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# Impact and Process Evaluation of the 2016 (PY9) Ameren Illinois Company Home Efficiency Income Qualified Program

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CADMUS

NAVIGANT



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# 1. Executive Summary

This report presents the results of the evaluation of the Program Year 9 (PY9) Ameren Illinois Company (AIC) Home Efficiency Income Qualified (HEIQ) Program. HEIQ is a home energy diagnostic and whole-house retrofit program that began as a pilot in PY3 and is in its sixth year of implementation. The target market for the program is AIC customers with homes heated by a fuel source (electricity or natural gas) provided by AIC and with a household income between 0% and 300% of federal poverty guidelines for household size. CLEAResult implements the program and reports to Leidos, who manages all of AIC's commercial and residential programs. Participants can join the program in one of two ways: by applying directly for a home audit through the program or by applying to the program through a program ally.

The expected savings from the HEIQ Program is 3% of the overall PY9 portfolio of electric savings and 9% of PY9 portfolio therm savings (including both residential and commercial).<sup>1</sup> Per the program implementation plan, AIC estimated that it would perform 1,794 audits and complete 1,350 retrofits in PY9, resulting in savings of 3,731 MWh, 1.81 MW, and 689,797 therms.

For PY9, the evaluation team conducted a process and impact evaluation of the HEIQ Program, which included interviews with program staff, participation analysis, and a literature review of best practices for low-income program design and marketing strategies.

## Program Impacts

The HEIQ Program had electric and gas program budgets of \$10,382,518 and \$3,409,632<sup>2</sup>, respectively. The program fell significantly short of its participation and savings goals in PY9, which AIC staff attributed to a slow start as the program implemented several program design changes. In PY9, the program reached 1,443 participants, including 622 audits (35% of goal) and 821 retrofits (61% of goal). The program achieved ex post net savings of 3,414 MWh, 1.18 MW, and 446,506 therms in PY9.

**Table 1. PY9 HEIQ Program Net Impacts**

	Ex Ante Gross	Realization Rate	Ex Post Gross	Net-to-Gross Ratio (NTGR)	Ex Post Net
<b>Energy Savings (MWh)</b>					
Total MWh	2,815	121%	3,414	1.00	3,414
<b>Demand Savings (MW)</b>					
Total MW	0.97	121%	1.18	1.00	1.18
<b>Therm Savings</b>					
Total Therms	470,762	95%	446,506	1.00	446,506

<sup>1</sup> Note that the percentage of expected savings here and throughout the plan is calculated based on AIC Plan 3 Compliance Filing from Docket 13-0498, dated January 28, 2014.

<sup>2</sup> Source: Ameren Illinois Program Year Nine Implementation Plan Sec. 8-103/8-104, July 8, 2016.



## Key Findings and Recommendations

- **Key Finding #1:** As of the end of PY9, there are many low-income communities in AIC's service territory that are largely untouched by AIC and IPA residential programs. This represents a large opportunity for future program delivery. We identified the top-20 communities in terms of the number of high-priority households (see Table 7).
  - **Recommendation:** We recognize that AIC may have other considerations than historical participation and eligibility when targeting communities. The evaluation team recommends that the program implementation team use the list of top-20 communities as a starting point to select communities or broader areas that they would like to target for future HEIQ participation. Once AIC approves them, our team can analyze the targeted areas at the street level to avoid multifamily locations and ineligible neighborhoods. This effort will essentially provide more refined targets at the most granular address-level.
- **Key Findings #2:** Neighborhood sweeps are an effective strategy for ensuring certain communities are well-covered by programs. Further, neighborhood sweep approaches often leverage community leaders who could help identify low-income parts of the neighborhood and attend kick-off events. These steps can help raise awareness of the program, lend credibility to the program representatives visiting homes, and help schedule some visits in advance of the sweeps.
  - **Recommendation:** Once AIC determines which communities they would like to target (see the recommendation under Key Finding #1), we recommend that AIC employs a neighborhood sweep approach in those communities. Neighborhood sweeps typically occur over the course of a few weeks and can cover around 500 homes. Fewer but more extensive sweeps could be undertaken if budget is available.
  - **Recommendation:** Should AIC employ neighborhood sweeps, we recommend that AIC identify community leaders (e.g., mayors, councilmembers, pastors, etc.,) to help raise awareness and enhance the credibility of the program. Community leaders can also be helpful in the planning stage to identify specific areas of most need. We also recommend holding kick-off events at community centers (e.g., schools, city halls, churches) with the community leaders present to lend credibility to the program.
- **Key Findings #3:** There is an opportunity to provide some additional educational collateral in tandem with the audit. Notably, it may not be possible to calculate or claim additional savings from education measures. However, educational components have the potential to improve customers' perceived value of the program and satisfaction with AIC. Additional education may also be helpful in convincing customers to invest in deeper retrofits. During the PY8 evaluation, some Program Allies reported that certain measures are harder to sell than others, specifically the air sealing and insulation. Their recommendation was to provide more education on these measures prior to the audit.
  - **Recommendation:** AIC could consider adding educational collateral to their audits beyond the audit report. One option is to provide a list of energy-saving tips after the audit. Given this would be for low-income customers, the collateral should focus on low/no cost tips for saving energy (e.g., turning off the lights or changing thermometer setpoints). Another option is to provide an education pamphlet (e-mail or mail) prior to the audits that explains what to expect during the audit and the equipment and systems that could be changed.
- **Key Finding #4:** Ex ante savings incorporates cooling degree days (CDD) and heating degree days (HDD) for conditioned basements or crawl space with the idea that this area is enclosed within the

thermal barrier due to the installation of proper air sealing measures. The evaluation team applied CDD and HDD for unconditioned basements and crawl spaces, as the area is not purposely conditioned, but indirectly conditioned due to duct leakage. Applying CDD and HDD using conditioned space assumptions creates overlap in savings for rim joist, crawl space, and basement wall insulation with air sealing and duct sealing measures.

- **Recommendation:** When calculating savings for rim joist, crawl space, and basement wall insulation, the evaluation team recommends recording the basement condition for each project and applying the associated CDDs and HDDs from the IL-TRM. If this information is unknown or cannot be collected, we recommend applying unconditioned assumptions, which is consistent with the approach in previous program evaluations.

## 2. Evaluation Approach

The Program Year 9 (PY9) evaluation of the Ameren Illinois Company (AIC) Home Efficiency Income Qualified (HEIQ) Program evaluation included both process and impact assessments. As part of the process evaluation, the evaluation team reviewed program materials and program tracking data, interviewed implementation and AIC staff, conducted a participation analysis, and completed a literature review of low-income program design and marketing best practices. The impact assessment included an engineering analysis. Per the evaluation plan, we applied a net-to-gross ratio (NTGR) of 1.0 to evaluated gross savings to obtain PY9 net savings.

### 2.1 Research Objectives

The evaluation team sought to answer the following research questions as part of the PY9 HEIQ Program evaluation.

#### 2.1.1 Impact Questions

- What were the estimated gross energy and demand impacts from the program?
- What were the estimated net energy and demand impacts from the program?

#### 2.1.2 Process Questions

- Program Design and Implementation Effectiveness
  - Was the program implemented according to design?
  - What were the program's marketing and outreach efforts?
  - What implementation challenges occurred in PY9 and how were they overcome?
- Program Participation
  - How many homes received audits? How many homes received retrofits? Has participation met expectations? If not, why?
- Opportunities for Expanding Low-Income Program Offerings
  - Which predominately low-income geographic areas have AIC's residential portfolio historically served?
  - Which areas are currently underserved? Which have the greatest need based on historical participation and household characteristics?
- Opportunities for Program Design Adjustments
  - Looking across the country, what program design features are shared by successful low-income programs?
  - How many programs provided direct install versus deeper retrofits (or both)?

- How were these programs marketed? Did they use community-based marketing strategies?
- What opportunities exist for AIC to alter the HEIQ Program's design to increase coverage of underserved communities and increase program savings?

## 2.2 Evaluation Tasks

Table 2 summarizes the PY9 evaluation activities conducted for the HEIQ Program, each of which is described in detail below.

**Table 2. Summary of PY9 HEIQ Program Evaluation Activities**

Activities	PY9 Impact	PY9 Process	Forward Looking	Details
Program Staff Interviews		✓	✓	Explore program implementation, changes to program design, and future plans for the HEIQ Program.
Program Materials Review	✓	✓		Review of implementation plans, marketing plans and collateral, and the program tracking database.
Participation Analysis		✓	✓	Analysis of historical participation across the residential program portfolio; identification of opportunities to serve low-income customers.
Literature Review		✓	✓	Review of best practices for low-income program design and marketing strategies.
Impact Analysis	✓			Calculate gross and net impacts using the IL-TRM V5.0 and Stakeholder Advisory Group (SAG)-approved NTGR values for PY9.

### 2.2.1 Program Staff Interviews

The evaluation team conducted interviews with the AIC program manager as well as Leidos and CLEAResult implementation staff to understand changes to program design, implementation, and evaluation priorities.

### 2.2.2 Program Materials Review

The evaluation team reviewed program materials, including program implementation plans, marketing plans and collateral, and program tracking databases to assess program implementation and provide recommendations for improvement, where applicable. The evaluation team also reviewed the program tracking database to assess program participation as an input to the impact evaluation.

### 2.2.3 Participation Analysis

With the increased program focus on low-income ratepayers in future years, the evaluation team built on work performed in PY8 to help AIC better understand the needs of customers that require extra assistance in making energy-saving upgrades to their homes. In PY8, the evaluation team conducted a historical participation analysis that mapped participation in the HEIQ Program from PY4 through PY8 alongside census data. The team provided AIC with a mapping tool that can be used to identify the geographic areas that have been underserved.

In PY9, the evaluation team expanded this tool to include data from most AIC and Illinois Power Agency (IPA) residential programs, in addition to adding HEIQ Program data from PY9. The purpose of this exercise was to identify which low-income communities have been well-served by existing and past residential programs and those that have been underserved. We conducted analyses to identify communities that would be good targets for low-income programs in the future. Appendix B provides technical detail on our participation analysis methods.

Table 3 below shows the residential programs included in the analysis. Notably, we excluded the Behavior Modification Program because customers are automatically enrolled and we excluded the IPA and AIC Multifamily Programs because they target market-rate properties.

**Table 3. Residential Program Included in Participation Analysis**

Program	PY4	PY5	PY6	PY7	PY8	PY9
All Electric Homes	N/A	N/A	✓	✓	N/A	N/A
Appliance Recycling	✓	✓	✓	✓	✓	✓
CFL Distribution	N/A	N/A	✓	N/A	N/A	✓
Energy Efficiency Kits	N/A	N/A	✓	N/A	N/A	N/A
HEIQ	✓	✓	✓	✓	✓	✓
Home Efficiency Standard	✓	✓	✓	✓	✓	✓
HVAC	✓	✓	✓	✓	✓	✓
Res Lighting (Online Store)	✓	✓	✓	✓	N/A	N/A
Moderate Income Kits	N/A	N/A	N/A	N/A	✓	✓
REEP	✓	✓	✓	N/A	N/A	N/A
Rural Kits	N/A	N/A	N/A	✓	✓	✓

**Legend:**

✓ : Data included in analysis

N/A: Program did not exist in that program year

## 2.2.4 Literature Review

To help AIC consider future program designs to meet its expanded low-income program goals, the evaluation team conducted a review of past and current low-income programs across the country. We gave special focus to eligibility requirements, whether these programs offered direct install measures or deeper retrofits (or some combination), and any community-based marketing strategies they used. We also explored best practices in program design and the non-energy benefits of low-income weatherization programs. Using these findings, we provided AIC with recommendations for potential program design and marketing adjustments. We delivered a detailed interim memo to AIC in August 2017, available in Appendix A, and we briefly summarize key findings and recommendations in this report.

We reviewed 19 different programs and ultimately chose nine programs to include. AIC's PY8 HEIQ Program was included for comparison purposes. We chose these programs based on three key criteria:

1. We could confirm the program targeted low-income customers;
2. There was sufficient information available on their design and/or marketing efforts; and
3. The program was implemented in 2010 or later.

The information we gathered for our review came from publicly-available evaluation and implementation reports, program and utility websites, annual reports, as well as studies and best practices reports from the American Council for an Energy-Efficient Economy (ACEEE) Impact Analysis.

The PY9 evaluation includes gross and net impact estimates. The impact evaluation team used savings algorithms from the IL-TRM V5.0, and data inputs from the program tracking database to estimate ex post gross savings. We calculated PY9 net savings by applying the SAG-approved NTGR of 1.0 to ex post gross electric and gas savings.

## 2.3 Sources and Mitigation of Error

Table 4 provides a summary of possible sources of error associated our evaluation of the HEIQ Program. We discuss each item in detail below.

**Table 4. Potential Sources of Error**

Research Task	Survey Error		Non-Survey Error
	Sampling	Non-Sampling	
Participation Analysis	N/A	N/A	Data processing error
Gross Savings Calculations	N/A	N/A	Analysis error
Net Savings Calculations	N/A	N/A	Analysis error

### Potential Analysis Error

- **Participation Analysis:** To minimize errors combining and mapping historical participation, all data and the list of programs included were reviewed by multiple team members.
- **Gross and Net Impact Calculations:** We applied IL-TRM V5.0 algorithms to the participant data in the program tracking database to calculate gross impacts. To minimize analytical errors, all impact calculations were reviewed by a separate team member to verify their accuracy.

## 3. Detailed Evaluation Findings

The following sections present detailed findings from the PY9 evaluation of the HEIQ Program.

### 3.1 Program Design and Implementation

#### 3.1.1 Program Design Changes

The HEIQ Program was implemented according to plan but underwent a variety of changes in PY9 to train Program Allies to perform audits, increase the quality of projects, and ensure pricing was standardized and appropriate for low- to moderate-income customers. According to program staff, implementing these changes led to a slow start, ultimately causing the program to fall short of its participation and savings goals. These program changes are detailed below:

- **Program ally Training:** Prior to PY9, program implementation staff (i.e., CLEAResult) performed all program audits before referring customers to Program Allies. Allies could perform their own audits, but those audits would not be done through the program and would not include the free program measures. In PY9, AIC began allowing Program Allies to perform program audits for moderate-income customers<sup>3</sup> if they completed a “mentoring program”. The training included an orientation to guidelines, materials, standardized modeling and project estimation tools, and installation requirements. Program Allies must also agree to send a staff person to receive Building Performance Institute (BPI) training and must shadow a program implementation staff person for up to five projects. Following that, program implementation staff shadow each Program ally’s first two to five audits.
- **Home Efficiency Specialists Team:** AIC created a new team of advisors to walk customers through the participation process from start to finish. They assist with applications and answer questions about the audit, on-bill financing, and proposed scope of work. This ensures a uniform set of expectations and information from the program. Advisors work to ensure all customers are satisfied with the program and ensure credibility since they reach out to customers once the application is started. To enhance follow-through, there are a series of checkpoints created to track the projects and keep customers updated throughout the process.
- **Work Scope Technical Review:** A technical review was added to ensure the project complies with program requirements and that the scope of work was appropriate for the home.
- **Standardized Pricing:** AIC introduced standardized pricing for all measures in PY9, which incorporated a review of historic project costs and Program ally feedback on reasonable rates to deliver a quality product while maintaining the affordability for low- to moderate-income participants. Notably, program staff mentioned that the standardized pricing resulted in a reduced pool of qualified Program Allies who agreed to the set prices.
- **Incentive Level Change:** Certain incentive levels were adjusted to lower customer costs. The most notable change was that air sealing and insulation measures became 100% covered.

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<sup>3</sup> Program Allies can perform program audits for moderate-income customers that they refer to the programs. All low-income customers and all customers who apply without a Program Ally’s referral receive an audit from program implementation staff.

### 3.1.2 Program Marketing Efforts

Program marketing channels included direct mail (i.e., bill inserts), e-mail, a webpage, digital media advertising, and community outreach and events. AIC also provided marketing support to Program Allies, including co-branded flyers and training on marketing strategies tailored to the income-qualified customer base.

For the first time, AIC launched an HEIQ webpage with the goal of streamlining the qualification and application process. According to AIC staff, the webpage generated a positive customer response, especially with the addition of the Home Efficiency Specialists to follow-up in case they start the application but do not complete it or they do not submit full documentation.

The program also worked to develop relationships with community groups and associations serving target customers. Outreach to community groups included frequent phone and e-mail communication, hosting “Lunch and Learns”, sponsoring community group events, advertising in community group publications, and marketing on community group websites and blogs.

### 3.1.3 Low-Income Program Design and Marketing Best Practices

In this section, we provide a summary of key findings from the literature review of low-income programs. The full memo submitted to AIC is available in Appendix A.

- **AIC’s HEIQ Program is largely comparable with the designs of other low-income programs reviewed.** The HEIQ Program was similar in that it offered an audit and a combination of direct install (e.g., low-cost domestic hot water and lighting) and deep retrofit (e.g., weatherization) measures. The AIC program also provides some measures not seen in many of the other programs (thermostats, motors). Notably, many programs we reviewed include appliance replacement in their deep retrofit offering while AIC maintains a separate appliance program.
- **Neighborhood sweeps and community-based marketing strategies have the potential to ensure predominately low-income areas are well-served.** A “neighborhood sweep” is a strategy where program representatives identify a target community (e.g., based on census data) and go door-to-door to conduct scheduled or on-the-spot audits and provide direct install measures. Community-based strategies help increase the credibility of the program by leveraging pre-existing networks in target communities and coordinating with community leaders (e.g., mayors) and decision makers (e.g., multifamily building owners) who can speak to the value and credibility of the program. As mentioned earlier, the program did do some coordinated marketing with community groups. However, AIC currently does not employ neighborhood sweeps.
- **Additional educational measures could increase customer satisfaction with the program and the likelihood of customers investing in deeper retrofits.** Several programs included an educational component beyond the audit report, such as preparatory materials delivered prior to the program or a list of low-/no-cost actions for additional energy savings. This potentially helps customers know what to expect from the program, understand the recommendations from the audit, and increase their perception of the program’s value.
- **Low-income weatherization programs have significant potential to deliver non-energy benefits.** These non-energy benefits include improved health and safety and other environmental, economic, and societal benefits. Multiple studies have monetized these non-energy benefits.



Our recommendations based on these findings are included in Section 4.

## 3.2 Program Participation

In this section, we review current participation data alongside historical program delivery data to provide insight into how the program has grown and where there are areas for increased program participation. Appendix B provides technical detail on our historical participation analysis methods.

### Program Participation Levels

In PY9, the HEIQ Program served 1,443 participants. Of the 1,443 participants, over half (57%) received only a retrofit, 24% received both an audit and a retrofit, and 19% received only an audit. This represents a marked difference from previous years, where the majority of participants receive both an audit and retrofit.

Per the program implementation plan, AIC estimated that it would perform 1,794 audits and complete 1,350 retrofits in PY9. The program ultimately fell short of these goals, which AIC staff attributed to a slow start as the program implemented several design changes (see Section 3.1.1). The program ultimately achieved 622 audits (35% of goal) and 821 retrofits (61% of goal).

In addition to looking at participation overall, the evaluation team assessed the level of conversion from program audit to completed project (i.e., the percentage of customers who received an audit who went on to install equipment). The evaluation team calculated the PY9 conversion rate by dividing the number of participants who received a retrofit following an audit (audit and retrofit) by the total number of participants who received an audit at all (whether or not they received a retrofit). However, participants who received an audit in one year and received the associated retrofit in the following year complicate this calculation. To account for these participants, every evaluation year we update conversion rates across previous program years using cumulative results. For instance, we incorporate any PY9 retrofits resulting from PY8 audits into the PY8 conversion rate.

Table 5 compares the updated conversion rates from PY4 through PY8 and the initial conversion rate for PY9 (to be updated in the PY10 evaluation). Notably, the conversion rates dropped significantly in PY9. This decrease may have been a result of the slow start mentioned above, in which case the “audit only” customers’ projects may not be finished and may be converted to retrofits in PY10.

**Table 5. PY4-PY9 HEIQ Program Conversion Rates**

Participant Type	PY4 Participants	PY5 Participants	PY6 Participants	PY7 Participants	PY8 Participants	PY9 Participants
(a) Audit and Retrofit	198	195	244	221	630	345
(b) Audit Only	48	27	20	12	8	277
(c) Retrofit Only	15	78	52	117	381	821
<b>Total Participants = a + b + c</b>	261	300	316	350	1,019	1,443
<b>Total Audits = a + b</b>	246	222	264	233	638	622
<b>Conversion Rate = a/(a + b)</b>	80%	88%	92%	95%	99%	55%

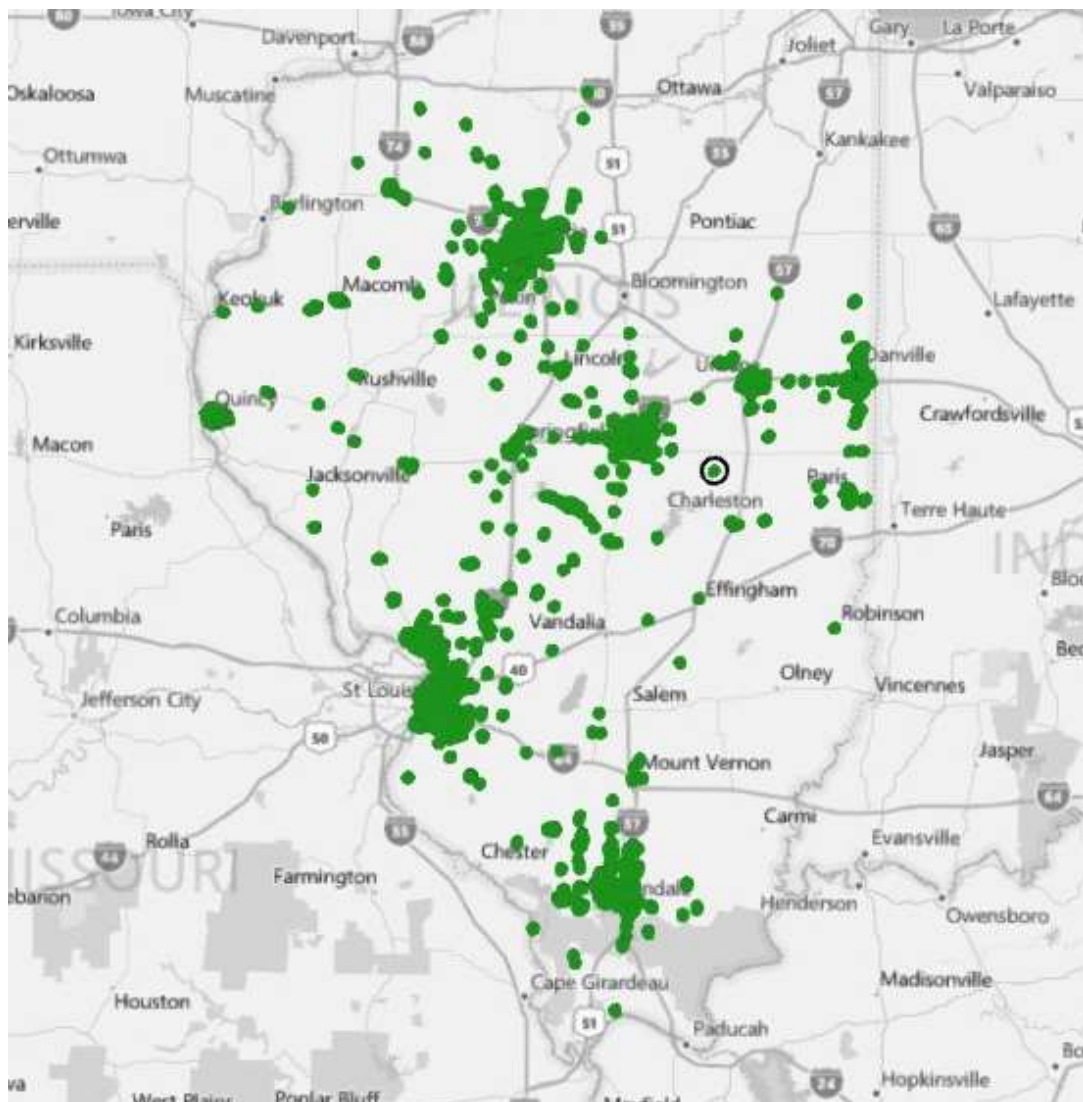
### Historical Participation

The HEIQ Program (formerly called the Moderate Income Program) began as a pilot in PY3, in Peoria. Throughout PY5 and PY6, program participation quickly spread to four main areas, including Peoria, East St.

Louis, Decatur, and Quincy. There are also some small pockets of relatively high participation in Macomb, Macon (South of Decatur), and Pekin (South of Peoria). In PY7, the HEIQ Program mainly grew in these four areas, but also began spreading to towns around the routes connecting these four cities.

Starting in PY8, the HEIQ Program started expanding east and south. The expansion east includes Townships of Champaign, Urbana, Wyton and Danville. The expansion in the south includes Benton, West Frankfort, Johnson City, Marion, Herrin, Carbondale, and Murphysboro. In PY9, the program continues to cover areas already served in PY4-PY8. Additionally, the program is now expanding more towards many rural areas in towns around the interstate highway routes of I-55, I-155, I-72 and I-74. There are also pockets of participation in Galesburg and Paris in PY9. Figure 1 below presents participation across AIC's territory as of PY9. Areas of heavy program participation are denoted by the concentrations of green dots.

Figure 1. HEIQ Participation as of PY9



Note: Green dots represent HEIQ Program participation

## Target Communities for Future Program Delivery

As of the end PY9, there are many low-income communities in AIC's service territory that are largely untouched by AIC and IPA residential programs<sup>4</sup>. To identify the communities (i.e., groups of census blocks) with the most potential for future targeting, we overlaid program tracking data with census data and developed three high-priority tiers of communities based on program eligibility (i.e., low-income single family households) and historical participation, shown in Table 6. The selection criteria we used captures nearly a third of residential AIC accounts. Appendix B provides technical detail on our tier development methods.

**Table 6. Targeting Tiers**

Tier	Description	Criteria	Number of Households	Percentage of Households
One	Low-income communities, mostly single-family areas, that are underserved by residential programs	<ul style="list-style-type: none"> <li>Over 50% of the households are low-income.</li> <li>Less than 10% of households are multifamily.</li> <li>Less than 10% of households participated in previous programs.</li> </ul>	147,321	10%
Two	Low-income communities with slightly fewer single-family homes compared to Tier One, but still underserved.	<ul style="list-style-type: none"> <li>Over 50% of the households are low-income.</li> <li>10-20% of households are multi-family.</li> <li>Less than 10% of households participated in previous programs.</li> </ul>	45,491	3%
Three	Low-income communities, with mostly single-family homes, that are slightly better served than Tier One and Tier Two.	<ul style="list-style-type: none"> <li>Over 50% of the households are low-income.</li> <li>Less than 10% of households are multi-family.</li> <li>10%-20% of households participated in previous programs.</li> </ul>	233,250	16%
<b>Total</b>			<b>426,062</b>	<b>29%</b>

Notably, the evaluation team's initial findings revealed that there is a lot of potential for participation due to the sheer size of the eligible population. Therefore, we optimized our tier criteria to focus only the "low hanging fruit", or the communities with the greatest concentration of eligible customers that have yet to participate in an AIC or IPA program. This resulted in relatively low cut-off points for some criteria (e.g., "20% multifamily" communities still have a sizable proportion of single-family homes). We recommend prioritizing Tier One communities, followed by Tier Two and then Tier Three. In the future, as more communities are more saturated with program participation, we would suggest widening these criteria to capture additional targets. Please see Appendix B for more information on how we developed the tier analysis.

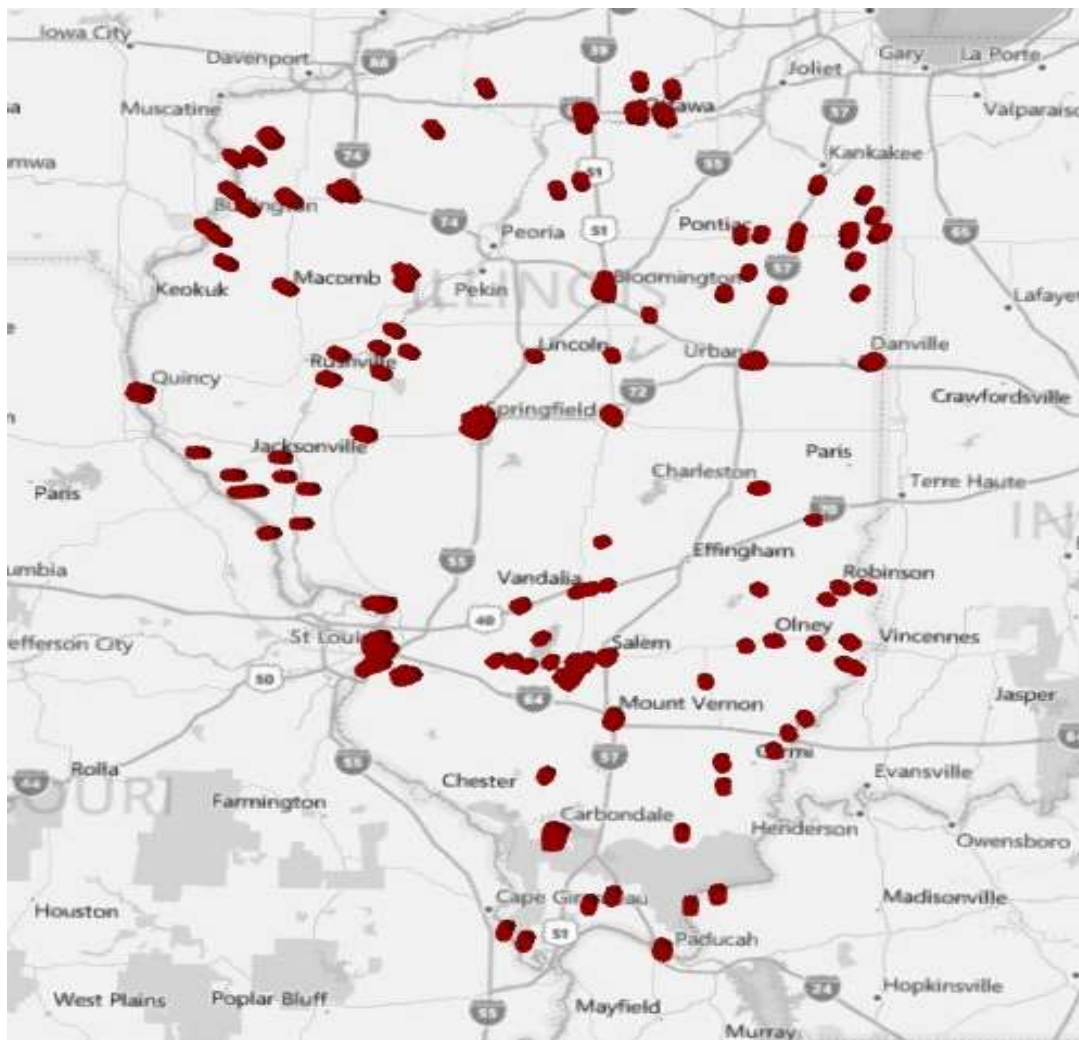
Figure 2 below shows the locations of Tier One communities across AIC's territory. Following that, Table 7 provides the names of 20 Tier One communities, ranked in terms of the number of estimated eligible

<sup>4</sup> Notably, we excluded the Behavior Modification Program because customers are automatically enrolled and we excluded the IPA and AIC Multifamily Programs because they target market-rate properties. Please refer to Table 3 for the list of programs we included.

households.<sup>5</sup> Notably, the same analysis with Tier Two and Tier Three communities results in very similar list. This is evidence that Tier One, Two, and Three communities are often clustered together and could be targeted at the same time.

As we detail further in Section 4, we recommend that AIC review this list to determine which areas are the highest priority for targeted program delivery. Using the historical participation tool, we can then work with AIC to delve deeper into these cities to target specific communities for outreach.

Figure 2. Map of “Tier One” Communities



Note: Each red dot is a Tier One census block and clusters of dots represent Tier One communities.

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<sup>5</sup> The evaluation team estimated “eligible households” based on the percentage of low-income and multifamily households in the census blocks per the census data. Notably, due to the known interactions between multifamily and low-income households, it is possible that we underestimated the eligible population. However, we applied the same approach to all cities, which normalizes the ranking.

Table 7. Target Tier One Communities

Ranking (Top 10)	Name*	Estimated Eligible Households	Ranking (11-20)	Name*	Estimated Eligible Households
1	Springfield	13,897	11	Belleville	2,675
2	Decatur	4,888	12	Jacksonville	2,294
3	Bloomington	4,370	13	Ottawa	1,954
4	Centralia	4,100	14	Alton	1,917
5	East Saint Louis	3,519	15	Salem	1,623
6	Danville	3,439	16	Marseilles	1,470
7	Galesburg	2,980	17	Olney	1,442
8	Carbondale	2,956	18	Quincy	1,338
9	Mount Vernon	2,897	19	Peru	1,283
10	Granite City	2,887	20	Monmouth	1,233

\*We named communities based on the city to which they belong.

### 3.3 Impact Assessment

The evaluation team applied savings algorithms from the IL-TRM V5.0 using program tracking database inputs and applied in-service rates (ISRs) from IL-TRM V5.0 to estimate program gross savings. To assess net impacts, the evaluation team applied the Illinois SAG-approved PY6 NTGR of 1.0 to ex post gross impacts.

#### 3.3.1 Measure Verification

The program offers a variety of measures to participants, including direct install measures, HVAC equipment, and building shell measures. To determine the verified measure quantities, the evaluation team applied ISRs provided in the IL-TRM V5.0 to ex ante measure quantities. Table 8 summarizes the quantity of installed measures based on the review of the program tracking database.

Table 8. PY9 HEIQ Program Verified Measure Quantities

Measure Category	Measure	Unit	Ex Ante Measure Quantity [a]	In-Service Rate [b]	Verified Measure Quantity
					[a * b]
Lighting	Compact Fluorescent Lamp (CFL) - Low (13W–15W)	Bulb	2,319	97%	2,247
	Specialty CFL - 14W Globe	Bulb	1,308	97%	1267
	Specialty CFL - 9W Candelabra	Bulb	1,128	97%	1,093
	CFL - Medium (18W–20W)	Bulb	865	97%	838
	CFL - High (23W–25W)	Bulb	690	97%	669
	Specialty CFL - 15W Reflector	Bulb	446	97%	432
Domestic Hot Water (DHW)	Faucet Aerator	Aerator	619	95%	588
	Shower Head	Shower Head	366	98%	359
HVAC	Furnace	Furnace	835	100%	835



Measure Category	Measure	Unit	Ex Ante Measure Quantity [a]	In-Service Rate [b]	Verified Measure Quantity
					[a * b]
	Central Air Conditioner (CAC)	CAC	822	100%	822
	ECM	Motor	691	100%	691
	Air Source Heat Pump (ASHP)	ASHP	98	100%	98
	Duct Sealing	Participant	27	100%	27
	Boiler	Boiler	14	100%	14
Controls	Programmable Thermostat	Thermostat	850	100%	850
	Smart Thermostat	Thermostat	70	100%	70
Envelope	Air Sealing	Cu. Ft./Min. (CFM)	1,206,348	100%	1,206,348
	Attic Insulation	Sq. Ft.	914,725	100%	914,725
	Wall Insulation	Sq. Ft.	284,836	100%	284,836
	Rim Joist Insulation	Linear Feet	89,592	100%	89,592
	Crawl Space Insulation	Sq. Ft.	44,714	100%	44,714
	Basement Wall Insulation	Linear Feet	2,119	100%	2,119
Total			2,553,482	N/A	2,553,234

Note: Numbers may not total due to rounding.

### 3.3.2 Ex Post Gross Impact Results

The total ex post gross savings for the PY9 HEIQ Program are 3,414 MWh, 1.18 MW, and 446,506 therms. As shown in Table 9, the gross realization rates are 121% for electric savings, 121% for demand savings, and 95% for therm savings.

Table 9. PY9 HEIQ Program Gross Impacts

Program	Number of Participants	Ex Ante Gross <sup>a</sup>			Ex Post Gross		
		MWh	MW	Therms	MWh	MW	Therms
HEIQ Program	1,443	2,815	0.97	470,762	3,414	1.18	446,506
Gross Realization Rate <sup>b</sup>					121%	121%	95%

<sup>a</sup> Source of ex ante savings: PY9 program tracking database.

<sup>b</sup> Gross Realization Rate = ex post gross value/ex ante gross value.

Table 10 summarizes the ex post gross electric savings by measure.

Table 10. PY9 HEIQ Program Gross Electric Impacts by Measure

Measure	Verified Measure Quantity	Units	Ex Ante Gross Impacts		Ex Post Gross Impacts		Gross Realization Rate <sup>a</sup>	
			kWh	kW	kWh	kW	kWh	kW
ASHP	98	ASHP	627,573	75.25	846,180	74.04	135%	98%
CAC	822	CAC	622,655	428.99	933,702	658.24	150%	153%
Air Sealing	1,185,005	CFM	358,733	195.48	441,866	216.62	123%	111%
ECM	691	Motor	343,582	19.00	342,689	19.00	100%	100%
Attic Insulation	899,028	Sq. Ft.	217,194	98.16	272,585	106.48	126%	108%
Crawl Space Insulation	43,268	Sq. Ft.	147,419	52.45	89,440	21.22	61%	40%
Programmable Thermostat	841	Thermostat	99,409	0.00	102,056	0.00	103%	N/A
Wall Insulation	277,597	Sq. Ft.	61,186	34.45	76,520	35.16	125%	102%
CFL - Low (13W–15W)	2,247	Bulb	56,666	5.54	56,666	5.54	100%	100%
Rim Joist Insulation	87,747	Linear Feet	48,473	25.84	29,736	9.51	61%	37%
Specialty CFL - 9W Candelabra	1,093	Bulb	42,741	4.55	42,741	4.55	100%	100%
Specialty CFL - 14W Globe	1,267	Bulb	39,491	4.85	39,491	4.85	100%	100%
Duct Sealing	27	Participant	30,415	10.18	18,831	7.25	62%	71%
CFL - High (23W–25W)	669	Bulb	27,539	2.69	27,539	2.69	100%	100%
CFL - Medium (18W–20W)	838	Bulb	23,251	2.27	23,251	2.27	100%	100%
Shower Head	76	Shower Head	20,115	1.85	20,115	1.85	100%	100%
Specialty CFL - 15W Reflector	432	Bulb	19,721	2.18	19,721	2.18	100%	100%
Smart Thermostat	67	Thermostat	17,775	4.31	22,487	6.42	127%	149%
Faucet Aerator	104	Aerator	6,574	2.99	6,574	2.99	100%	100%
Basement Wall Insulation	2,023	Linear Feet	4,072	2.41	2,110	0.97	52%	40%
<b>Total</b>	<b>2,503,941<sup>b</sup></b>	<b>N/A</b>	<b>2,814,583</b>	<b>973.45</b>	<b>3,414,301</b>	<b>1,181.83</b>	<b>121%</b>	<b>121%</b>

Note: Numbers may not total due to rounding;

<sup>a</sup> Gross Realization Rate = ex post gross value/ex ante gross value

<sup>b</sup> Total verified measure quantities account for measures that impact electric consumption and therefore do not equal the total verified measure quantity shown in Table 8. Additionally, the sum of the total verified measure quantities in Table 10 and Table 11 do not equal the total verified measure quantity in Table 8 as envelope measures impact both electric and gas consumption and quantities are captured in both tables.

Table 11 summarizes the ex post gross therm savings by measure.

**Table 11. PY9 HEIQ Program Gross Therm Impacts by Measure<sup>a</sup>**

Measure	Verified Measure Quantity	Units	Ex Ante Gross Impacts	Ex Post Gross Impacts	Gross Realization Rate <sup>b</sup>
			Therms	Therms	
Furnace	835	Furnace	201,798	216,006	107%
Air Sealing	1,093,838	CFM	71,853	68,559	95%
Attic Insulation	809,976	Sq. Ft.	57,632	54,642	95%
Programmable Thermostat	764	Thermostat	40,807	37,597	92%
Crawl Space Insulation	39,128	Sq. Ft.	37,262	20,389	55%
Wall Insulation	272,610	Sq. Ft.	23,487	20,706	88%
Rim Joist Insulation	81,838	Linear Feet	13,470	7,608	56%
Boiler	14	Boiler	7,721	10,005	130%
Duct Sealing	27	Participant	5,760	1,526	26%
Smart Thermostat	64	Thermostat	4,189	4,189	100%
Shower Head	282	Shower Head	3,180	3,179	100%
Basement Wall Insulation	2,059	Linear Feet	2,096	595	28%
Faucet Aerator	485	Aerator	1,506	1,506	100%
<b>Total</b>	<b>2,301,920<sup>c</sup></b>	<b>N/A</b>	<b>470,762</b>	<b>446,506</b>	<b>95%</b>

Note: Numbers may not total due to rounding.

<sup>a</sup> This table excludes lighting measures since ex post impact analysis does not include waste heat penalties.

<sup>b</sup> Gross Realization Rate = ex post gross value/ex ante gross value.

<sup>c</sup> Total verified measure quantities account for measures that impact gas consumption and therefore do not equal the total verified measure quantity shown in Table 8. Additionally, the sum of the total verified measure quantities in Table 10 and Table 11 do not equal the total verified measure quantity in Table 8 as envelope measures impact both electric and gas consumption and quantities are captured in both tables.

Differences in ex post and ex ante gross savings stem from differences in input values for the savings algorithms for each measure. The evaluation team carefully reviewed the differences between ex ante and ex post variable assumptions for all program measures. For reporting purposes, we include details explaining differences for measures<sup>6</sup> that account for more than 5% of the total program ex ante energy savings. Table 12 summarizes the reasons for discrepancies between ex ante and ex post gross savings for these measures. We provide more detail following the table.

<sup>6</sup> This includes ASHPs, CACs, air sealing, ECM, attic insulation, and crawl space insulation for electric savings and furnaces, air sealing, attic insulation, programmable thermostats, and crawl space insulation for gas savings.



Table 12. Reasons for Differences in Realization Rates

Measure	Gross Realization Rate			Source of Discrepancy		
	kWh RR	kW RR	Therms RR	CDD*/HDD*	HVAC Efficiency	Other Discrepancies
ASHP	135%	98%	N/A		✓	• Cooling and heating load reduction
CAC	150%	153%	N/A		✓	• Cooling load reduction
Air Sealing	123%	111%	95%			• Differences in actual data inputs for $pre_{cfm}$ , $post_{cfm}$ , cooling present, $n_{cool}$ , $n_{heat}$ , number of stories per home
Attic Insulation	126%	108%	95%			• Differences in actual data inputs for R-pre, R-post, cooling present, $n_{cool}$ , $n_{heat}$
Crawl Space Insulation	61%	40%	55%	✓		
Furnace	N/A	N/A	107%		✓	• Heating load reduction
Programmable Thermostat	103%	N/A	92%			• HVAC type • Missing gas savings

\*Cooling Degree Days (CDD); Heating Degree Days (HDD)

Through our discussions with the implementer, we identified the sources of the differences between ex ante and ex post savings for the measures provided in Table 12. Note that while certain inputs may increase savings, others decrease savings. The combination of all inputs brings about the overall realization rate for a specific measure. We describe the differences in the ex ante and ex post savings calculations in detail below.

- **Heating and Cooling Load Reduction:** The implementer applied algorithms for ASHPs, CACs, furnaces, and boilers from the IL-TRM V5.0. However, we learned that HVAC equipment was right-sized for homes with improved envelope measures, thus reducing heating and cooling loads. Ex post calculations included the savings from right-sizing based on the reduced heating and cooling loads, as a result of a better insulated and sealed home. As a result, ex post savings for ASHPs, CACs, furnaces, and boilers are greater than ex ante savings.
- **HVAC Efficiency Discrepancies:** The implementer applied the HVAC efficiencies (SEER, EER, HSPF, AFUE) using the values provided in the IL-TRM V5.0. The evaluation team applied the actual efficiencies provided in the database. When the actual efficiency was unknown, the evaluation team applied the IL-TRM V5.0 value based on the actual equipment age. In cases where both the actual efficiency and age are unknown, the evaluation team applied the average efficiencies for all participants in the program tracking database (see Appendix C for more detail). As a result, ex post savings for ASHPs and furnaces are smaller than ex ante savings, and greater than ex ante savings for Central Air Conditioners.
- **CDD and HDD Discrepancies:** For crawl space measures, the implementer applied IL-TRM V5.0 CDD and HDD values for conditioned spaces to calculate ex ante savings. However, based on discussions with the implementer, and our understanding of the baseline conditions, the evaluation team applied

unconditioned CDD and HDD values consistent with how we handled these measures in previous program years. As a result, ex post estimates are smaller than ex ante savings.

- **Differences in Actual Data Inputs for Air Sealing and Attic Insulation:** The evaluation team calculated ex post savings for air sealing and attic insulation using actual data from the database for variables such as pre and post R-values, pre and post air flow conditions (measured in cubic feet per minute), cooling and heating efficiencies, number of stories per home, and whether central air conditioning is present. The evaluation team is unable to pinpoint exact reasons for differences in ex post and ex ante savings. It appears that the implementer incorporated actual data for these variables, but the evaluation team does not have the ex ante custom inputs to compare to ex post to verify what is causing these differences.
- **HVAC Type for Programmable Thermostats:** Differences in ex ante and ex post savings are due to calculations based on HVAC type. The implementer advised to use the primary heating type from the database when calculating programmable thermostat savings, however there are four cases where the implementer uses a different assumption. Ex ante calculations include gas savings where the database indicates heat pump and electric resistance HVAC types. As a result, ex post gas savings are smaller than ex ante.
- **Missing Gas Savings for Programmable Thermostat:** There is one case where ex ante has missing gas savings for a participant who has a gas furnace. As a result, ex post gas savings are slightly greater than ex ante.

### 3.3.3 Ex Post Net Impact Results

In determining the overall net savings, the team applied the SAG approved NTGR of 1.00. Thus, the ex post net savings are equal to the ex post gross savings of 3,414 MWh, 1.18 MW, and 446,506 therms with overall realization rates of 121%, 121%, and 95% for energy, demand, and therms, respectively.

**Table 13. PY9 HEIQ Program Net Impacts**

Program Component	Ex Ante Net <sup>a</sup>			Ex Post Net		
	MWh	MW	Therms	MWh	MW	Therms
HEIQ Program	2,815	0.97	470,762	3,414	1.18	445,506
Net Realization Rate <sup>b</sup>				121%	121%	95%

<sup>a</sup> Source of ex ante savings: PY9 program tracking database.

<sup>b</sup> Net Realization Rate = ex post net value/ex ante net value.

## 4. Conclusions and Recommendations

Below we summarize the key conclusions from the evaluation and provide recommendations to AIC staff. We have divided this section into two parts, the first focusing on increasing program participation and outreach strategies, the second on impact analyses algorithms and assumptions.

### Program Participation and Outreach Strategies

- **Key Finding #1:** As of the end PY9, there are many low-income communities in AIC's service territory that are largely untouched by AIC and IPA residential programs. This represents a large opportunity for future program delivery. We identified the top-20 communities in terms of the number of high-priority households (see Table 7).
  - **Recommendation:** We recognize that AIC may have other considerations than historical participation and eligibility when targeting communities. The evaluation team recommends that the program implementation team use the list of top-20 communities as a starting point to select communities or broader areas that they would like to target for future HEIQ participation. Once AIC approves them, our team can analyze the targeted areas at the street level to avoid multifamily locations and ineligible neighborhoods. This effort will essentially provide more refined targets at the most granular address-level.
- **Key Findings #2:** Neighborhood sweeps are an effective strategy for ensuring certain communities are well-covered by programs. Further, neighborhood sweep approaches often leverage community leaders who could help identify low-income parts of the neighborhood and attend kick-off events. These steps can help raise awareness of the program, lend credibility to the program representatives visiting homes, and help schedule some visits in advance of the sweeps.
  - **Recommendation:** Once AIC determines which communities they would like to target (see the recommendation under Key Finding #1), we recommend that AIC employs a neighborhood sweep approach in those communities. Neighborhood sweeps typically occur over the course of a few weeks and can cover around 500 homes. Fewer but more extensive sweeps could be undertaken if budget is available.
  - **Recommendation:** Should AIC employ neighborhood sweeps, we recommend that AIC identify community leaders (e.g., mayors, councilmembers, pastors, etc.,) to help raise awareness and enhance the credibility of the program. Community leaders can also be helpful in the planning stage to identify specific areas of most need. We also recommend holding kick-off events at community centers (e.g., schools, city halls, churches) with the community leaders present to lend credibility to the program.
- **Key Findings #3:** There is an opportunity to provide some additional educational collateral in tandem with the audit. Notably, it may not be possible to calculate or claim additional savings from education measures. However, educational components have the potential to improve customers' perceived value of the program and satisfaction with AIC. Additional education may also be helpful in convincing customers to invest in deeper retrofits. During the PY8 evaluation, some Program Allies reported that certain measures are harder to sell than others, specifically the air sealing and insulation. Their recommendation was to provide more education on these measures prior to the audit
  - **Recommendation:** AIC could consider adding educational collateral to their audits beyond the audit report. One option is to provide a list of energy-saving tips after the audit. Given this would

be for low-income customers, the collateral should focus on low-/no-cost tips for savings energy (e.g., turning off the lights or changing thermometer setpoints). Another option is to provide an education pamphlet (e-mail or mail) prior to the audits that explains what to expect during the audit and the equipment and systems that could be changed.

- **Key Finding #4:** Ex ante savings incorporates CDD and HDD for conditioned basements or crawl space with the idea that this area is enclosed within the thermal barrier due to the installation of proper air sealing measures. The evaluation team applied CDD and HDD for unconditioned basements and crawl spaces, as the area is not purposely conditioned, but indirectly conditioned due to duct leakage. Applying CDD and HDD using conditioned space assumptions creates overlap in savings for rim joist, crawl space, and basement wall insulation with air sealing and duct sealing measures.
- **Recommendation:** The evaluation team recommends applying unconditioned assumptions when calculating rim joist, crawl space, and basement wall insulation savings. This approach is consistent with previous program evaluations.

## Appendix A. Literature Review Memo



PY9 Literature  
Review Findings

## Appendix B. Participation Analysis Detailed Methods

In this appendix, we summarize the key steps we took to develop the historical participation and targeting analysis.

### Step One: Compile Program Tracking Data

The evaluation team combined program tracking data from the AIC and IPA residential programs listed in the table below.

**Table 14. Residential Program Included in Participation Analysis**

Program	PY4	PY5	PY6	PY7	PY8	PY9
All Electric Homes	N/A	N/A	✓	✓	N/A	N/A
Appliance Recycling	✓	✓	✓	✓	✓	✓
CFL Distribution	N/A	N/A	✓	N/A	N/A	✓
Energy Efficiency Kits	N/A	N/A	✓	N/A	N/A	N/A
HEIQ	✓	✓	✓	✓	✓	✓
Home Efficiency Standard	✓	✓	✓	✓	✓	✓
HVAC	✓	✓	✓	✓	✓	✓
Res Lighting (Online Store)	✓	✓	✓	✓	N/A	N/A
Moderate Income Kits	N/A	N/A	N/A	N/A	✓	✓
REEP	✓	✓	✓	N/A	N/A	N/A
Rural Kits	N/A	N/A	N/A	✓	✓	✓

**Legend:**

✓ : Data included in analysis

N/A: Program did not exist in that program year

We performed the following data cleaning steps and QA/QC checks:

- We determined the unit of analysis for each database. In most cases, this was the household. However, for certain programs such as the CFL Distribution in PY9, the data was provided at the distributor level and therefore the unit of analysis was the distributor.
- Account data and site level information were tracked inconsistently and queried differently for each of the programs and across each of the program years. The evaluation team cross-compared and compiled information across all databases to fully populate details and develop unique household IDs across all of the tracking data. This step allows us to more accurately identify the number of unique participants and the number of customers that participated in more than one program or multiple times in the same program.

### Step Two: Geocoding

The evaluation team used addresses to develop geospatial coordinates for each household. When exact coordinates could not be determined, the team used a set of estimation methods that leverages street names, city centroids, zip centroids, and Google searches to estimate the location of certain obscure, missing, or invalid address data. With the estimated geospatial coordinates, the evaluation team assigned each household to a census block.

### Step Three: Overlay Census Data

We collected 2015 Five-Year American Community Survey (ACS) census data at the census block group level as well as at the census tract level on the following demographics:

- Age distribution (population)
- Ethnic diversity (tract level only)
- Income ranges (household income)
- Education (population over 25)
- Housing units (occupied housing units)
- Household size (occupied housing units)
- Home size, number of bedrooms (occupied housing units)
- Occupation makeup (employed population 16 and over)
- Owner vs renter (occupied housing units)
- Housing vintage (occupied housing units)

### Step Four: Tier Analysis

As part of the targeting analysis, the evaluation team used a process of elimination to rule out census blocks that would have the fewest households eligible for HEIQ. The steps for isolating the most eligible areas for targeting include:

- Identify and keep census blocks where half of the households are “low-income”, or have household incomes of under \$50,000.
- Out of the census blocks with high concentrations of low-income households, we removed blocks where over 20% of the households are multifamily. We removed these blocks because the HEIQ Program does not target multifamily properties.
- We removed blocks in which over 20% of the households had participated in at least one residential energy efficiency programs listed in Table 14. These areas are historically well-served by the various programs and do not need additional targeting.

For the remaining census blocks groups, the evaluation split them into the three tiers in Table 15 below.

**Table 15. Targeting Tier Criteria**

Tier	Description	Criteria
One	Low-income communities, mostly single-family areas, that are underserved by residential programs	<ul style="list-style-type: none"> <li>• Over 50% of the households are low-income.</li> <li>• Less than 10% of households are multifamily.</li> <li>• Less than 10% of households participated in previous programs.</li> </ul>
Two	Low-income communities with slightly fewer single-family homes compared to Tier One, but still underserved.	<ul style="list-style-type: none"> <li>• Over 50% of the households are low-income.</li> <li>• 10-20% of households are multi-family.</li> <li>• Less than 10% of households participated in previous programs.</li> </ul>
Three	Low-income communities, with mostly single-family homes, that are slightly better served than Tier One and Tier Two.	<ul style="list-style-type: none"> <li>• Over 50% of the households are low-income.</li> <li>• Less than 10% of households are multi-family.</li> <li>• 10%-20% of households participated in previous programs.</li> </ul>



## Appendix C. Engineering Analysis Algorithms

In PY9, the impact evaluation efforts estimated gross impact savings for the HEIQ Program by applying savings algorithms from the IL-TRM V5.0 using the information provided in the program tracking database. We present the algorithms and input variables used to calculate all evaluation program savings below.

### C.1 CFL Algorithms

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

#### Equation 1. Standard and Specialty CFL Algorithms

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

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

Where:

$Watts_{Base}$  = Wattage of existing equipment

**Table 16. Baseline Wattages for Lighting Measures**

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

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

$Watts_{EE}$  = Wattage of installed CFL

**Table 17. CFL Wattages for Lighting Measures**

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

Hours = Annual operating hours

**Table 18. Annual Hours of Use for Lighting Measures**

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

WHF<sub>e</sub> = Waste heat factor for energy (accounts for cooling savings from efficient lighting)

**Table 19. Waste Heat Factors for Energy**

Bulb Location	WHF <sub>e</sub>
Interior single family or unknown location	1.06
Exterior or uncooled location	1.00

WHF<sub>d</sub> = Waste heat factor for demand (accounts for cooling savings from efficient lighting)

**Table 20. Waste Heat Factors for Demand**

Bulb Location	WHF <sub>d</sub>
Interior single family or unknown location	1.11
Exterior or uncooled location	1.00

CF = Summer peak coincidence factor

**Table 21. Coincidence Factors for Lighting Measures**

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

ISR = In-service rate of installed CFLs = 96.9%

## C.2 Lighting Measures Heating Penalty

The evaluation team determined gas heating penalties for all lighting measures using the algorithm below. Based on the agreement between the Illinois Commerce Commission (ICC) and AIC, we do not include heating penalties in the ex post energy savings, but will include this in the data for the PY9 cost-effectiveness analysis (see Appendix D).

**Equation 2. Heating Penalty Algorithms**

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

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

Where:

$Watts_{Base}$  = Wattage of existing equipment (see Table 16)

$Watts_{EE}$  = Wattage of installed CFLs (see Table 17)

Hours = Annual operating hours (see Table 18)

HF = Heating Factor = 0.49

$\eta_{Heat}$  = Efficiency of heating equipment

**Table 22. nHeat for Heating Fuel Penalties**

Heating Equipment	nHeat	
	COP	AFUE
Gas Furnace/Boiler	N/A	0.70
Electric Resistance	1.00	N/A
Heat Pump	2.26	N/A

ISR = In-service rate or the percentage of units rebated that get installed = 96.9%

Table 23 summarizes the heating penalties (by heating equipment) for the six lighting measures offered through the program.

**Table 23. Per-Measure Heating Fuel Penalties for CFL Lighting**

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

<sup>a</sup> Heating penalties include a 96.9% ISR

### C.3 Water Heating Conservation Measure Algorithms

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

#### Equation 3. Low-Flow Shower Head Algorithms

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

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

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

#### Equation 4. Low-Flow Faucet Aerator Algorithms

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

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

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

Where:

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

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

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

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

**Table 24. GPM for Water Heating Measures**

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

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

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

**Table 25.  $L_{Base}$  and  $L_{Low}$  for Water Heating Measures**

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

$HH$  = Average number of people per household = 2.56

$SPCD$  = Showers per capita per day = 0.60

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

$DF$  = Drain factor

**Table 26. Drain Factor for Faucet Aerators**

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

FPH = Faucets per household for single-family homes

**Table 27. Faucets Per Household**

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

EPG<sub>Electric</sub> = Energy per gallon (EPG) of hot water supplied by electric water heater

EPG<sub>Gas</sub> = Energy per gallon of hot water supplied by gas water heater

**Table 28. EPG for Water Heating Measures**

Measure	EPG <sub>Electric</sub>	EPG <sub>Gas</sub>
Faucet Aerator – Kitchen	0.09690	0.00415
Faucet Aerator – Bathroom	0.07950	0.00341
Shower Head	0.11700	0.00501

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

**Table 29. Hours for Water Heating Measures**

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

CF = Summer peak coincidence factor

**Table 30. Coincidence Factors for Water Heating Measures**

Measure	CF
Faucet Aerator	0.0220
Shower Head	0.0278

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

**Table 31. ISR for Water Heating Measures**

Measure	ISR
Faucet Aerator	95%
Shower Head	98%

## C.4 Programmable Thermostats Algorithms

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

### Equation 5. Programmable Thermostat Algorithms

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

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

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

Where:

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

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

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

**Table 32. Electric Heating Consumption by Climate Zone**

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

$Gas\_Heating\_Consumption$  = Estimated annual household heating consumption for gas-heated homes (applied per participant based on project location)

**Table 33. Gas Heating Consumption by Climate Zone**

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

$Htg\ Reduction$  = Reduction in heating energy consumption = 6.2%

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

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

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

## C.5 Smart Thermostats Algorithms

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

### Equation 6. Smart Thermostat Algorithms

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

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

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

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

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

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

Where:

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

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

**Table 34. Full Load Cooling Hours by Climate Zone**

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

$Capacity_{Cool}$  = Cooling capacity of air conditioner in units of Btuh = Actual; If unknown assumed 33,600 BTU/h

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

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

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

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

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

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

**Table 35. Electric Heating Consumption by Climate Zone**

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

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

**Table 36. Gas Heating Consumption by Climate Zone**

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

Htg Reduction = Reduction in heating energy consumption = 7.4%

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

F<sub>e</sub> = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

CF = Summer peak coincidence factor = 0.34

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

## C.6 Central Air Conditioner Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) air conditioners using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for cooling load reduction as a result of installing envelope improvement measures (e.g. insulation, air sealing, duct sealing).<sup>7</sup> All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

### Equation 7. Central Air Conditioner Algorithms

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

<sup>7</sup> Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.



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

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

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

Where:

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

**Table 37. Full Load Cooling Hours by Climate Zone**

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

$Capacity_{exist}$  = Cooling capacity of existing central air conditioner in units of Btuh = Actual; If unknown assumed same capacity as installed energy efficient central air conditioner (n=90)

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

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

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

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

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

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

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

CF = Summer peak coincidence factor = 0.68

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

## C.7 Air Source Heat Pump Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) air source heat pumps using the algorithms below. The savings algorithms were slightly modified from the IL-

TRM V5.0 to account for cooling and heating load reductions as a result of installing envelope improvement measures (e.g. insulation, air sealing, duct sealing).<sup>8</sup> All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

### Equation 8. Air Source Heat Pump Algorithms

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

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

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

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

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

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

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

Where:

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

**Table 38. Full Load Cooling Hours by Climate Zone**

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

$Capacity_{Cool\_exist}$  = Cooling capacity of existing cooling equipment in units of Btuh = Actual; If unknown assumed same capacity as installed ASHP (n=12)

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

$Capacity_{Heat\_exist}$  = Heating capacity of existing heating equipment in units of Btuh = Actual; If unknown assumed same capacity as installed ASHP (n=60)

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

<sup>8</sup> Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

$SEER_{exist}$  = Baseline ASHP cooling efficiency for ER installations in units of SEER = Actual; If unknown assumed TRM defaults (see Table 39)

**Table 39. Early Replacement Cooling Efficiency ( $SEER_{exist}$ )**

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

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

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

**Table 40. Full Load Heating Hours by Climate Zone**

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

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

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

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

**Table 41. Early Replacement Heating Efficiency ( $HSPF_{exist}$ )**

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

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

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

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

**Table 42. Early Replacement Cooling Efficiency ( $EER_{exist}$ )**

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

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

CF = Summer peak coincidence factor = 0.72

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

## C.8 Gas Boiler Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) gas boilers using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for heating load reduction as a result of installing envelope improvement measures (e.g. insulation, air sealing, duct sealing).<sup>9</sup> All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

### Equation 9. Gas Boiler Algorithms

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

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

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

### Equation 10. Gas Boiler Heating Loads

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

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

Where:

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

### Equation 10.

$\Delta therms_{Envelope\&Duct}$  = Total therm savings for insulation, air sealing, and duct sealing measures for those who installed both envelope measures and boiler replacements  
 $AFUE_{base}$  = Baseline boiler efficiency for TOS installations in units of AFUE = 82% AFUE<sup>10</sup>

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

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

<sup>9</sup> Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

<sup>10</sup> Illinois TRM V4.0 specifies a baseline boiler efficiency of 82% AFUE for program years beyond 2013.

HF	= Household factor to adjust heating consumption for single-family homes = 100%
Capacity <sub>exist</sub>	= Heating capacity of existing boiler in units of Btuh = Actual
Capacity <sub>eff</sub>	= Heating capacity of installed energy efficient boiler in units of Btuh = Actual
FLH <sub>Heat</sub>	= Full Load Heating Hours (applied per participant based on project location)

**Table 43. Full Load Heating Hours by Climate Zone**

Climate Zone	FLH <sub>Heat</sub>
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

ISR	= In-service rate of installed boilers = 100%
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## C.9 Gas Furnace Algorithms

The evaluation team determined ex post measure savings for time of sale (TOS) and early replacement (ER) gas furnaces using the algorithms below. The savings algorithms were slightly modified from the IL-TRM V5.0 to account for heating load reduction as a result of installing envelope improvement measures (e.g. insulation, air sealing, duct sealing).<sup>11</sup> All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

### Equation 11. Gas Furnace Algorithms

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

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

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

### Equation 12. Gas Furnace Heating Loads

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

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

Where:

<sup>11</sup> Additional load reduction savings applies only to participants who installed both envelope measures and new HVAC equipment due to right sizing HVAC equipment.

Heat\_Load = Calculated using formulas in Equation 12

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

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

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

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

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

$\text{Capacity}_{\text{exist}}$  = Heating capacity of existing furnace in units of Btuh = Actual

$\text{Capacity}_{\text{eff}}$  = Heating capacity of installed energy efficient furnace in units of Btuh = Actual

$\text{FLH}_{\text{Heat}}$  = Full Load Heating Hours (applied per participant based on project location)

**Table 44. Full Load Heating Hours by Climate Zone**

Climate Zone	$\text{FLH}_{\text{Heat}}$
1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

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

## C.10 EC Motor Algorithms

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

### Equation 13. EC Motor Algorithms

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

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

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

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

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

$$\Delta\text{kW} = \Delta\text{kWh}_{\text{Cooling}} / \text{FLH}_{\text{Cool}} * \text{CF} * \text{ISR}$$

$$\Delta\text{therms} = -\Delta\text{kWh}_{\text{Heating}} * 0.03412 * \text{ISR}$$

Where:

$\text{FLH}_{\text{Cool}}$  = Full Load Cooling Hours (applied per participant based on project location)

**Table 45. Full Load Cooling Hours by Climate Zone**

Climate Zone	FLH <sub>Cool</sub>
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor = 0.68

ISR = In-service rate of installed EC Motors = 100%

## C.11 Duct Sealing Algorithms

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

### Equation 14. Duct Sealing Algorithms

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

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

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

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

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

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

Where:

DE<sub>after</sub> = Distribution efficiency after duct sealing

DE<sub>before</sub> = Distribution efficiency before duct sealing

FLH<sub>Cool</sub> = Full Load Cooling Hours (applied per participant based on project location)

**Table 46. Full Load Cooling Hours by Climate Zone**

Climate Zone	FLH <sub>Cool</sub>
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

FLH<sub>Heat</sub> = Full Load Heating Hours (applied per participant based on project location)

**Table 47. Full Load Heating Hours by Climate Zone**

Climate Zone	FLH <sub>Heat</sub>
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1 (Rockford)	1,969
2 (Chicago)	1,840
3 (Springfield)	1,754
4 (Belleville)	1,266
5 (Marion)	1,288

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

$Capacity_{Heat}$  = Heating capacity of heating equipment in units of Btuh = Actual; If unknown assumed average from database 89,243 BTUh

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

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



$n_{Cool}$  = Cooling efficiency in units of SEER = Actual; if unknown applied values in Table 48 based on equipment age

**Table 48.  $n_{Cool}$  for Duct Sealing Measures**

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

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

$n_{Heat}$  = Heating efficiency in units of COP = Actual; if unknown applied values in Table 49 based on equipment age

**Table 49.  $n_{Heat}$  for Duct Sealing Measures**

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

$n_{System}$  = Pre duct sealing heating system efficiency; calculated using =  $n_{Heat} * DE_{before}$ ; if unable to calculate, assume 0.70

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

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

**Table 50. Coincidence Factors for Air Sealing Measures**

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

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

## C.12 Air Sealing Algorithms

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

### Equation 15. Air Sealing Algorithms

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

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

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

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

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

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

Where:

CFM<sub>Existing</sub> = Infiltration at 50 Pascals as measured by blower door before air sealing

CFM<sub>New</sub> = Infiltration at 50 Pascals as measured by blower door after air sealing

N<sub>Cool</sub> = Conversion factor from leakage at 50 Pascal to leakage at natural conditions (applied per participant based on project location and height of home)<sup>12</sup>

**Table 51. N<sub>Cool</sub> by Climate Zone and Number of Stories**

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

<sup>a</sup> An average of N<sub>Cool</sub> values for 2 and 3 stories

<sup>b</sup> An average of N<sub>Cool</sub> values for 1, 1.5, 2, and 3 stories

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

**Table 52. Cooling Degree Days by Climate Zone**

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

DUA = Discretionary Use Adjustment = 0.75

$\eta_{Cool}$  = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 53 based on equipment age

<sup>12</sup> For projects where the height of the home (number of stories) was not provided in the tracking database, the evaluation team applied the N<sub>Cool</sub> value for an unknown number of stories.

**Table 53.  $\eta_{Cool}$  for Air Sealing Measures**

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

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

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

**Table 54. Latent Multiplier by Climate Zone**

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

$N_{Heat}$  = Conversion factor from leakage at 50 Pascal to leakage at natural conditions (applied per participant based on project location and height of home)<sup>13</sup>

**Table 55.  $N_{Heat}$  by Climate Zone and Number of Stories**

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

<sup>a</sup> An average of  $N_{heat}$  values for 2 and 3 stories

<sup>b</sup> An average of  $N_{heat}$  values for 1, 1.5, 2, and 3 stories

<sup>13</sup> For projects where the height of the home (number of stories) was not provided in the tracking database, the evaluation team applied the  $N_{heat}$  value for an unknown number of stories.

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

**Table 56. Heating Degree Days by Climate Zone**

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

$\eta_{\text{Heat}}$  = Efficiency of space heating equipment = Actual; if unknown applied values in Table 57 based on equipment age

**Table 57.  $\eta_{\text{Heat}}$  for Air Sealing Measures**

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

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

FLH<sub>Cool</sub> = Full Load Cooling Hours (applied per participant based on project location)

**Table 58. Full Load Cooling Hours by Climate Zone**

Climate Zone	FLH <sub>Cool</sub>
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

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

**Table 59. Coincidence Factors for Air Sealing Measures**

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

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

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

### C.13 Attic and Wall Insulation Algorithms

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

#### Equation 16. Attic Insulation Algorithms

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

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

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

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

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

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

#### Equation 17. Wall Insulation Algorithms

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

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

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

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

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

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

Where:

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

$R_{New}$  = Total attic or wall assembly R-value after the installation of additional insulation. For attic insulation we used actual post-retrofit R-values provided in the program tracking database. For wall insulation we used actual post-retrofit R-values provided in the program tracking database. For those with missing R-values (or R-values exceeding typical wall insulation R-values (>R-23)) we applied the average R-value (R-13.7) from participants with post-retrofit wall insulation R-value data (n=352; 93%).

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

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

FF = Framing factor adjustment to account for area of framing

**Table 60. Framing Factors for Attic and Wall Areas**

Measure	Framing Factor
Attic Insulation	0.07
Wall Insulation	0.25

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

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

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

**Table 61. Cooling Degree Days by Climate Zone**

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

DUA = Discretionary Use Adjustment = 0.75

$\eta_{Cool}$  = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 62 based on equipment age

**Table 62.  $\eta_{Cool}$  for Attic and Wall Insulation Measures**

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

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

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

**Table 63. Heating Degree Days by Climate Zone**

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

$\eta_{\text{Heat}}$  = Efficiency of space heating equipment = Actual; if unknown applied values in Table 64 based on equipment age

**Table 64.  $\eta_{\text{Heat}}$  for Attic and Wall Insulation Measures**

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

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

$\text{FLH}_{\text{Cool}}$  = Full Load Cooling Hours (applied per participant based on project location)

**Table 65.  $\text{FLH}_{\text{Cool}}$  by Climate Zone**

Climate Zone	$\text{FLH}_{\text{Cool}}$
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

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

**Table 66. Coincidence Factors for Attic and Wall Insulation Measures**

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

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

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

## C.14 Rim Joist Insulation Algorithms

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

### Equation 18. Rim Joist Insulation Algorithms

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

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

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

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

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

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

Where:

$R_{Old\_AG}$  = R-value of existing foundation wall assembly above grade

**Table 67. Rim Joist Above Grade R-Value**

Variable	R-Value
R-value <sub>Joist (1.5")</sub>	1.88
R-value <sub>outdoor air film</sub>	0.17
R-value <sub>wallboard</sub>	0.45
R-value <sub>indoor air film</sub>	0.68
<b>Total R-value</b>	<b>3.18</b>

Source: ASHRAE Fundamentals, 2013 Section 27.3.

$R_{Added}$  = R-value of additional insulation. Actual R-values provided in the program tracking database. For those with missing R-values (or R-values exceeding typical rim joist R-values (>R-22)) we applied the average R-value (R-13.3) from participants with added insulation R-value data (n=685; 96%).

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

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



- FF = Framing factor that accounts for area of framing = 0.05<sup>14</sup>
- ADJ<sub>Cool</sub> = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80
- ADJ<sub>Heat</sub> = Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60
- CDD = Cooling Degree Days (applied per participant based on project location)

**Table 68. Cooling Degree Days by Climate Zone**

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

- DUA = Discretionary Use Adjustment = 0.75
- $\eta_{\text{Cool}}$  = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 69 based on equipment age

**Table 69.  $\eta_{\text{Cool}}$  for Rim Joist Insulation Measures**

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

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

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

<sup>14</sup> Average framing factor for joists running from front-to-back (0.094) and from side-to-side (0). The front-to-back FF was calculated based on 1.5" joists for every 16" ( $1.5"/16" = 0.094$ ). The side-to-side FF is 0 since joists are continuous and uninterrupted.

**Table 70. Heating Degree Days by Climate Zone for Unconditioned Basement**

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

 $\eta_{\text{Heat}}$ 

= Efficiency of space heating equipment = Actual; if unknown applied values in Table 71 based on equipment age

**Table 71.  $\eta_{\text{Heat}}$  for Rim Joist Insulation Measures**

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

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

 $\text{FLH}_{\text{Cool}}$ 

= Full Load Cooling Hours (applied per participant based on project location)

**Table 72.  $\text{FLH}_{\text{Cool}}$  by Climate Zone**

Climate Zone	$\text{FLH}_{\text{Cool}}$
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF

= Summer Peak Coincidence Factor (varies by cooling equipment type)

**Table 73. Rim Joist Insulation Coincidence Factors**

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

 $F_e$ 

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

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

## C.15 Crawl Space Insulation Algorithms

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

### Equation 19. Crawl Space Insulation Algorithms

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

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

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

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

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

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

Where:

$R_{Old\_AG}$	= Above-grade existing R-value of crawl space = 1.0
$R_{Old\_BG}$	= Below-grade existing R-value of crawl space insulation (assume 2.0' below grade) = 5.41
$R_{Added}$	= R-value of additional insulation. Actual R-values provided in the program tracking database. For those with missing R-values (or R-values exceeding typical crawl space R-values (>R-21)) we applied the average R-value (R-12.0) from participants who installed with added insulation R-value data (n=380; 94%).
$ADJ_{cool}$	= Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80
$ADJ_{Heat}$	= Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60
LF	= Total linear feet of installed insulation (sq. ft.) = Actual
$H_{AG}$	= Height of crawl space wall above grade = 1 foot
$H_{BG}$	= Height of crawl space wall below grade = 2 feet
FF	= Framing factor that accounts for area of framing = 0 (spray foam)
CDD	= Cooling Degree Days (applied per participant based on project location)

**Table 74. Cooling Degree Days by Climate Zone**

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

DUA = Discretionary Use Adjustment = 0.75

$\eta_{\text{Cool}}$  = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 75 based on equipment age

**Table 75.  $\eta_{\text{Cool}}$  for Crawl Space Insulation Measures**

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

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

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

**Table 76. Heating Degree Days by Climate Zone for Unconditioned Basement**

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

$\eta_{\text{Heat}}$  = Efficiency of space heating equipment = Actual; if unknown applied values in Table 77 based on equipment age

**Table 77.  $\eta_{\text{Heat}}$  for Crawl Space Insulation Measures**

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

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

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

**Table 78.  $FLH_{\text{Cool}}$  by Climate Zone**

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

CF = Summer Peak Coincidence Factor (varies by cooling equipment type)

**Table 79. Crawl Space Insulation Coincidence Factors**

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

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

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

## C.16 Basement Sidewall Insulation

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

**Equation 20. Basement Sidewall Insulation Algorithms**

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

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

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

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

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

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

- $R_{\text{Old\_AG}}$  = Above-grade existing R-value = 1.0
- $R_{\text{Old\_BG}}$  = Below-grade existing R-value of basement wall insulation (assume 6.0' below grade) = 9.46
- $R_{\text{Added}}$  = R-value of additional insulation = Actual
- $\text{ADJ}_{\text{cool}}$  = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80
- $\text{ADJ}_{\text{Heat}}$  = Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60
- $L_{\text{Total}}$  = Total length of insulated basement wall perimeter = Actual
- $H_{\text{AG}}$  = Height of basement wall above grade = 1 foot
- $H_{\text{BG}}$  = Height of basement wall below grade = 6 feet
- $H_{\text{Total}}$  = Total height of basement wall ( $H_{\text{AG}} + H_{\text{BG}}$ ) = 7 feet
- $FF$  = Framing factor that accounts for area of framing = 0 (spray foam)
- $CDD$  = Cooling Degree Days (applied per participant based on project location)

**Table 80. Cooling Degree Days by Climate Zone**

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

- $DUA$  = Discretionary Use Adjustment = 0.75
- $\eta_{\text{Cool}}$  = Seasonal Energy Efficiency Ratio (SEER) of cooling system = Actual; if unknown applied values in Table 81 based on equipment age

**Table 81.  $\eta_{\text{Cool}}$  for Crawl Space Insulation Measures**

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

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

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

**Table 82. Heating Degree Days by Climate Zone for Unconditioned Basement**

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

$\eta_{\text{Heat}}$  = Efficiency of space heating equipment = Actual; if unknown applied values in Table 83 based on equipment age

**Table 83.  $\eta_{\text{Heat}}$  for Crawl Space Insulation Measures**

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

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

FLH<sub>Cool</sub> = Full Load Cooling Hours (applied per participant based on project location)

**Table 84. FLH<sub>Cool</sub> by Climate Zone**

Climate Zone	FLH <sub>Cool</sub>
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer Peak Coincidence Factor (varies by cooling equipment type)

**Table 85. Crawl Space Insulation Coincidence Factors**

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F<sub>e</sub> = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

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



## Appendix D. Cost-Effectiveness Inputs

Table 86 presents total gross impacts for AIC cost-effectiveness calculations. These values differ from those included in the main report due to the inclusion of heating penalties for lighting measures and the reduction in waste heat for EC motors.<sup>15</sup> Overall, the application of waste heat factors reduces total gross energy savings by 0.13% and therm savings by 3.40%.

**Table 86. PY9 HEIQ Program Gross Impacts (Including Heating Penalties)**

	kWh	kW	Therms
Gross Savings	3,414,301	1,182	446,506
Lighting Heating Penalty	- 4,525	0	-4,581
EC Motor Heating Penalty	0	0	-10,619
<b>Total Gross Savings with Heating Penalty</b>	<b>3,409,775</b>	<b>1,182</b>	<b>431,306</b>

### Lighting Heating Penalty

The inclusion of waste heat factors for lighting is based on the concept that heating loads are increased to supplement the reduction in heat that was once provided by the existing lamp type. We applied the heating penalty to 6,759 lamps based on heating fuel type and installed lamp type. The heating fuel type is known for 59% (4,008 lamps) of the installed lighting measures. For the remaining 2,748 lamps with unknown space heating fuel types, we applied waste heat factors assuming gas heating as directed per the IL-TRM V5.0. Table 87 summarizes the percentages of installed lamps for each heating fuel type.

**Table 87. PY9 HEIQ Program Heating Fuel Type for Lighting Measures**

Heating Fuel	Heating Equipment	% of Installed Lamps
Gas	Furnace/Boiler	94.2%
Electric	Electric Resistance	3.4%
Electric	Heat Pump	2.5%

The total heating penalty for lighting measures is 4,525 kWh and 4,581 therms.

### EC Motor Heating Penalty

High efficiency EC motors operate at cooler temperatures than traditional furnace blower motors. The amount of heat released decreases due to cooler operating conditions. Heating equipment must make up for this loss of heat during the heating season, resulting in an increase in HVAC heating loads (negative therm savings). We applied the heating penalty to all 691 EC motors incented within the program for a total heating penalty of 10,619 therms.

<sup>15</sup> Heating penalties are not included in savings calculations for goal attainment purposes per AIC and ICC Staff agreement.

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