe Insulation Installation Annual Energy Savings

$$\boldsymbol{Annual\ Therms\ Savings} = \frac{\boldsymbol{Heat\ Loss}\left(\frac{\boldsymbol{Btu}}{\boldsymbol{hr}}\right)\boldsymbol{\ x\ Annual\ Operating\ Hours}\left(\frac{\boldsymbol{hrs}}{\boldsymbol{yr}}\right)}{\boldsymbol{Boiler\ Efficiency\ x\ 100,000}\left(\frac{\boldsymbol{BTU}}{\boldsymbol{CCF}}\right)}$$

Where:

Annual Operating Hours = number of hours facility operates annually = 8,760 hours

Boiler Efficiency = 85.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Typically, a table detailing the inputs into pipe insulation savings calculations would be included below. However, this ECM includes over 200-line items. The table can be provided upon request.

Steam Trap Replacement

Calculations for the annual therms savings use the following equation:

Steam Trap Replacement Annual Energy Savings

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)

OpHrs = annual hours the system is pressurized (hrs./yr.), 8000

H_{fg} = latent heat of evaporation (BTU/lb)

EC_{Base} = combustion efficiency of boiler (%), 85.0%

Therm Conversion Factor = 100,000 (BTU/therm)

The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here: https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

The following table shows relevant failed steam traps parameters required for annual energy savings.

Steam Trap Parameters

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Service (Drip/Process)	Feedwater Temperature (°F)	Boiler Efficiency	Operating Hours
1	7/32 - 1/4	125	6	Drip	220	85%	8,000
2	7/32 - 3/16	125	6	Drip	220	85%	8,000
3	7/32 - 3/16	125	6	Drip	220	85%	8,000
4	7/32 - 3/16	125	6	Process	220	85%	8,000
5	7/32 - 3/16	125	6	Process	220	85%	8,000
6	7/32 - 3/16	125	6	Drip	220	85%	8,000
7	7/32 - 3/16	125	6	Drip	220	85%	8,000
8	7/32 - 3/16	125	6	Drip	220	85%	8,000
9	7/32 - 3/16	125	6	Drip	220	85%	8,000
10	1/8	125	6	Drip	220	85%	8,000
11	1/8	125	6	Drip	220	85%	8,000
12	5/32	125	6	Drip	220	85%	8,000
13	1/4	125	6	Process	220	85%	8,000
14	5/32 - 3/16	125	6	Drip	220	85%	8,000
15	1/8	125	6	Drip	220	85%	8,000
16	1/8	125	6	Drip	220	85%	8,000
17	1/8	125	6	Drip	220	85%	8,000
18	1/8	125	6	Drip	220	85%	8,000
19	7/64	125	6	Drip	220	85%	8,000
20	1/8	125	6	Drip	220	85%	8,000
21	1/8	125	6	Drip	220	85%	8,000
22	1/8	125	6	Drip	220	85%	8,000
23	1/8	125	6	Drip	220	85%	8,000
24	5/64	125	6	Drip	220	85%	8,000
25	5/39	125	6	Drip	220	85%	8,000

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Steam Leak Repairs	10 years
Pipe Insulation	20 years
Steam Trap Replacement	5 years

Calculated Savings:

Steam Leak Repairs

Steam Leak Repairs Savings

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Enthalpy (BTU/lb)	System Enthalpy (BTU/lb)	Therms Savings
1	Air Dry Roof East Side	1	3	1,194.00	1005.72	2,892
2	SK2 Kettle	1	1	1,194.00	1005.72	940
3	302 CIP	1	1	1,194.00	1005.72	940
4	Behind SK1 Kettle	1	1	1,194.00	1005.72	940
5	Air dryer on roof fitting	1	0.25	1,194.00	1005.72	617
					Total:	**6,329**

Pipe Insulation

Pipe Insulation Annual Energy Savings

Entry #	Pipe Size	Total length	Pipe or Valve	Process Temperature (°F)	Pre Surface Temp (°F)	Post Surface Temp (°F)	Pre Heat Loss	Post Heat Loss	Gas Savings	Therms Savings
1	0.5	60.00	Pipe	275	274.8	94.2	128.40	18.61	109.79	679
2	0.75	44.00	Pipe	268	267.8	96.4	147.80	20.48	127.32	577
3	1	111.42	Pipe	277	276.8	98.9	190.50	23.39	167.11	1,919
4	1.25	20.00	Pipe	270	269.8	104.0	216.70	24.27	192.43	397
5	1.5	68.75	Pipe	260	259.8	96.5	238.60	26.7	211.90	1,501
6	2	352.75	Pipe	271	270.8	96.6	320.00	33.05	286.95	10,432
7	3	73.70	Pipe	286	285.7	101.0	505.90	47.82	458.08	3,479
8	4	17.35	Pipe	250	249.8	101.3	481.80	44.41	437.39	782
9	6	25.06	Pipe	287	286.6	113.6	886.10	79.08	807.02	2,084
10	8	11.40	Pipe	302	301.5	109.7	1,300.00	107.2	1,192.80	1,402
11	12	9.38	Pipe	267	266.7	112.1	1,428.00	113	1,315.00	1,272
									Total:	**24,524**

Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Discharge Rate (lbs./hr.)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	Latent Heat of Evaporation, H_{fg} (BTU/lb)	Percent Failed	Therms Savings
1	203.0	1,194.00	188.28	1,005.72	100%	19,215
2	123.0	1,194.00	188.28	1,005.72	100%	11,643
3	123.0	1,194.00	188.28	1,005.72	90%	10,478
4	60.0	1,194.00	188.28	1,005.72	100%	5,679
5	60.0	1,194.00	188.28	1,005.72	100%	5,679
6	94.0	1,194.00	188.28	1,005.72	100%	8,898
7	94.0	1,194.00	188.28	1,005.72	100%	8,898
8	94.0	1,194.00	188.28	1,005.72	100%	8,898
9	94.0	1,194.00	188.28	1,005.72	90%	8,008
10	58.0	1,194.00	188.28	1,005.72	100%	5,490
11	58.0	1,194.00	188.28	1,005.72	100%	5,490
12	91.0	1,194.00	188.28	1,005.72	100%	8,614
13	150.0	1,194.00	188.28	1,005.72	90%	12,779
14	118.0	1,194.00	188.28	1,005.72	40%	4,468
15	58.0	1,194.00	188.28	1,005.72	80%	4,392
16	58.0	1,194.00	188.28	1,005.72	80%	4,392
17	58.0	1,194.00	188.28	1,005.72	0%	-
18	58.0	1,194.00	188.28	1,005.72	0%	-
19	45.0	1,194.00	188.28	1,005.72	100%	4,260
20	58.0	1,194.00	188.28	1,005.72	50%	2,745
21	58.0	1,194.00	188.28	1,005.72	40%	2,196
22	58.0	1,194.00	188.28	1,005.72	40%	2,196
23	58.0	1,194.00	188.28	1,005.72	0%	-
24	58.0	1,194.00	188.28	1,005.72	60%	3,294
25	37.0	1,194.00	188.28	1,005.72	80%	2,802
					Total:	**150,513**

Overall, project savings are as follows:

Overall Project Savings

Measure	Expected Annual therms Savings	Realized Annual therms Savings	Realization Rate	Lifetime therms Savings	Annual Water Gallons Savings	Lifetime Water Gallons Savings
Steam Leak Repairs	7,302	6,329	86.7%	63,290	55,659	556,950
Steam Traps	150,943	150,513	99.7%	752,565	0	0
Pipe Insulation	22,628	24,524	108.4%	490,480	0	0
TOTAL	**180,873**	**181,366**	**100.3%**	**1,306,335**	**55,659**	**556,950**

The realization rate for project #003 is 100.3%. The realization rate is high because ex-ante estimation took the average of surface temperature and ambient temperature for all pipe and then plugged into 3E plus to calculate pre and post heat loss. The ex-post estimation took the average of surface temperature and ambient temperature for each pipe size, and then plugged average surface temperature and ambient temperature into 3Eplus to calculate pre and post heat loss.

Program C&I Solutions
Project ID PRJ-2176009
Steam Trap Replacement
Measures Steam Leak Repair
Pipe and Valve Insulation

Project Background

The participant is a hospital that received incentives from Black Hills Energy for:

- ECM #1: Steam trap replacements
- ECM #2: Steam leak repairs
- ECM #3: Pipe and Valve Insulation

The site uses steam throughout the facility for various process needs. A condensate return system will take condensate from where steam cools and will use this hot water to produce more steam instead of using makeup water. Savings will come from requiring less energy to produce steam using the hot condensate water instead of the makeup water.

Steam Trap Replacement Parameters

Line Size (inches)	Orifice Size (inches)	Feedwater Temperature (°F)	Inlet Pressure (psig)	Outlet Pressure (psig)	Applied Discharge Rate (lb/hr)
1/2	1/8	120	50	0	27

Steam Leak Repair Parameters

Leak No.	System Pressure (psig)	Feedwater Temperature (°F)	Plume Length (ft)	Operating Hours (hr)	Combustion Efficiency
1	50	210	3	8,760	83.5%
2	50	210	3	8,760	83.5%

Bare Pipe Insulated Parameters - Pipe

Length (feet)	Pipe Diameter (inches)	Insulation Thickness	Heat Loss (BTU/hr/ft)
4	0.5”	1.5	129.57
38	1”	1.5	198.74
45	2”	1.5	282.19
38	3”	1.5	507.99
18	4”	1.5	647.49
50	1”	1.5	72.95
13	2”	1.5	103.31
11	2”	1.5	91.32
10	2”	1.5	127.97

Bare Pipe Insulated Parameters - Valve

Pipe Size	Quantity	Insulation Thickness	Heat Loss (BTU/hr/ft)
4	6	1.5	648.97
4	1	1.5	648.97
3	2	1.5	509.13
3	1	1.5	509.13

M&V Methodology

ECM#1: Steam Trap Replacement

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A- Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Steam trap orifice sizes (1/8’’ for one steam trap)
- Annual Hours of Operation
    - 8,760 hours (drip)
    - 2,628 hours (Process 1)
    - 2,000 hours (Process 2)
    - 5,256 hours (Process 3)
- Inlet / outlet system pressures
- Boiler efficiency (82% estimated)

Calculations for annual therms savings use the following equation:

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)
OpHrs = annual hours the system is pressurized (hrs./yr.)
H_{fg} = latent heat of evaporation (BTU/lb) = 970.4 BTU/lb
EC_{Base} = combustion efficiency of boiler (%)
Therm Conversion Factor = 100,000 (BTU/therm)
The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here:
https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

ECM #2: Steam Leak Repairs

An alternative method was used to calculate the steam loss before steam leak repairs. The more traditional method equates the orifice diameter flow rate, using the orifice diameter of the leak and the system's absolute pressure. Due to the difficulty in determining the exact diameter of an orifice leak, the alternate method was used.

Calculations follow the methods established by G.G. Rajan for a steam leak rate as a function of the length of an active steam plume.

$$Leak\ Rate\ \left(\frac{kg}{hr}\right) = 2.5678\ x \exp[1.845\ x\ Plume\ Length\ (m)]$$

$$Leak\ Rate\ \left(\frac{lb}{hr}\right) = 5.661\ x \exp\ [0.562\ x\ Plume\ Length\ (ft)]$$

$$Heat\ Loss\ \left(\frac{Btu}{hr}\right) = Leak\ Rate\ \left(\frac{lb}{hr}\right) x\ \left[Steam\ Enthalpy\ \left(\frac{Btu}{lb}\right) - FW\ Enthalpy\ \left(\frac{Btu}{lb}\right) - MW\ Enthalpy\ \left(\frac{Btu}{lb}\right)\right]$$

Where:

Leak Rate = calculated value using the Leak Rate equation
Steam Enthalpy = saturated steam region based on system steam pressure
FW Enthalpy = steam look up table based on feedwater temperature

MV Enthalpy = steam look up table based on makeup water temperature, derived from average temperature of water main in each zone

Energy Savings

The annual energy savings from repairing a steam leak is calculated with the following equation:

$$Annual\ Energy\ Savings\ (therms) = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right) x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Eff_{Boiler}\ (\%)\ x\ 100{,}000\ \frac{Btu}{therm}}$$

Where:

Annual Operating Hours = number of hours facility operates annually (obtained from facility representative)
Eff_{Boiler} = 81.3% (Note: only one boiler was tested)
100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

ECM #3: Pipe, Valve, and Tank Insulation

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A- Retrofit Isolation: Key Parameter Measurement. Through this method, energy savings are calculated using key data and through the North American Insulation Manufacturers Association's 3E Plus software (http://www.pipeinsulation.org/).

Measurement and verification activities are based on the following assumptions:

- The facility operates 8,760 hours annually
- Variable Insulation thickness: 1.5 in
- Insulation material type: 850F Min. Fiber Pipe and Tank, Type IIIB, C1393-14
- Boiler Efficiency: 83.5%
- The average annual ambient air temperature 75°F

The 3E Plus software was used to calculate heat loss (btu/hr/ft) for bare piping (pre-retrofit) and piping with 1-in insulation (post-retrofit). The software required these inputs: process temperature, ambient temperature, pipe size, base metal, insulation, and jacket material. Annual therms savings was calculated using the following equation:

$$Annual\ Therms\ Savings = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right)\ x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Boiler\ Efficiency\ x\ 100{,}000\ \left(\frac{BTU}{CCF}\right)}$$

Where:

Heat loss = Difference between pre and post heat measurements (btu/hr/ft) multiplied by the pipe length

AOH = Annual operating hours (8,760 hours)

Boiler efficiency = 83.5%

Therms conversion factor = $\frac{1\ therm}{100{,}000\ BTU/CcF}$

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Steam Leak Repairs	10 years
Steam Trap Replacement	5 years
Pipe and Valve Insulation	20 years

Calculated Savings:

ECM #1: Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Discharge Rate (lb/hr)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	Therms Savings
1	½"	50	0	27	1,179.6	88	2,783
						Total	**2,783**

ECM #2: Steam Leak Repairs

Steam Leak Repairs Savings

Steam Leak #	Plume Length (ft)	Steam Pressure (psig)	Leak Rate (lbs./hr.)	System Enthalpy (BTU/lb)	Heat Loss (BTU/hr)	Therms Savings
1	3	50	30.56	1,145.42	35,000.82	3,672
2	3	50	30.56	1,138.52	34,789.97	3,650
					Total	**7,322**

ECM #3: Pipe and Valve Insulation

Using the above parameters, calculated savings of each insulation installation are presented in the table below.

Insulated pipe savings

Length (feet)	*Pipe Diameter (inches)*	*Insulation Thickness*	*Heat Loss (BTU/hr/ft)*	*Gas Savings (Therms)*
4	0.5”	1.5	129.57	54
38	1”	1.5	198.74	792
45	2”	1.5	282.19	1,332
38	3”	1.5	507.99	2,025
18	4”	1.5	647.49	1,223
50	1”	1.5	72.95	383
13	2”	1.5	103.31	141
11	2”	1.5	91.32	105
10	2”	1.5	127.97	134
			Total	**6,190**

Insulated valves savings

Total Equivalent Length	*Quantity*	*Insulation Thickness*	*Heat Loss (BTU/hr/ft)*	*Gas Savings (Therms)*
4	6	1.5	648.97	1,134
4	1	1.5	648.97	189
3	2	1.5	509.13	286
3	1	1.5	509.13	143
			Total	**1,752**

Overall project savings are as follows:

Overall Project Savings

Measure	Expected Annual Therms Savings	Realized Annual Therms Savings	Realization Rate	Lifetime Therms Savings	Annual Water Gallons Savings	Lifetime Water Gallons Savings
Steam Traps	2,783	2,783	100.0%	13,915	64,269	642,690
Steam Leaks	7,322	7,322	100.0%	73,220	-	-
Insulation	7,942	7,942	100.0%	158,840	-	-
TOTAL	**18,047**	**18,047**	**100.0%**	**245,975**	**64,269**	**642,690**

Program	C&I Solutions
Project ID	PRJ-2176549
	Steam Trap Replacement
Measures	Steam Leak Repairs
	Pipe Insulation

Project Background

The participant is a hospital that received incentives from Black Hills Energy for:

- ECM #1: Steam leak repairs
- ECM #2: Steam trap replacement
- ECM #3: Pipe Insulation

The site uses steam throughout the facility primarily for two process needs: space heating and in some cases, domestic water heating. Savings will come from repairing the failed steam traps and steam leaks throughout the site's pipework, as well as properly insulating sections of pipe throughout the facility's pipework.

M&V Methodology

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A - Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Supply water temperature is 66.10°F based on the AR TRM 8.0
- Annual operating hours for the site are 8,760 hours
- Combustion efficiency is 83.0% (for both pre-retrofit and post-retrofit condition)

Steam Leak Repairs

An alternative method was used to calculate the steam loss before steam leak repairs. The more traditional method equates the orifice diameter flow rate, using the orifice diameter of the leak and the system's absolute pressure. Due to the difficulty in determining the exact diameter of an orifice leak, the alternate method was used.

Calculations follow the methods established by G.G. Rajan for a steam leak rate as a function of the length of an active steam plume.

Equating Steam Plume Length to Flow Rate

$$Leak\ Rate\ \left(\frac{kg}{hr}\right) = 2.5678\ x \exp[1.845\ x\ Plume\ Length\ (m)]$$

$$Leak\ Rate\ \left(\frac{lb}{hr}\right) = 5.661\ x \exp\ [0.562\ x\ Plume\ Length\ (ft)]$$

Calculation for Heat Loss

$$Heat\ Loss\ \left(\frac{Btu}{hr}\right) = Leak\ Rate\ \left(\frac{lb}{hr}\right) x\ \left[Steam\ Enthalpy\ \left(\frac{Btu}{lb}\right) - MW\ Enthalpy\ \left(\frac{Btu}{lb}\right)\right]$$

Where:

Leak Rate = calculated value using the Leak Rate equation
Steam Enthalpy = saturated steam region based on system steam pressure
MV Enthalpy = steam look up table based on makeup water temperature, derived from average temperature of water main in each zone (34.2 BTU/lb)

The following table shows relevant steam leak parameters required for annual energy savings calculations.

Steam Leak Parameters

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Pressure (psig)	Leak Rate (lbs./hr.)	Boiler Efficiency
1	Penthouse #3 Vent Lines From PRV	1	5.0	30	94.03	83.0%
2	Penthouse #3 Vent Lines From PRV	1	5.0	30	94.03	83.0%
3	4" Main Steam Header Blind Flange	1	3.0	75	30.56	83.0%

Energy Savings

The annual energy savings from repairing a steam leak is calculated with the following equation:

Steam Leak Repair Annual Energy Savings

$$Annual\ Energy\ Savings\ (therms) = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right) x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Boiler\ Efficiency(\%)\ x\ 100{,}000\ \frac{Btu}{therm}}$$

Where:

Annual Operating Hours = number of hours facility operates annually = 8,760 hours

Boiler Efficiency = 83.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Steam Trap Replacement

The following table shows relevant failed steam traps parameters required for annual energy savings.

Steam Trap Parameters

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Service (Drip/Process)	Feedwater Temperature (°F)	Boiler Efficiency	Operating Hours
1	1/8	75	0	Drip	120	83%	8,760
2	1/8	75	0	Drip	120	83%	8,760
3	1/8	75	0	Drip	120	83%	8,760

Calculations for the annual therms savings use the following equation:

Steam Trap Replacement Annual Energy Savings

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)

OpHrs = annual hours the system is pressurized (hrs./yr.)

H_{fg} = latent heat of evaporation (BTU/lb) found in Table 6

EC_{Base} = combustion efficiency of boiler (%), 83.0%

Therm Conversion Factor = 100,000 (BTU/therm)

The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here: https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

Pipe Insulation

Through this method, energy savings are calculated using key data and through the North American Insulation Manufacturers Association's 3E Plus software:

(http://www.pipeinsulation.org/).

Measurement and verification activities are based on the following assumptions:

- Hours of operation are 8,760

- Insulation thickness: 1.50 in
- Insulation material type: 850°F Min. Fiber Pipe and Tank, Type IIIB, C1393-14
- Process temperatures are 274°F and 320°F
- Boiler Efficiency: 83.0%
- The average annual ambient air temperature 75°F

The 3E Plus software was used to calculate heat loss (btu/hr/ft) for bare piping (pre-retrofit) and piping with 1-in insulation (post-retrofit). The software required these inputs: process temperature, ambient temperature, pipe size, base metal, insulation, and jacket material. Annual therms savings was calculated using the following equation:

Pipe Insulation Installation Annual Energy Savings

$$\textbf{Annual Therms Savings} = \frac{\textbf{Heat Loss } \left(\frac{\textbf{Btu}}{\textbf{hr}}\right) \textbf{ x Annual Operating Hours } \left(\frac{\textbf{hrs}}{\textbf{yr}}\right)}{\textbf{Boiler Efficiency x } \mathbf{100,000} \left(\frac{\textbf{BTU}}{\textbf{CCF}}\right)}$$

Where:

Annual Operating Hours = number of hours facility operates annually = 8,760 hours

Boiler Efficiency = 83.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Pipe/Vale Insulation Parameters

Entry #	*Description*	*Pipe or Valve*	*Quantity*	*Pipe Length / Valve Equivalent Length (ft)*	*Diameter (in)*
1	GRM 3'' Steam Pipe	Pipe	1	2	3
2	GRM 2" Steam Pipe	Pipe	1	2	2
3	GRM 1" Steam Pipe	Pipe	1	6	1
4	GRM 3/4'' Steam Pipe	Pipe	1	12	1
5	GRM 4'' Steam Pipe	Pipe	1	4	4
6	GRM 3'' Regulator	Valve	1	3.35	3
7	GRM 3'' Y Strainer	Valve	1	3.35	3
8	GRM 3'' Gate Valves	Valve	1	3.35	3
9	GRM 3/4'' Y Strainer	Valve	1	2	0.75
10	GRM 2'' Regulator	Valve	1	3	2
11	GRM 2'' Y Strainer	Valve	1	3	2

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Steam Leak Repairs	10 years
Steam Trap Replacement	5 years
Pipe Insulation	20 years

Calculated Savings:

Steam Leak Repairs

Steam Leak Repairs Savings

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Enthalpy (BTU/lb)	System Enthalpy (BTU/lb)	Therms Savings
1	Penthouse #3 Vent Lines From PRV	1	5.0	1,172.70	1,138.52	11,299
2	Penthouse #3 Vent Lines From PRV	1	5.0	1,172.70	1,138.52	11,299
3	4" Main Steam Header Blind Flange	1	3.0	1,185.90	1,151.72	3,714
					Total:	**26,312**

Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Discharge Rate (lbs./hr.)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	Latent Heat of Evaporation, H_{fg} (BTU/lb)	Therms Savings
1	37	1185.9	88	1026.38	3,859
2	37	1185.9	88	1026.38	3,859
3	37	1185.9	88	1026.38	3,859
				Total:	**11,576**

Pipe Insulation

Pipe Insulation Annual Energy Savings

Entry #	Description	Pipe or Valve	Temperature (°F)	Pre Heat Loss	Post Heat Loss	Therms Savings
1	GRM 3'' Steam Pipe	Pipe	320	650.6	68.2	123
2	GRM 2" Steam Pipe	Pipe	320	452.9	51.6	85
3	GRM 1" Steam Pipe	Pipe	320	263.4	35.7	144
4	GRM 3/4'' Steam Pipe	Pipe	320	215.2	32.9	231
5	GRM 4'' Steam Pipe	Pipe	274	616.2	63.1	233
6	GRM 3'' Regulator	Valve	320	650.6	68.2	165
7	GRM 3'' Y Strainer	Valve	320	650.6	68.2	165
8	GRM 3'' Gate Valves	Valve	320	650.6	68.2	329
9	GRM 3/4'' Y Strainer	Valve	320	215.2	32.9	31
10	GRM 2'' Regulator	Valve	274	338.9	39.7	76
11	GRM 2'' Y Strainer	Valve	274	338.9	39.7	76
					Total:	**1,657**

Overall project savings are as follows:

Overall Project Savings

Measure	*Expected Annual therms Savings*	*Realized Annual therms Savings*	*Realization Rate*	*Lifetime therms Savings*	*Annual Water Gallons Savings*	*Lifetime Water Gallons Savings*
Steam Leak Repair	26,312	26,312	100.0%	263,120	229,900	2,299,000
Steam Trap Replacement	11,576	11,576	100.0%	53,708	N/A	N/A
Pipe Insulation	1,657	1,657	100.0%	33,140	N/A	N/A
TOTAL	**39,545**	**39,545**	**100.0%**	**354,140**	**229,900**	**2,299,000**

Program	C&I Solutions
Project ID	PRJ-2135401
	Steam Trap Replacement
Measures	Steam Leak Repairs
	Pipe Insulation

Project Background

The participant is a college that received incentives from Black Hills Energy for:

- ECM #1: Steam leak repairs
- ECM #2: Steam trap replacement
- ECM #3: Pipe Insulation

The site uses steam throughout the facility primarily for two process needs: space heating, domestic water heating, and kitchen equipment. The participant's three boilers serve the heating needs for multiple buildings throughout the college campus. Savings will come from repairing the failed steam traps and steam leaks throughout the site's pipework, as well as properly insulating sections of pipe throughout the facility's pipework.

M&V Methodology

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A - Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Supply water temperature is 65.6°F based on the AR TRM 8.0
- Annual operating hours for the site are 8,760 hours
- Combustion efficiency is 83.0% (for both pre-retrofit and post-retrofit condition)

Steam Leak Repairs

An alternative method was used to calculate the steam loss before steam leak repairs. The more traditional method equates the orifice diameter flow rate, using the orifice diameter of the leak and the system's absolute pressure. Due to the difficulty in determining the exact diameter of an orifice leak, the alternate method was used.

Calculations follow the methods established by G.G. Rajan for a steam leak rate as a function of the length of an active steam plume.

Equating Steam Plume Length to Flow Rate

$$Leak\ Rate\ \left(\frac{kg}{hr}\right) = 2.5678\ x \exp[1.845\ x\ Plume\ Length\ (m)]$$

$$Leak\ Rate\ \left(\frac{lb}{hr}\right) = 5.661\ x \exp\ [0.562\ x\ Plume\ Length\ (ft)]$$

Calculation for Heat Loss

$$Heat\ Loss\ \left(\frac{Btu}{hr}\right) = Leak\ Rate\ \left(\frac{lb}{hr}\right) x\ \left[Steam\ Enthalpy\ \left(\frac{Btu}{lb}\right) - MW\ Enthalpy\ \left(\frac{Btu}{lb}\right)\right]$$

Where:

Leak Rate = calculated value from Leak Rate equation
Steam Enthalpy = saturated steam region based on system steam pressure
MV Enthalpy = steam look up table based on makeup water temperature, derived from average temperature of water main in each zone (34.2 BTU/lb)

The following table shows relevant steam leak parameters required for annual energy savings calculations.

Table 18. Steam Leak Parameters

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Pressure (psig)	Leak Rate (lbs./hr.)	Boiler Efficiency
1	Hutch Mechanical Room	1	1.0	34	9.93	83.0%
2	LRC Mechanical Room	1	1.0	34	9.93	83.0%
3	LRC Mechanical Room	1	1.0	34	9.93	83.0%
4	MAE Kitchen/Kettle	1	1.0	34	9.93	83.0%

Energy Savings

The annual energy savings from repairing a steam leak is calculated with the following equation:

Steam Leak Repair Annual Energy Savings

$$Annual\ Energy\ Savings\ (therms) = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right) x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Boiler\ Efficiency(\%)\ x\ 100{,}000\ \frac{Btu}{therm}}$$

Where:

Annual Operating Hours = number of hours facility operates annually = 8,760 hours

Boiler Efficiency = 83.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Steam Trap Replacement

The following table shows relevant failed steam traps parameters required for annual energy savings.

Steam Trap Parameters

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Service (Drip/Process)	Feedwater Temperature (°F)	Boiler Efficiency	Operating Hours
1	1/4	34	0	Drip	200	83%	8,760
2	7/32	34	0	Drip	200	83%	8,760
3	1/4	34	0	Drip	200	83%	8,760
4	5/32	34	0	Drip	200	83%	8,760
5	5/32	34	0	Drip	200	83%	8,760
6	1/8	34	0	Drip	200	83%	8,760
7	0.181''	34	0	Drip	200	83%	8,760
8	0.181''	34	0	Drip	200	83%	8,760
9	0.181''	34	0	Drip	200	83%	8,760

Calculations for the annual therms savings use the following equation:

Steam Trap Replacement Annual Energy Savings

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)

OpHrs = annual hours the system is pressurized (hrs./yr.)

H_{fg} = latent heat of evaporation (BTU/lb) found in Table 6

EC_{Base} = combustion efficiency of boiler (%), 83.0%

Therm Conversion Factor = 100,000 (BTU/therm)

The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here: https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

Pipe Insulation

Through this method, energy savings are calculated using key data and through the North American Insulation Manufacturers Association's 3E Plus software:

(http://www.pipeinsulation.org/).

Measurement and verification activities are based on the following assumptions:

- Hours of operation are 8,760
- Insulation thickness: 1.50 in
- Insulation material type: 850°F Min. Fiber Pipe and Tank, Type IIIB, C1393-14
- Process temperatures are between 125°F and 280°F
- Boiler Efficiency: 83.0%
- The average annual ambient air temperature 75°F

The 3E Plus software was used to calculate heat loss (btu/hr/ft) for bare piping (pre-retrofit) and piping with 1-in insulation (post-retrofit). The software required these inputs: process temperature, ambient temperature, pipe size, base metal, insulation, and jacket material. Annual therms savings was calculated using the following equation:

Pipe Insulation Installation Annual Energy Savings

$$\textbf{Annual Therms Savings} = \frac{\textbf{Heat Loss } \left(\frac{\textbf{Btu}}{\textbf{hr}}\right) \textbf{ x Annual Operating Hours } \left(\frac{\textbf{hrs}}{\textbf{yr}}\right)}{\textbf{Boiler Efficiency x } 100,000 \left(\frac{\textbf{BTU}}{\textbf{CCF}}\right)}$$

Where:

Annual Operating Hours = number of hours facility operates annually = 8,760 hours

Boiler Efficiency = 83.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Pipe/Vale Insulation Parameters

Entry #	Description	Pipe / Valve	Quantity	Pipe Length / Valve Equivalent Length (ft)	Diameter (in)
1	Mabee Dock 8'' HX Pipe	Pipe	1	8.5	8
2	Mabee Dock 2'' HX Pipe	Pipe	1	9	2
3	Mabee Dock 1.25'' Condensate Pipe	Pipe	1	1.5	2

4	Bell Science 6'' HX Pipe	Pipe	1	3.25	6
5	Bell Science 10'' Heat Exchanger	Pipe	1	1	10
6	Hutch Mechanical 4'' HW/HX Pipe	Pipe	1	6	4
7	Hutch Mechanical 4'' Stm/HX Pipe	Pipe	1	1	4
8	Hutch Mechanical 10'' Heat Exchanger	Pipe	1	1	10
9	Hutch Mechanical 2'' Condensate Pipe	Pipe	1	36	2
10	Hutch Mechanical 2'' Pipe Condensate Tank	Tank	1	9	2
11	Walker 3rd Floor 12'' Heat Exchanger	Pipe	1	0.5	12
12	Walker 3rd Floor 6'' Condensate HX Pipe	Pipe	1	0.5	6
13	Walker 3rd Floor 8'' Condensate HX Pipe	Pipe	1	0.5	8
14	Walker 3rd Floor 1'' Condensate Pipe	Pipe	1	1	1
15	Jay Alvin 6'' Steam Pipe	Pipe	1	4	2
16	Jay Alvin 2'' Condensate Return	Pipe	1	1	2
17	Jay Alvin 1.5'' Condensate Return	Pipe	1	12	2
18	Jay Alvin 6'' HX Pipe	Pipe	1	2	6
19	Jay Alvin 10'' Heat Exchanger	Pipe	1	0.5	10
20	Boiler Plant 4'' DA Pipe	Pipe	1	3	4
21	Boiler Plant 2'' DA Pipe	Pipe	1	6	2
22	SBC 6'' HX Pipe	Pipe	1	3	6
23	Art Building 1.5'' Condensate Return Pipe	Pipe	1	54	2
24	Cathedral 6'' Pipe	Pipe	1	3	6
25	Cathedral 6'' Tunnel Pipe	Pipe	1	4	6
26	Bell Science 6'' HX Valve	Valve	1	3.58	1
27	Bell Science 6'' DHW Fitting	Valve	1	3.58	1
28	Hutch Mechanical 4'' HW Valve	Valve	1	3.58	1
29	Hutch Mechanical 4'' HW Fitting	Valve	1	3.47	1
30	Hutch Mechanical 6'' Fitting HW Tank	Tank	1	3.58	1
31	Walker 3rd Floor 6'' Condensate Fitting	Valve	1	3.58	1
32	J Alvin 6'' PRV	Valve	1	3.58	1
33	Boiler Plant 1.5'' DA Valve	Valve	1	2.75	1
34	SBC 3'' PRV	Valve	1	3.35	1
35	SBC 4'' PRV	Valve	1	3.47	1
36	SBC 3'' PRV	Valve	1	3.35	1
37	Walker 3rd Floor Condensate Reservoir	Tank	1	2	2
38	SBC Condensate Reservoir	Tank	1	2.3	2.3
39	SBC Condensate Reservoir	Tank	1	2.3	2.3
40	LRC Condensate Reservoir	Tank	1	2	1
41	LRC Condensate Reservoir	Tank	1	2	1
42	Art Building Condensate Reservoir	Tank	1	1.2	1.4
43	Art Building Condensate Reservoir	Tank	1	1.2	1.4
44	LRC Condensate Tank	Tank	1	1.5	3

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Steam Leak Repairs	10 years
Steam Trap Replacement	5 years
Pipe Insulation	20 years

Calculated Savings:

Steam Leak Repairs

Steam Leak Repairs Savings

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Enthalpy (BTU/lb)	System Enthalpy (BTU/lb)	Therms Savings
1	Hutch Mechanical Room	1	1.0	1,174.30	1,140.62	1,195
2	LRC Mechanical Room	1	1.0	1,174.30	1,140.62	1,195
3	LRC Mechanical Room	1	1.0	1,174.30	1,140.62	1,195
4	MAE Kitchen/Kettle	1	1.0	1,174.30	1,140.62	1,195
					Total:	**4,782**

Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Discharge Rate (lbs./hr.)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	Latent Heat of Evaporation, H_{fg} (BTU/lb)	Percent Failed	Therms Savings
1	81	1174.3	168.13	1006.17	100%	8,708
2	62	1174.3	168.13	1006.17	60%	4,014
3	81	1174.3	168.13	1006.17	40%	3,483
4	31	1174.3	168.13	1006.17	50%	1,699
5	31	1174.3	168.13	1006.17	40%	1,359
6	20	1174.3	168.13	1006.17	70%	1,561
7	43.1	1174.3	168.13	1006.17	90%	4,119
8	43.1	1174.3	168.13	1006.17	60%	2,746
9	43.1	1174.3	168.13	1006.17	30%	1,373
				Total:		**29,063**

Pipe Insulation

Pipe Insulation Annual Energy Savings

Entry #	Description	Pipe or Valve	Temperature (°F)	Pre Heat Loss	Post Heat Loss	Therms Savings
1	Mabee Dock 8'' HX Pipe	Pipe	200	504.90	52.23	406
2	Mabee Dock 2'' HX Pipe	Pipe	200	112.70	14.86	93
3	Mabee Dock 1.25'' Condensate Pipe	Pipe	200	139.00	18.54	19
4	Bell Science 6'' HX Pipe	Pipe	200	294.00	33.55	89
5	Bell Science 10'' Heat Exchanger	Pipe	200	608.90	59.93	58
6	Hutch Mechanical 4'' HW/HX Pipe	Pipe	200	146.70	17.65	82
7	Hutch Mechanical 4'' Stm/HX Pipe	Pipe	200	349.50	38.08	33
8	Hutch Mechanical 10'' Heat Exchanger	Pipe	200	801.00	76.40	76
9	Hutch Mechanical 2'' Condensate Pipe	Pipe	200	146.80	18.79	486
10	Hutch Mechanical 2'' Pipe Condensate Tank	Tank	200	59.12	8.40	48
11	Walker 3rd Floor 12'' Heat Exchanger	Pipe	200	1040.00	96.94	50
12	Walker 3rd Floor 6'' Condensate HX Pipe	Pipe	200	555.20	58.94	26
13	Walker 3rd Floor 8'' Condensate HX Pipe	Pipe	200	681.10	68.09	32
14	Walker 3rd Floor 1'' Condensate Pipe	Pipe	200	72.89	11.26	7
15	Jay Alvin 6'' Steam Pipe	Pipe	200	690.00	71.54	261
16	Jay Alvin 2'' Condensate Return	Pipe	200	263.30	31.63	24
17	Jay Alvin 1.5'' Condensate Return	Pipe	200	214.50	27.71	237
18	Jay Alvin 6'' HX Pipe	Pipe	200	690.00	71.54	131
19	Jay Alvin 10'' Heat Exchanger	Pipe	200	1097.00	101.00	53
20	Boiler Plant 4'' DA Pipe	Pipe	200	349.50	38.08	99
21	Boiler Plant 2'' DA Pipe	Pipe	200	183.30	22.89	102
22	SBC 6'' HX Pipe	Pipe	200	634.80	66.42	180
23	Art Building 1.5'' Condensate Return Pipe	Pipe	200	91.98	13.02	450
24	Cathedral 6'' Pipe	Pipe	200	504.10	54.10	142
25	Cathedral 6'' Tunnel Pipe	Pipe	200	529.40	56.51	200
26	Bell Science 6'' HX Valve	Valve	200	294.00	33.55	165
27	Bell Science 6'' DHW Fitting	Valve	200	529.40	56.51	299
28	Hutch Mechanical 4'' HW Valve	Valve	200	146.70	17.65	82
29	Hutch Mechanical 4'' HW Fitting	Valve	200	146.70	17.65	54
30	Hutch Mechanical 6'' Fitting HW Tank	Tank	200	581.30	61.41	329
31	Walker 3rd Floor 6'' Condensate Fitting	Valve	200	746.80	76.77	424
32	J Alvin 6'' PRV	Valve	200	690.00	71.54	392
33	Boiler Plant 1.5'' DA Valve	Valve	200	157.10	20.97	22
34	SBC 3'' PRV	Valve	200	506.60	54.38	143
35	SBC 4'' PRV	Valve	200	332.20	36.40	125
36	SBC 3'' PRV	Valve	200	506.60	54.38	143
37	Walker 3rd Floor Condensate Reservoir	Tank	200	176.60	16.58	34
38	SBC Condensate Reservoir	Tank	200	171.80	16.18	38
39	SBC Condensate Reservoir	Tank	200	171.80	16.18	38
40	LRC Condensate Reservoir	Tank	200	171.80	16.18	33

41	LRC Condensate Reservoir	Tank	200	171.80	16.18	33
42	Art Building Condensate Reservoir	Tank	200	171.80	16.18	19
43	Art Building Condensate Reservoir	Tank	200	171.80	16.18	19
44	LRC Condensate Tank	Tank	200	261.20	23.43	38
Total:						**5,814**

Overall, project savings are as follows:

Overall Project Savings

Measure	*Expected Annual therms Savings*	*Realized Annual therms Savings*	*Realization Rate*	*Lifetime therms Savings*	*Annual Water Gallons Savings*	*Lifetime Water Gallons Savings*
Steam Leak Repair	4,782	4,782	100.0%	145,315	41,772	417,720
Steam Trap Replacement	29,063	29,063	100.0%	47,820	N/A	N/A
Pipe Insulation	6,481	6,481	100.0%	129,620	N/A	N/A
TOTAL	**40,325**	**40,325**	**100.0%**	**322,755**	**41,772**	**417,720**

Program	C&I Solutions
Project ID	PRJ-2178782
	Faucet Aerators
Measures	Air Sealing
	Duct Sealing

Project Background

The participant is a multi-family apartment complex that received incentives from Black Hills Energy for implementing the following energy efficient measures:

- ECM #1: Faucet Aerators
- ECM #2: Air Infiltration
- ECM #3: Duct Sealing

M&V Methodology

Faucet Aerators

On-site, evaluators verified the presence of one aerator listed on the project application. Savings for the domestic hot water measures were calculated using 3.3.2 Faucet Aerators in the Arkansas TRM 8.0. The savings values for low-flow faucet aerators are for the retrofit of existing operational faucet aerators with a flow rate of 2.2 gallons per minute or higher. Facilities that use both gas and electric water heaters are eligible for this measure.

Faucet Aerator Savings Parameters

Building Type	Fuel Type	Weather Zone
Multifamily	Gas	9

Air Sealing

Evaluators also verified the presence of relevant air sealing listed on the project application. Air sealings save energy by properly sealing any conditioned/heated air leakage in existing air filtration systems. Savings for the domestic air sealing measures were calculated using 2.2.9 Air Infiltration in the Arkansas TRM 8.0 with project-specific assumptions seen below.

Air Infiltration Savings Parameters

Building Type	Fuel Type	Wind Shielding	Ceiling Height	Weather Zone
Multifamily	Electric AC with Gas	Normal	8 ‘	9

Duct Sealing

On-site, evaluators verified the presence of relevant duct sealing listed on the project application. Duct sealings save energy by properly sealing any conditioned/heated air leakage in existing air

duct systems. Savings for the domestic duct sealing measures were calculated using 2.1.11 Duct Sealing in the Arkansas TRM 8.0 with project-specific assumptions below

Duct Sealing Savings Parameters

Building Type	Fuel Type	Weather Zone	Heating Degree Days (HDD)
Multifamily	Gas	9	4402

Savings Calculations

Faucet Aerators

Annual gas therms savings can be calculated by using the following equation:

Deemed Faucet Aerator Savings

$$Annual\ Therms\ Savings = \frac{\rho \times C_P \times U \times (F_B - F_P) \times \left(T_H - T_{Supply}\right) \times \frac{1}{E_t} \times \frac{Days}{Year}}{100{,}000\,\frac{Btu}{therm}}$$

The calculation assumptions are detailed below:

Faucet Aerators Calculation Assumptions

Parameter	Description	Value
F_B	Average baseline flow rate of aerator (GPM)	2.2
F_P	Average post measure flow rate of aerator (GPM)	≤ 1.5
$Days/Year$	Annual building type operating days for the applications: 1. Prison 2. Hospital, nursing home 3. Dormitory 4. Multifamily 5. Lodging 6. Commercial 7. School	 365 365 274 365 365 250 200
$Tsupply$	Average supply (cold) water temperature (ºF) from Table 328	Zone 9: 65.6 Zone 8: 66.1 Zone 7: 67.8 Zone 6: 70.1
T_H	Average mixed water (after aerator) temperature (ºF)	105
U_B	Baseline water usage duration, following applications: 1. Prison 2. Hospital, nursing home 3. Dormitory 4. Multifamily 5. Lodging 6. Commercial 7. School	 30 min/day/unit 3.0 min/day/unit 30 min/day/unit 3.0 min/day/unit 3.0 min/day/unit 30 min/day/unit 30 min/day/unit
ρ	Unit conversion: 8.33 pounds/gallon	8.33
C_P	Heat capacity of water – 1 Btu/lb °F	1
E_t	Thermal Efficiency of water heater	Default values: 0.98 for electric resistance 2.2 (COP) for heat pump, 0.80 for gas
P	Hourly water consumption during peak period as a fraction of average daily consumption for applications: 1. Prison 2. Hospital, nursing home 3. Dormitory 4. Multifamily 5. Lodging 6. Commercial 7. School	 0.04 0.03 0.04 0.03 0.02 0.08 0.05

Faucet Aerator Annual therms Savings

Building Type	Fuel Type	Expected Annual therms Savings	Realized Annual therms Savings	Realization Rate
Multifamily	Gas	2.0	2.0	100%
Total		**2.0**	**2.0**	**100%**

Air Infiltration

Annual gas therms savings can be calculated by using the following equations:

Maximum Allowable CFM50

$$CFM_{50,pre} / ft^2 = \frac{ACH_{Nat,pre} \times h \times N}{60}$$

Deemed Air Infiltration Savings

$$therms_{savings} = CFM_{50} \times GSF$$

The calculation assumptions are detailed below:

Air Infiltration Calculation Assumptions

Parameter	Description	Value
$CMF_{50,\ pre} / ft^2$	per square foot pre-installation infiltration rate	
$ACH_{Nat,\ pre}$	maximum pre-installation air change rate	(ACH_{Nat}) = 3.0
60	Constant to convert from minutes to hours	60
h	ceiling height (ft)	8.0 (project-specific value)
N	N factor	24
CMF_{50}	Air infiltration reduction in Cubic Feet per Minute at 50 pascals, as measured by the difference between pre- and post-installation blower door air leakage tests	Calculated
GSF	corresponding gas savings factor from table	Given

Air Infiltration Reduction – Deemed Savings Values – Zone 9 Northwest Region

Equipment Type	kWh Savings / CFM_{50} (ESF)	kW Savings / CFM50 (DSF)	therms Savings / CFM50 (ESF)
Electric AC with Gas Heat	0.166	0.000098	**0.095**
Gas Heat Only (No AC)	0.073	0.073	0.073
Electric AC with Resistance Heat	2.344	0.000098	N/A
Heat Pump	1.099	0.000098	N/A

Air Infiltration – N Factor

Wind Shielding	Number of Stories		
	Single Story	Two Story	Three + Story
Well Shielded	25.8	20.6	18.1
Normal	21.5	17.2	15.1
Exposed	19.4	15.5	13.5

Pre-Retrofit Infiltration Cap (CFM50 / ft2)

Wind Shielding	Number of Stories		
	Single Story	Two Story	Three + Story
Well Shielded	11.0	8.8	7.7
Normal	9.1	7.3	6.4
Exposed	8.2	6.6	5.7

Air Infiltration Annual therms Savings

CFM_{50} / ft^2	*Fuel Type*	*Expected Annual therms Savings*	*Realized Annual therms Savings*	*Realization Rate*
7.3	Electric AC with Gas	4,383	4,627	105.55%
Total		**4,383**	**4,627**	**105.55%**

Duct Sealing

Annual gas therms savings can be calculated by using the following equations:

Deemed Duct Sealing Savings

$$therms_{savings,H} = \frac{\left(DL_{pre} - DL_{post}\right) \times 60 \times HDD \times 24 \times 0.018}{100{,}000 \times AFUE}$$

OR

$$therms_{savings,H} = \frac{\Delta DSE \times EFLH_H \times CAP}{100{,}000 \times AFUE}$$

The calculation assumptions are detailed below:

Duct Sealing Calculation Assumptions

Parameter	Description	Value
DL_{pre}	Pre-improvement duct leakage at 25 Pa (ft3/min)	Measured
DL_{post}	Post- improvement duct leakage at 25 Pa (ft3/min)	Measured
ΔDSE	Assumed improvement in distribution system efficiency	5% or 0.05
60	Constant to convert from minutes to hours	60
HDD	Heating degree days	Zone 9: 4402 Zone 8: 3919 Zone 7: 3344 Zone 6: 2946
24	Constant to convert from days to hours	24
0.018	Volumetric heat capacity of air (Btu / ft3 • °F)	0.018
$EFLH_H$	Equivalent full load heating hours	Zone 9: 1868 Zone 8: 1738 Zone 7: 1681 Zone 6: 1521
CAP	Heating capacity (Btuh or BTU/hr)	Given
100,000	Constant to convert from Btu to therms	100,000
AFUE	Annual Fuel Utilization Efficiency of existing system	0.78

Duct Sealing Annual therms Savings

Building Type	*Fuel Type*	*Expected Annual therms Savings*	*Realized Annual therms Savings*	*Realization Rate*
Multifamily	Electric AC with Gas	13,326	13,290	99.73%
Total		**13,326**	**13,290**	**99.73%**

Results

The overall project savings are outlined in the table below.

Verified Gross Savings, Realization Rates, and Lifetime Savings

Measure	*Expected Annual therms*	*Realized Annual therms*	*Annual therms Realization Rate*	*EUL*	*Lifetime therms*	*Annual Water Savings (gal)*	*Lifetime Water Savings (gal)*
Total	**17,712**	**17,919**	**101.2%**	**16.19**	**290,142**	**599**	**9,699**

Program	C&I Solutions
Project ID	PRJ-2174721
Measures	Pipe Insulation Steam Trap Replacement

Project Background

The participant is a food processing plant that received incentives from Black Hills Energy for:

- ECM #1: Pipe Insulation
- ECM #2: Steam trap replacement

The site uses steam throughout the facility primarily for two process needs: space heating and in some cases, domestic water heating. Savings will come from steam trap repairs throughout the site's pipework, as well as properly insulating sections of pipe throughout the facility's pipework.

M&V Methodology

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A - Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Supply water temperature is 66.1°F based on the AR TRM 8.0
- Combustion efficiency is 82.0% (for both pre-retrofit and post-retrofit condition)

Pipe Insulation

For this measure, energy savings are calculated using key data and through the North American Insulation Manufacturers Association's 3E Plus software:

(http://www.pipeinsulation.org/).

Measurement and verification activities are based on the following assumptions:

- Hours of operation are 8,760
- Insulation thickness: 1.50 in
- Insulation material type: 850°F Min. Fiber Pipe and Tank, Type IIIB, C1393-14 and 850F MF BLANKET, Type IV, C553-13
- Boiler Efficiency: 82.0%

- Process temperatures: between 273°F and 310°F
- The average ambient air temperature: 75°F

The 3E Plus software was used to calculate heat loss (btu/hr/ft) for bare piping (pre-retrofit) and piping with 1.5-inch insulation (post-retrofit). The software required these inputs: process temperature, ambient temperature, pipe size, base metal, insulation, and jacket material. Annual therms savings was calculated using the following equation:

Pipe Insulation Installation Annual Energy Savings

$$\textbf{Annual Therms Savings} = \frac{\textbf{Heat Loss } \left(\frac{\textbf{Btu}}{\textbf{hr}}\right) \textbf{ x Annual Operating Hours } \left(\frac{\textbf{hrs}}{\textbf{yr}}\right)}{\textbf{Boiler Efficiency x } \mathbf{100,000} \left(\frac{\textbf{BTU}}{\textbf{CCF}}\right)}$$

Where:

Annual Operating Hours = number of hours facility operates annually = 8,760 hours

Boiler Efficiency = 82.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Pipe/Vale Insulation Parameters

Entry #	*Description*	*Pipe or Valve*	*Quantity*	*Pipe Length / Valve Equivalent Length (ft)*	*Diameter (in)*
1	Armstrong-Flo-Rite-#665-3-HW HX (Body and Head)	Pipe	1	33.3	6
2	4” Valve, Gate, 300#	Valve	1	3.47	4
3	3” Valve, Gate, 300#	Valve	1	3.35	3
4	2” Strainer	Valve	1	3	2
5	3” Valve, Gate, 125%	Valve	1	3.35	3
6	3” Strainer, 150#	Valve	1	3.35	3
7	2” Armstrong GP2000 Regulator Valve	Valve	1	6	2
8	6” Valve, Check, 300#	Valve	1	3.58	6
9	4” Valve, Gate, 250#	Valve	1	3.47	4

Steam Trap Replacement

Calculations for the annual therms savings use the following equation:

Steam Trap Replacement Annual Energy Savings

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)

OpHrs = annual hours the system is pressurized (hrs./yr.)

H_{fg} = latent heat of evaporation (BTU/lb)

EC_{Base} = combustion efficiency of boiler (%), 82.0%

Therm Conversion Factor = 100,000 (BTU/therm)

The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here: https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

The following table shows relevant parameters required for annual energy savings.

Steam Trap Parameters

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Service (Drip/Process)	Feedwater Temperature (°F)	Boiler Efficiency	Operating Hours
1	7/32 - 1/4	25	0	Process	210	82%	6,240
2	7/32 - 3/16	50	0	Drip	210	82%	8,760
3	7/32 - 3/16	50	0	Drip	210	82%	8,760
4	7/32 - 3/16	50	0	Process	210	82%	6,240
5	7/32 - 3/16	50	0	Process	210	82%	6,240
6	7/32 - 3/16	50	0	Process	210	82%	6,240
7	7/32 - 3/16	50	0	Process	210	82%	6,240
8	7/32 - 3/16	50	0	Process	210	82%	6,240
9	7/32 - 3/16	50	0	Process	210	82%	6,240
10	1/8	50	0	Process	210	82%	6,240
11	1/8	50	0	Process	210	82%	6,240
12	5/32	50	0	Process	210	82%	6,240
13	1/4	50	0	Process	210	82%	6,240
14	5/32 - 3/16	25	0	Process	210	82%	6,240
15	1/8	25	0	Process	210	82%	6,240
16	1/8	25	0	Process	210	82%	6,240
17	1/8	25	0	Process	210	82%	6,240
18	1/8	50	0	Process	210	82%	6,240
19	7/64	50	0	Process	210	82%	6,240
20	1/8	50	0	Process	210	82%	6,240
21	1/8	50	0	Drip	210	82%	8,760

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Pipe Insulation	20 years
Steam Trap Replacement	5 years

Calculated Savings:

Pipe Insulation

Pipe Insulation Annual Energy Savings

Entry #	Pipe Size	Total length	Pipe or Valve	Process Temperature (°F)	Pre Surface Temp (°F)	Post Surface Temp (°F)	Pre Heat Loss	Post Heat Loss	Gas Savings	Therms Savings
1	6	33.3	Pipe	273	272.1	96.8	575.6	89.18	486.42	1,730
2	4	3.47	Valve	275	274.7	94.7	620.5	63.56	556.94	206
3	3	3.35	Valve	275	274.7	93.9	489.7	52.75	436.95	156
4	2	3	Valve	307	306.7	95.1	419.3	48.07	371.23	119
5	3	3.35	Valve	307	306.6	96.1	602.1	60.04	542.06	194
6	3	3.35	Valve	307	306.6	96.1	602.1	60.04	542.06	194
7	2	6	Valve	275	274.8	91.2	341.3	37.5	303.8	195
8	6	3.58	Valve	273	272.6	96.7	883.7	83.91	799.79	306
9	4	3.47	Valve	310	309.6	97.4	777.3	73.6	703.7	261
									Total:	**3,362**

Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Discharge Rate (lbs./hr.)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	Latent Heat of Evaporation, H_{fg} (BTU/lb)	Percent Failed	Therms Savings
1	18.0	1,170.40	178.2	992.20	100%	1,359
2	17.0	1,179.60	178.2	1,001.40	100%	1,819
3	17.0	1,179.60	178.2	1,001.40	100%	1,819
4	30.0	1,179.60	178.2	1,001.40	100%	2,286
5	30.0	1,179.60	178.2	1,001.40	100%	2,286
6	30.0	1,179.60	178.2	1,001.40	100%	2,286
7	30.0	1,179.60	178.2	1,001.40	100%	2,286
8	30.0	1,179.60	178.2	1,001.40	100%	2,286
9	30.0	1,179.60	178.2	1,001.40	100%	2,286
10	30.0	1,179.60	178.2	1,001.40	100%	2,286
11	30.0	1,179.60	178.2	1,001.40	100%	2,286
12	17.0	1,179.60	178.2	1,001.40	100%	1,295
13	30.0	1,179.60	178.2	1,001.40	100%	2,286
14	73.0	1,170.40	178.2	992.20	100%	5,512
15	73.0	1,170.40	178.2	992.20	100%	5,512
16	11.0	1,170.40	178.2	992.20	100%	831
17	11.0	1,170.40	178.2	992.20	100%	831
18	30.0	1,179.60	178.2	1,001.40	100%	2,286
19	30.0	1,179.60	178.2	1,001.40	100%	2,286
20	30.0	1,179.60	178.2	1,001.40	100%	2,286
21	17.0	1,179.60	178.2	1,001.40	100%	1,819
					Total:	**48,229**

Overall, project savings are as follows:

Overall Project Savings

Measure	Expected Annual therms Savings	Realized Annual therms Savings	Realization Rate	Lifetime therms Savings	Annual Water Gallons Savings	Lifetime Water Gallons Savings
Pipe Insulation	3,357	3,362	100%	67,240	NA	NA
Steam Trap Replacement	48,229	48,228	100%	241,140	NA	NA
TOTAL	**51,586**	**51,590**	**100%**	**308,380**	**NA**	**NA**

Program	C&I Solutions
Project ID	PRJ-2176730
Measures	Steam Leak Repairs Steam Trap Replacement

Project Background

The participant is an industrial facility that received incentives from Black Hills Energy for:

- ECM #1: Steam leak repairs
- ECM #2: Steam trap replacement

The site uses steam throughout the facility primarily for two process needs: space heating and in some cases, domestic water heating. Savings will come from steam leaks throughout the site's pipework, as well as properly insulating sections of pipe throughout the facility's pipework. There is an additional condensate return measure claiming 40% of savings that is not included in this report .

M&V Methodology

The M&V effort for this project follows the guidelines of the 2012 International Performance Measurement and Verification Protocol (IPMVP) Option A - Retrofit Isolation: Key Parameter Measurement.

Measurement and verification activities are based on the following assumptions:

- Supply water temperature is 66.1°F based on the AR TRM 8.0
- Combustion efficiency is 84.0% (for both pre-retrofit and post-retrofit condition)

Steam Leak Repairs

An alternative method was used to calculate the steam loss before steam leak repairs. The more traditional method equates the orifice diameter flow rate, using the orifice diameter of the leak and the system's absolute pressure. Due to the difficulty in determining the exact diameter of an orifice leak, the alternate method was used.

Calculations follow the methods established by G.G. Rajan for a steam leak rate as a function of the length of an active steam plume.

Equating Steam Plume Length to Flow Rate

$$Leak\ Rate\ \left(\frac{kg}{hr}\right) = 2.5678\ x \exp[1.845\ x\ Plume\ Length\ (m)]$$

$$Leak\ Rate\ \left(\frac{lb}{hr}\right) = 5.661\ x \exp\ [0.562\ x\ Plume\ Length\ (ft)]$$

Calculation for Heat Loss

$$Heat\ Loss\ \left(\frac{Btu}{hr}\right) = Leak\ Rate\ \left(\frac{lb}{hr}\right) x\ \left[Steam\ Enthalpy\ \left(\frac{Btu}{lb}\right) - FW\ Enthalpy\ \left(\frac{Btu}{lb}\right)\right]$$

Where:

Leak Rate = calculated value using the Leak Rate equation
Steam Enthalpy = saturated steam region based on system steam pressure
FW Enthalpy = steam look up table based on feedwater temperature,
derived from average temperature of water main in each zone (34.2 BTU/lb)

The following table shows relevant steam leak parameters required for annual energy savings calculations.

Steam Leak Parameters

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Pressure (psig)	Leak Rate (lbs./hr.)	Boiler Efficiency
1	Cubotex #11: 1/2" 90° leaking	1	1	110	9.93	84.0%
2	Cubotex #14: 1 1/4" valve off main steam piping leaking	1	1	110	9.93	84.0%
3	Cubotex #15: 1 1/4" T leaking	1	1	110	9.93	84.0%

Energy Savings

The annual energy savings from repairing a steam leak is calculated with the following equation:

Steam Leak Repair Annual Energy Savings

$$Annual\ Energy\ Savings\ (therms) = \frac{Heat\ Loss\ \left(\frac{Btu}{hr}\right) x\ Annual\ Operating\ Hours\ \left(\frac{hrs}{yr}\right)}{Boiler\ Efficiency(\%)\ x\ 100{,}000\ \frac{Btu}{therm}}$$

Where:

Annual Operating Hours = 8,760 hours

Boiler Efficiency = 84.0%

100,000 Btu/CCF = conversion factor (BTU/yr. to CCF/yr.)

Steam Trap Replacement

Calculations for the annual therms savings use the following equation:

Steam Trap Replacement Annual Energy Savings

$$Annual\ \ therms\ Savings = \frac{Steam\ Trap\ Discharge\ Rate \times OpHrs \times h_{fg}}{EC_{Base} \times Therm\ Conversion\ Factor}$$

Where:

Steam Trap Discharge Rate = steam loss from the system (lb/hr)

OpHrs = annual hours the system is pressurized (hrs./yr.), 8000

H_{fg} = latent heat of evaporation (BTU/lb)

EC_{Base} = combustion efficiency of boiler (%), 85.0%

Therm Conversion Factor = 100,000 (BTU/therm)

The discharge rate (lb/hr) was calculated using Armstrong's "Steam Loss Through Failed Trap Calculator" (found here: https://www.armstronginternational.com/knowledge/resources-library/calculators/steam-loss)

The following table shows relevant failed steam traps parameters required for annual energy savings.

Steam Trap Parameters

Steam Trap #	Orifice Size (in.)	Inlet Pressure (psig)	Outlet Pressure (psig)	Service (Drip/Process)	Feedwater Temperature (°F)	Boiler Efficiency	Operating Hours
1	3/16	110	5	Drip	180	84%	7,488
2	7/64	110	5	Drip	180	84%	7,488
3	7/64	110	5	Drip	180	84%	7,488
4	1/8	110	5	Process	180	84%	7,488
5	1/8	110	5	Drip	180	84%	7,488
6	1/8	110	5	Drip	180	84%	7,488
7	5/32	110	5	Drip	180	84%	7,488
8	1/8	110	5	Drip	180	84%	7,488
9	1/8	110	5	Drip	180	84%	7,488
10	1/8	110	5	Drip	180	84%	7,488
11	1/8	110	5	Drip	180	84%	7,488

Measure Life

Estimated Useful Life by Measure

Measure	EUL
Steam Leak Repairs	10 years
Steam Trap Replacement	5 years

Calculated Savings:

Steam Leak Repairs

Steam Leak Repairs Savings

Steam Leak #	Description	Quantity of Leaks	Plume Length (ft)	Steam Enthalpy (BTU/lb)	System Enthalpy (BTU/lb)	Therms Savings
1	Cubotex #11: 1/2" 90° leaking	1	1	1192.00	1043.96	1,081
2	Cubotex #14: 1 1/4" valve off main steam piping leaking	1	1	1192.00	1043.96	1,081
3	Cubotex #15: 1 1/4" T leaking	1	1	1192.00	1043.96	1,081
					Total:	**3,243**

Steam Trap Replacement

Steam Trap Replacement Savings

Steam Trap #	Discharge Rate (lbs./hr.)	Steam Enthalpy (BTU/lb)	Feedwater Enthalpy (BTU/lb)	Latent Heat of Evaporation, H_{fg} (BTU/lb)	Percent Failed	Therms Savings
1	117.0	1,192.00	148.04	1,043.96	100%	10,888
2	40.0	1,192.00	148.04	1,043.96	100%	3,722
3	40.0	1,192.00	148.04	1,043.96	100%	3,722
4	33.0	1,192.00	148.04	1,043.96	80%	1,437
5	52.0	1,192.00	148.04	1,043.96	100%	4,839
6	52.0	1,192.00	148.04	1,043.96	100%	4,839
7	81.0	1,192.00	148.04	1,043.96	100%	7,538
8	52.0	1,192.00	148.04	1,043.96	100%	4,839
9	52.0	1,192.00	148.04	1,043.96	100%	4,839
10	52.0	1,192.00	148.04	1,043.96	100%	4,839
11	52.0	1,192.00	148.04	1,043.96	100%	4,839
					Total:	**56,343**

Overall project savings are as follows:

Overall Project Savings

Measure	*Expected Annual therms Savings*	*Realized Annual therms Savings*	*Realization Rate*	*Lifetime therms Savings*	*Annual Water Gallons Savings*	*Lifetime Water Gallons Savings*
Steam Leak Repairs	3,602	3,243	90.0%	32,430	28,247	282,470
Steam Trap Replacement	56,343	56,343	100.0%	281,715	NA	NA
Total:	**59,945**	**59,587**	**99.4%**	**314,145**	**28,247**	**282,470**

The realization rate for project #011 is 99.4%.

9. Appendix B: Deferred Replacement Cost Calculations

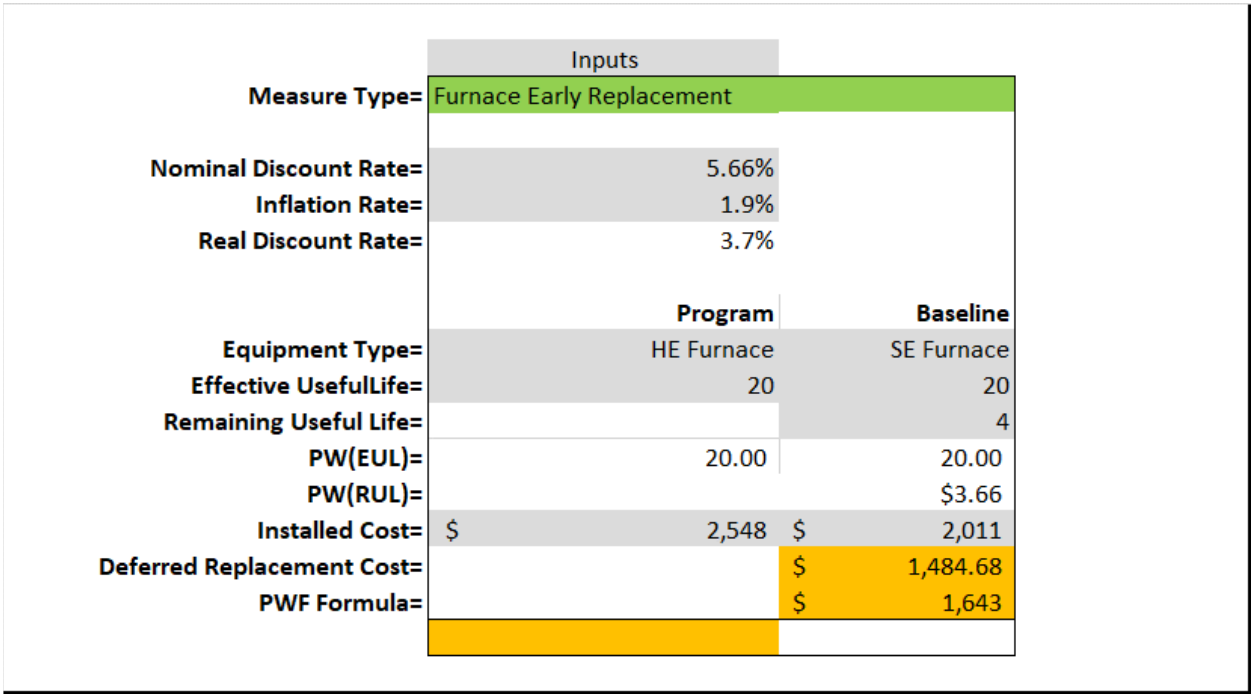
This appendix presents the calculations of deferred replacement costs for residential and commercial tankless water heaters as well as residential furnace early retirement.

	Inputs		
Measure Type=	Res Tankless (ROB + NC)		
Nominal Discount Rate=		5.66%	
Inflation Rate=		1.9%	
Real Discount Rate=		3.7%	
		Program	**Baseline**
Equipment Type=	Tankless WH		Storage WH
Effective UsefulLife=		20	11
Remaining Useful Life=			
PW(EUL)=		13.97	8.91
PW(RUL)=			
Installed Cost=		$1,219	$614
Deferred Replacement Cost=			$ 348.90
PWF Formula=			$ 348.90
Incremental Cost=	$	256.10	

Figure 9-1: Residential Tankless WH Avoided Replacement Cost Calculation

	Inputs		
Measure Type=	C&I Tankless (ROB + NC)		
Nominal Discount Rate=		5.66%	
Inflation Rate=		1.9%	
Real Discount Rate=		3.69%	
		Program	**Baseline**
Equipment Type=	Tankless WH		Storage WH
Effective UsefulLife=		20	15
Remaining Useful Life=			
PW(EUL)=		13.97	11.36
PW(RUL)=			
Installed Cost=		$1,219	$614
Deferred Replacement Cost=			$ 140.91
PWF Formula=			$ 140.91
Incremental Cost=	$	464.09	

Figure 9-2: C&I Tankless WH Avoided Replacement Cost Calculation



	Inputs	
Measure Type=	Furnace Early Replacement	
Nominal Discount Rate=	5.66%	
Inflation Rate=	1.9%	
Real Discount Rate=	3.7%	
	Program	**Baseline**
Equipment Type=	HE Furnace	SE Furnace
Effective UsefulLife=	20	20
Remaining Useful Life=		4
PW(EUL)=	20.00	20.00
PW(RUL)=		$3.66
Installed Cost=	$ 2,548	$ 2,011
Deferred Replacement Cost=		$ 1,484.68
PWF Formula=		$ 1,643

Figure 9-3: Furnace Early Retirement Deferred Replacement Cost Calculation

10. Appendix C: Sample TRM Calculations

10.1 Residential Furnaces (TRM V8.0 Section 2.1.3)

According to Arkansas TRM V8.0, savings for residential furnaces are calculated as follows:[30]

$$Annual\ Therm\ Savings\ =\ Heat\ load\ \times \left({}^{1}/_{AFUE_{base}}\ -\ {}^{1}/_{AFUE_{eff}}\right)$$

$$Heat\ load\ =\ {}^{therms}/_{site\ area}/year \times site\ area$$

Site area = ft.^{2} of the project site. If unknown, use installed capacity (btuh)/30 (btuh/ft2).

$AFUE_{base}$ = baseline efficiency of the furnace, 80% AFUE.

$AFUE_{eff}$ = efficiency of the new furnace installed, in AFUE.

Table 10-1 summarizes the heating load multipliers per square foot from the TRM V8.0.

Table 10-1: TRM V8.0 Annual Furnace Heating Load

Vintage	Heating Load (Therms/Ft.2/Year			
	Zone 9 – Fayetteville	Zone 8 – Fort Smith	Zone 7 – Little Rock	Zone 6 – El Dorado
1979 & Earlier	.404	.360	.336	.296
1980-1989	.303	.270	.252	.222
1990-1999	.202	.180	.168	.148
2000 & Later	.152	.135	.126	.111

Example savings calculations for a home in Zone 8 are as follows:

- Retrofit – 90,000 Input BTU furnace, 95% AFUE
- Output BTU = 90,000 x .95 = 85,500
- Square Feet = 85,500 / 30 = 2,450
- Year built: 1986

$$Retrofit\ Therms\ Savings = 2{,}450 ft.^2 \times .270 \frac{Therms}{ft.^2} \times \left(\frac{1}{.80} - \frac{1}{.95}\right) = 130.56\ Therms$$

The same furnace in a new construction project would save:

$$NC\ Therms\ Savings = 2{,}850 ft.^2 \times .135 \frac{Therms}{ft.^2} \times \left(\frac{1}{.80} - \frac{1}{.95}\right) = 75.94\ Therms$$

[30] Arkansas TRM V8.0 Volume 2, Page 44

10.2 Residential Water Heater Replacement (TRM V8.0 Section 2.3.1)

Energy savings values for storage tank water heaters were developed using installed Energy Factor ratings as determined by the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products. Tank sizing must follow AHRI standards.

In TRM V8.0 Savings are calculated as:[31]

$$therm_{Savings} = \frac{\rho \times C_p \times V \times \left(T_{SetPoint} - T_{Supply}\right) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{Conversion\ Factor}$$

ρ = Water density, 8.33 lbs./gal.

C_p = Specific heat of water, 1 BTU/lb·°F

V = Estimated annual hot water use (gal per year)

$T_{SetPoint}$ = Water heater set point, if unavailable, use 120°F

T_{Supply} = Average supply water temperature

EF_{pre} = Baseline value

EF_{post} = Energy Factor of new water heater

$Conversion\ Factor$ = 100,000 BTU = 1 therm

Baseline energy factors are summarized in Table 10-2.

Table 10-2: Residential Water Heating Baseline Uniform Energy Factors

Draw Pattern	Equivalent Gallons	Baseline UEF
Very Small	20	.3056
Low	30	.5412
Medium	40	.5803
High	50	.6270

Volume estimates are provided in Table 10-3.

Table 10-3: TRM V8.0 Estimated Annual Hot Water Use

Weather Zone	40 Gal.	50 Gal.	65 Gal.	80 Gal.
9	18,401	20,911	25,093	30,111
8	18,331	20,831	24,997	29,996
7	18,267	20,758	24,910	29,892
6	17,815	20,245	24,293	29,152

Supply water temperatures are presented in Table 10-4

[31] Arkansas TRM V8.0, Volume 2. Pg. 122-135

Table 10-4: Residential Water Supply Inlet Temperatures

Weather Zone		Supply Water Temp
9	Fayetteville	65.6
8	Fort Smith	66.1
7	Little Rock	67.8
6	El Dorado	70.1

Example savings calculations are as follows:

- Retrofit – 199,000 Input BTU Tankless Water Heater, 96% UEF
- High Draw Pattern
- Location: Fort Smith, Zone 8.

$$Therms\ Savings = \frac{1 \times 8.33 \times 20{,}831 \times (120 - 66.1) \times \left(\frac{1}{.627} - \frac{1}{.96}\right)}{100{,}000} = 51.74\ Therms$$

10.3 Smart Thermostats (TRM V8.0 Section 2.1.12)

The savings multipliers for smart thermostats are shown in Table 10-5[32].

Table 10-5: Smart Thermostat Deemed Savings Factors

Baseline	Therms/Ft.2	kWh/Ft.2
Manual	.037	.450
Programmable	.009	.113
Default	.033	.399

10.4 Commercial Furnaces (TRM V8.0 Section 3.1.9)

Therms savings calculations for commercial furnaces apply more facility-specific information than the residential methodology. Savings were calculated as follows:[33]

$$Therms\ Savings = \frac{BTU\ Capacity * EFLH_H * \left(\frac{1}{Effic_{pre}} - \frac{1}{Effic_{post}}\right)}{100{,}000\ Therms/BTU}$$

The TRM V8.0 EFLH values are summarized in Table 10-6.

[32] AR TRM V8.0 Vol 2.0 Pg. 83

[33] Arkansas TRM V8.0, Pg. 252

Table 10-6: EFLH Values[34]

Building Type	Zone 6	Zone 7	Zone 8	Zone 9
Assembly	615	854	915	1032
College/University	674	936	1002	1130
Fast Food Restaurant	287	439	472	549
Full Menu Restaurant	178	321	362	438
Grocery Store	692	941	1001	1129
Health Clinic	641	878	915	1045
Lodging	391	589	637	722
Large Office (>30k Ft^2)	816	1020	1060	1157
Small Office (<30k Ft^2)	351	534	564	644
Religious Worship	575	798	854	963
Retail	781	1043	1133	1287
School	777	1030	1094	1236

For example, if a Small Office in Fort Smith (Zone 8) installed a 70,000 BTU 96% AFUE Furnace, the resulting therms savings are calculated as:

$$Therms\ Savings = \frac{70{,}000\ BTU * 564\ EFLH * \left(\frac{1}{.80} - \frac{1}{.96}\right)}{100{,}000\ BTU/Therm} = 82.24\ Therms$$

10.5 Commercial Water Heaters (TRM V8.0 Section 3.3.1)

Therms savings for commercial water heaters are calculated as:[35]

$$therms\ Savings = \frac{\rho * C_P * V * \left(T_{SetPoint} - T_{Supply}\right) * \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right) * Days/Year}{Conversion\ Factor}$$

P = Water Density, 8.33 lbs./Gallon

C_P = Specific Heat of Water, 1 BTU/Lb. F

V = Average daily hot water use (gallons)

$T_{setpoint}$ = Water Heater setpoint, 140 deg. F

T_{supply} = Supply water temperature, 58 deg. F

EF_{pre} = Energy factor of existing water heater (.62 - .0019V)

EF_{post} = Energy factor of installed water heater

Days/Year = Days per year of operation

Conversion Factor = 100,000 BTU = 1 therm

[34] Arkansas TRM V8.0 Volume 2, Table 478. Pg. 526.
[35] Arkansas TRM V8.0, Volume 2. Pg. 357-368

Table 10-7 presents the volume and days of usage values for a facility by square footage.[36]

Table 10-7: Hot Water Requirements by Facility Size

Building Type	Gallons / Unit / Day	Unit	Units / 1,000 ft.2	Applicable Days / Year	Gallons / 1,000 ft.2 / Day
Small Office	1	Person	2.3	250	2.3
Large Office	1	Person	2.3	250	2.3
Fast Food Rest.	.7	Meal/Day	784.6	365	549.2
Sit-down Rest.	2.4	Meal/Day	340	365	816
Retail	2	Employee	1	365	2.0
Grocery	2	Employee	1.1	365	2.2
Warehouse	2	Employee	.5	250	1.0
Elementary School	.6	Person	9.5	200	5.7
Jr. High/High School	1.8	Person	9.5	200	17.1
Health	90	Patient	3.8	365	342.0
Motel	20	Unit (Room)	5	365	100.0
Hotel	14	Unit (Room)	2.2	365	30.8
Other	1	Employee	.7	250	.7

Table 10-8 presents the volume and days of usage values by unit produced or person served.

Table 10-8: Hot Water Requirements by Unit or Person

Building Type	Size Factor	Average Daily Demand
Dormitories	Men	13.1 Gal. per Man
	Women	12.3 Gal. per Woman
Hospitals	Per Bed	90.0 Gal. per Patient
Hotels	Single Room with Bath	50.0 Gal. per Unit
	Double Room with Bath	80.0 Gal. per Unit
Motels	# Units:	
	Up to 20	20.0 Gal. per Unit
	21 to 100	14.0 Gal. per Unit
	101 and Up	10.0 Gal. per Unit
Restaurants	Full Meal Type	2.4 Gal. per Meal
	Dive-in Snack Type	0.7 Gal. per Meal
Schools	Elementary	0.6 Gal. Per Student
	Secondary and High School	1.8 Gal. Per Student

10.6 Commercial Faucet Aerators (TRM V8.0 Section 3.3.2)

Savings are calculated as follows:[37]

$$Annual\ Therms = [(F_B * U_B) - (F_P * U_P) * Days * (T_H - T_C) * C_H * C_G / Eff_G]$$

The inputs for this equation are defined in Table 10-9.

[36] Ibid

[37] Arkansas TRM V8.0, Volume 2. Pg. 369-372

Table 10-9: DI Aerator Savings Calculation Parameters

Parameter	Description	Value
F_B	Baseline Flow Rate (GPM)	2.2
F_P	Post Flow Rate (GPM)	≤ 1.5
Days	Annual operating days for the facility[38]	
	Prison	365
	Hospital, Nursing Home	365
	Dormitory	274
	Multifamily	365
	Lodging	365
	Commercial	250
	School	200
T_C	Average supply (cold) water temperature (deg. F)	Zone 9: 65.6
		Zone 8: 66.1
		Zone 7: 67.8
		Zone 6: 70.1
T_H	Average mixed hot water temperature (deg. F)	105
U_B	Baseline water Usage Duration	
	Prison	30 min/day/unit
	Hospital, Nursing Home	3 min/day/unit
	Dormitory	30 min/day/unit
	Multifamily	3 min/day/unit
	Lodging	3 min/day/unit
	Commercial	30 min/day/unit
	School	30 min/day/unit
U_P	Post Water Usage Duration (assumed)	= U_B
C_H	Unit Conversion: 8.33 BTU/Gallons/deg. F	8.33
C_G	Unit Conversion: 1 Therm/100,000 BTU	1/100,000
Eff_G	Efficiency of Gas Water Heater	.8

These values translate into per-faucet savings values by facility type, detailed in Table 10-10 and Table 10-11 for 1.0 and 0.5 GPM aerators, respectively.[39]

Table 10-10: 1.0 GPM Commercial Aerator Savings

Facility Type	Fayetteville (Zone 9)	Fort Smith (Zone 8)	Little Rock (Zone 7)	El Dorado (Zone 6)
Prison	53.91	53.22	50.90	47.75
Hospital / Nursing Home	5.35	5.32	5.09	4.78
Dormitory	40.47	39.95	38.21	35.85
Multifamily	5.35	5.32	5.09	4.78
Lodging	5.35	5.32	5.09	4.78
Commercial	36.92	3645	34.86	32.71
School	29.54	29.16	27.89	26.16

[38] For facilities that operate year-round: conservatively assume operating days of 360/year; for schools open weekdays except summer: 360 x (5/7) x (9/12) = 193; for dormitories with few occupants in the summer: 360 x (9/12) = 270; and for normal commercial buildings: 360 x (5/7) = 257

[39] Table values interpolated based on data in Arkansas TRM V8.0, Volume 2. Pg. 369-372

Table 10-11: 0.5 GPM Commercial Aerator Savings

Facility Type	Fayetteville (Zone 9)	Fort Smith (Zone 8)	Little Rock (Zone 7)	El Dorado (Zone 6)
Prison	76.37	75.40	72.10	67.65
Hospital / Nursing Home	7.64	7.54	7.21	6.76
Dormitory	57.33	56.60	54.13	50.78
Multifamily	7.64	7.54	7.21	6.76
Lodging	7.64	7.54	7.21	6.76
Commercial	52.31	51.64	49.39	46.33
School	41.85	41.31	39.51	37.07

10.7 Pre-Rinse Spray Valves (TRM V8.0 Section 3.8.11)

Low-flow pre-rinse spray valves PRSVs were also direct-installed at a wide range of facility types with food service applications. The savings per unit for these were calculated as follows:[40]

$$Annual\ Therms = [(F_B * U_B) - (F_P * U_P)] * Days * (T_H - T_C) * C_H * C_G / Eff_G$$

$$Peak\ Therms = P * [(F_B * U_B) - (F_P * U_P)] * (T_H - T_C) * C_H * C_G / Eff_G$$

Table 10-12 presents the definition of these parameters.[41]

Table 10-12: Pre-Rinse Spray Valves Savings Calculation Parameters

Parameter	Description	Value
F_B	Baseline Flow Rate (GPM)	2.25
F_P	Post Flow Rate (GPM)	1.28
Days	Annual operating days for the facility[42]	
	Fast Food Restaurant	365
	Casual Dining Restaurant	365
	Institutional	365
	Higher Education	274
	School / K-12	200
T_C	Average supply (cold) water temperature (deg. F)	Zone 9: 65.6
		Zone 8: 66.1
		Zone 7: 67.8
		Zone 6: 70.1
T_H	Average mixed hot water temperature (deg. F)	120
U_B	Baseline water Usage Duration	
	Fast Food Restaurant	45 min/day/unit
	Casual Dining Restaurant	105 min/day/unit
	Institutional	210 min/day/unit

[40] Arkansas TRM V8.0, Volume 2. Pg. 514-517

[41] Ibid

[42] For facilities that operate year-round: conservatively assume operating days of 360/year; for schools open weekdays except summer: 360 x (5/7) x (9/12) = 193; for dormitories with few occupants in the summer: 360 x (9/12) = 270; and for normal commercial buildings: 360 x (5/7) = 257

	Higher Education	210 min/day/unit
	School / K-12	105 min/day/unit
U_P	Post Water Usage Duration (assumed)	= U_B
C_H	Unit Conversion: 8.33 BTU/Gallons/deg. F	8.33
C_G	Unit Conversion: 1 Therm/100,000 BTU	1/100,00
Eff_G	Efficiency of Gas Water Heater	.8

10.8 Commercial Low Flow Showerheads (TRM V8.0 Section 3.3.5)

Savings are calculated as follows:[43]

$$Annual\ therms = \frac{8.33 * C_p * \Delta V * \left(T_{HW} - T_{Suppy}\right) * \left(\frac{1}{E_t}\right)}{100{,}000\,BTU/therm} * \frac{days}{year}$$

In this formula, ΔV is calculated as follows:

$$\Delta V = U * N * \left(Q_b - Q_p\right) * F_{HW}$$

U = average shower duration (7.8 minutes)

N = Number of showers per showerhead per day

Q_b = Baseline flow rate (2.5 GPM);

Q_p = Installed flow rate (in GPM); and

F_{HW} = Hot Water Fraction (share of water which is from the water heater)

The inputs for this equation are defined in Table 10-13

Table 10-13: DI Showerhead Savings Calculation Parameters

Parameter	Description	Value
F_B	Baseline Flow Rate (GPM)	2.2
F_P	Post Flow Rate (GPM)	≤ 1.5
Days	Annual operating days for the facility	
	Hospital, Nursing Home	365
	Lodging	365
	Commercial	250
	24 Hour Fitness Center	365
	School	200
T_C	Average supply (cold) water temperature (deg. F)	Zone 9: 65.6
		Zone 8: 66.1
		Zone 7: 67.8
		Zone 6: 70.1
T_H	Average mixed hot water temperature (deg. F)	120
U_P	Post Water Usage Duration (assumed)	= U_B
C_G	Unit Conversion: 1 Therm/100,000 BTU	1/100,00
E_T	Efficiency of Gas Water Heater	.8

[43] Arkansas TRM V8.0, Volume 2. Pg. 381-388

Table 10-14: Daily Hot Water Reduction

Installed Flow Rate	Weather Zone	Hospital / Nursing	Lodging	Commercial Employee Shower	24 Fitness Center	Schools
2.0 GPM	9	2.5	3.5	1.9	56.3	2.0
	8	2.5	3.5	1.9	56.1	2.0
	7	2.5	3.5	1.8	55.4	2.0
	6	2.4	3.4	1.8	54.4	2.0
1.75 GPM	9	3.8	5.3	2.8	84.4	3.1
	8	3.8	5.3	2.8	84.1	3.1
	7	3.7	5.2	2.8	83.1	3.0
	6	3.6	5.1	2.7	81.5	3.0
1.5 GPM	9	5.0	7.1	3.8	112.6	4.1
	8	5.0	7.0	3.7	112.2	4.1
	7	4.9	6.9	3.7	110.8	4.0
	6	4.9	6.8	3.6	108.7	.9

10.9 Commercial Door Air Infiltration (TRM V8.0 Section 3.2.11)

Savings are calculated as follows[44]:

$$Annual\ therms = \frac{\left(CFM_{pre,day} * Hours_{day} + CFM_{pre,night} * Hours_{night}\right)\left(CFM_{reduction} * 1.08 * \Delta T * \frac{1.0kW}{ton}\right)}{80\%\ AFUE * \frac{100{,}000Btu}{therm}}$$

$$Peak\ therms = Annual\frac{therms}{ELFH_H}$$

The inputs for this equation are defined in Table 10-15.

Table 10-15: DI Door Infiltration Savings Calculation Parameters

Parameter	Description	Value
CFM_{pre}	Calculated pre-retrofit air infiltration rate (ft^3/min)	
CFMreduction	Average infiltration reduction	79%
ΔT	Change in temperature across gap barrier	
$Hours_{day}$	12-hour cycles per day, per month	4,380 hours
$Hours_{night}$	12-hour cycles per day, per month	4,380 hours
$EFLH_H$	Equivalent full-load hours	See table below

[44] Arkansas TRM V8.0, Volume 2. Pg. 350-356

Table 10-16: $EFLH_H$ By Weather Zone

Building Type	Zone 6	Zone 7	Zone 8	Zone 9
Assembly	575	798	855	824
College/University	630	874	936	902
Fast Food Restaurant	288	440	474	455
Full Menu Restaurant	181	328	370	336
Grocery Store	688	935	995	965
Health Clinic	646	885	922	895
Lodging	389	587	635	605
Large Office (>30k Sq.ft)	811	1,014	1,054	1,036
Small Office (≤30k Sq.ft)	353	538	568	538
Religious Worship	537	745	798	769
Retail	780	1,041	1,131	1,099
School	774	1,026	1,089	1,064

These values translate into per linear foot savings values by weather zone, detailed in the table below.

Table 10-17: Deemed Annual Therm Savings per Linear Foot

Weather Zone	Gap Width (inches)			
	1/8	1/4	1/2	3/4
Zone 9	5.34	10.80	21.43	32.16
Zone 8	4.64	9.38	18.62	27.96
Zone 7	3.91	7.92	15.71	23.58
Zone 6	2.89	5.86	11.62	17.44