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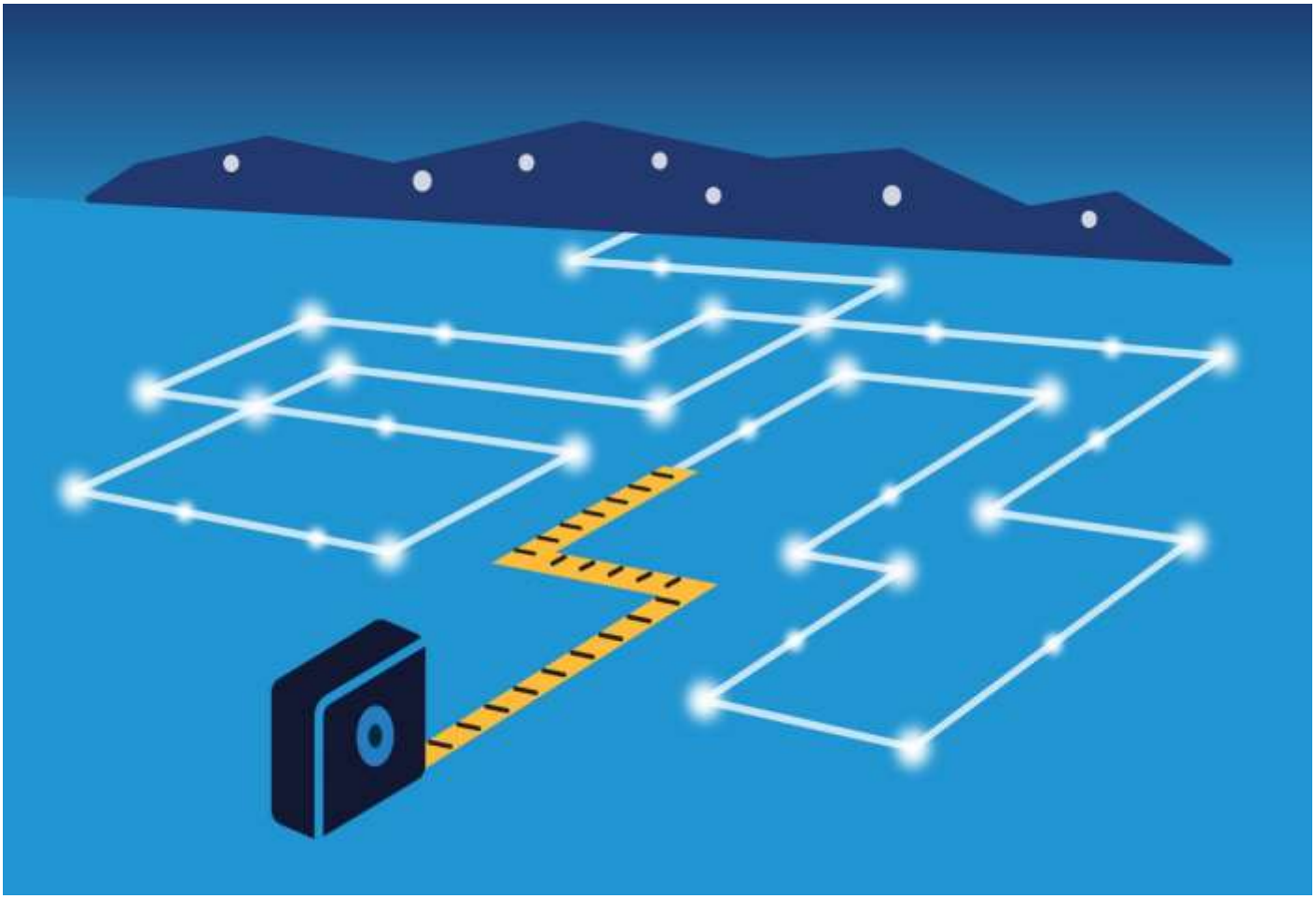

Impact and Process Evaluation of the 2014 Illinois Power Agency All-Electric Homes Program

Final

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1. Executive Summary

This report describes the evaluation of the program year seven (PY7) All-Electric Homes (AEH) Program, one of five stand-alone Illinois Power Agency (IPA) energy efficiency programs, implemented from June 2014 to May 2015. The program targets multifamily and single-family customers whose homes use electric resistance heating, providing incentives for customers to install air-source heat pumps or ductless mini-split heat pumps. For single-family customers, AEH also offers an energy audit (with direct-install measures), air sealing, and insulation incentives.

AEH began as a pilot program in PY6 (June 2013–May 2014), implemented by CLEAResult (formerly Conservation Services Group [CSG]). CLEAResult continued to implement the program in PY7.

Program Impacts

Table 1 summarizes gross and net electricity and demand savings from the PY7 AEH Program. The program achieved 67% gross realization rates primarily because ex ante assumptions assumed colder climates and larger unit installations than actually occurred during this program year.

Table 1. PY7 Net AEH Program Impacts

	Ex Ante Gross	Gross Realization Rate	Ex Post Gross	NTGR	Ex Post Net
Energy Savings (MWh)					
Total MWh	11,805	67%	7,880	73%	5,719
Demand Savings (MW)					
Total MW	1.362	67%	0.914	72%	0.659

Program Participation

The program exceeded its installation goals for HVAC measures. As expected by program staff, a large number of projects were located in southern Illinois. The majority of single-family residences participating in AEH were professionally managed (i.e., renter occupied).

Key Findings and Recommendations

The AEH program exceeded its HVAC measure installation goals, was fully subscribed, and received high satisfaction rankings from trade allies in PY7. The evaluation found the program encouraged HVAC and envelope contractors to continue or begin forming partnerships to complete whole-house projects, contributing to an increase in the delivery of whole-house energy efficiency services. The evaluation team provides the following recommendations for future program planning.

- **Key Finding #1:** The program achieved lower ex post savings than those expected by the program implementer due to different assumptions regarding equipment capacity and climate zones.
  - **Recommendation #1:** To minimize discrepancies and maximize gross realization rates for programs implementing the PY7 program measures, planning assumptions should be tailored to expected participant characteristics. AEH's target customers are clustered in southern Illinois, and therefore we recommend basing ex ante savings calculations on climate zone 4 or 5 rather than climate zone 3 to better match forecasted project characteristics.

- **Key Finding #2:** The program only installed one water heater temperature adjustment measure out of 197 projects receiving direct-install measures as the implementer determined that supporting this measure proved too time consuming.
  - **Recommendation #2:** Instead of offering water heater temperature adjustment as a direct-install measure, consider including it as an energy saving tip provided through the Behavior Modification program, if it is not already part of the program.
- **Key Finding #3:** The one-year IPA program cycle can present planning/logistical challenges for trade allies and customers if programs, such as AEH, are constantly changing. This could to lead to confusion and decreased satisfaction.
  - **Recommendation #3:** Prioritize program stability to allow efficient delivery of programs with high customer demand. AIC should consider how it might adjust its portfolio to provide consistency for trade allies and customers.

2. Evaluation Approach

This report describes the evaluation of the program year seven (PY7) All-Electric Homes (AEH) Program, one of five Illinois Power Agency (IPA) funded energy efficiency programs. AEH began as a pilot program in PY6 and continued with some modifications in PY7.

The PY7 evaluation involved process and impact assessments. To evaluate the AEH program's PY7 performance, the evaluation team conducted the following:

- Program staff interviews
- Trade ally surveys (HVAC and building envelope/home performance contractors)
- Incremental cost analysis
- Program marketing review
- Program document review
- Multifamily metering results analysis (continuation of work started in PY6)
- Analysis of program impacts using the program-tracking database, Illinois Statewide Technical Reference Manual for Energy Efficiency Version 2.0 (IL-TRM), and stakeholder advisory group (SAG) approved net-to-gross ratios (NTGRs)

At the beginning of PY7, the evaluation team installed meters in multifamily residences that received air-source heat pump (ASHP) and ductless mini-split heat pump (DMSHP) systems through AEH during PY6. A separate report (attached in Appendix B) provides metering methods, discussion, and results.

2.1 Research Objectives

The PY7 AEH Program evaluation sought to provide the following:

- Useful information for updating IL-TRM 4.0 values related to incremental HVAC equipment costs and key parameters for estimating energy savings
- Insights and lessons learned from program staff and trade allies
- Estimated gross and net electric savings attributable to AEH

The PY7 AEH Program impact evaluation addressed the following questions:

1. What are the estimated gross energy and demand impacts from this program?
2. What are the estimated net energy and demand impacts from this program?
3. What are the estimated equivalent full-load hours (EFLH)[1] for the installed heat pumps?

[1] A SAG memorandum, dated February 21, 2014, from the Vermont Energy Investment Corporation TRM Team indicates the Illinois Statewide TRM Version 2.0 places a high evaluation priority on EFLH heating for multifamily heating systems. As EFLHs are not directly

The evaluation team also explored the following process-related research questions:

1. Program Participation:
    a. How many projects were completed and by how many different customers in each sector (single-family/multifamily)?
2. Program Design and Implementation:
    a. What program marketing and outreach efforts did the program employ in PY7? Did they effectively drive participation in each targeted market sector?
    b. What were lessons learned from the program's second year of operation?
    c. What are the incremental costs of HVAC equipment?
3. Trade Ally Experience and Satisfaction:
    a. How satisfied were trade allies with the AEH program in PY7? Are they likely to participate in other AIC programs?
4. Whole House Efficiency Services:
    a. Did the addition of shell measures in PY7 encourage HVAC contractors to partner with shell contractors and vice versa?

2.2 Evaluation Tasks

As shown in Table 2, the evaluation team used a variety of approaches to assess the PY7 AEH program.

Table 2. Summary of PY7 Evaluation Methods

Task	PY7 Impact	PY7 Process	Forward Looking	Details
Program Staff Interviews		✓	✓	Interviewed AIC and CLEAResult managers to understand goals, program changes, progress to date, lessons learned, challenges, and future plans.
Marketing and Document Review		✓		Reviewed marketing plan and materials, and compared these against best practices.
Trade Ally Surveys		✓		Surveyed 16 HVAC and shell contractors to obtain feedback on their program experience and satisfaction.
Invoice Reviews and HVAC Distributor Interviews		✓	✓	Determined incremental costs of installed ASHP and DMSHPs; interviewed 10 distributors to gather information on industry trends, program awareness, and different efficiencies of equipment as a percent of sales over time.
Impact Analysis	✓			Summarized program participation and calculated savings impacts using IL-TRM 2.0 and SAG-approved NTGRs.

metered, the evaluation team metered energy consumption and calculated savings for each hour, and then used the total metered savings to back-calculate an EFLH value (as the Statewide TRM Version 2.0 also uses this value).

Task	PY7 Impact	PY7 Process	Forward Looking	Details
Metering Analysis	✓		✓	Removed meters installed in June 2014, on 39 DMSHP and 40 ASHP systems in multifamily properties. Analyzed results to prepare updates for the IL-TRM.

As CLEAResult conducted a survey of PY7 customers and the PY9 program design would likely differ greatly from PY7, the evaluation team and AIC chose not to pursue additional customer surveys to develop NTGRs for future program years.

Descriptions of each evaluation activity follow.

2.2.1 Program Staff Interviews

To assess the program's effectiveness and implementation, the evaluation team conducted two interviews with AIC program staff and the AEH implementation manager. These interviews addressed the program's design, operations, marketing efforts, implementation barriers, and communications. The team also inquired about the program's future status.

2.2.2 Marketing and Document Review

The evaluation team reviewed the AEH PY7 marketing plan, a project tracking spreadsheet with notes on each project and customer, PY7 implementation plan, and customer-facing marketing collateral to compare marketing practices against best practices. The team also thoroughly examined program tracking database extracts.

2.2.3 Trade Ally Surveys

AEH Program trade allies, responsible for generating the majority of program leads, fall into two categories: heating and cooling contractors and building envelope/home performance contractors. The majority of AEH contractors maintain existing relationships with CLEAResult and participate in other AIC programs, such as the HVAC and Home Performance (HP) programs.

As part of the evaluation of these AIC programs, the evaluation team conducted phone and online surveys with these contractors. To maximize data collection efficiencies, we added a short, AEH-specific[2] set of questions (provided as Appendix Appendix D) to these research efforts. These questions covered program experience, satisfaction, and program improvements. Sixteen HVAC and building envelope/home performance contractors responded to the AEH question battery.

2.2.4 Invoice Reviews and Distributor Interviews for Incremental Cost Analysis

The evaluation team requested copies of AEH customer invoices for a sample of randomly selected projects that included heat pump measures. We reviewed:

- 35 invoices for ASHP systems installed in multifamily residences
- 35 invoices for ASHP systems in single-family residences

[2] Only a subset of contractors surveyed through other program evaluations reported participating in AEH.

- 35 invoices for DMSHP systems in multifamily residences
- 31 invoices for DMSHP systems in single-family residences (census)

From these invoices, the team analyzed costs as a function of capacity and efficiency levels.

The team also interviewed 10 HVAC distributors to fill in gaps in the invoice analysis. Distributor interviews examined the following:

- Distributor program awareness
- The current program's effect on customer purchasing decisions
- Incremental costs of high-efficiency equipment
- Distributors' views on 18+ SEER incentive options

Sample Design and Response

CLEAResult's program manager provided the evaluation team with a list of 27 distributors, which included individual distributor contact information and region. Using this list, the team interviewed distributors in Illinois during September 2015. As shown in Table 3, the effort resulted in 10 completed surveys.

Table 3. Completed Distributor Interviews

Distributor Sample[a]	Target	Completed	Response Rate
27	10	10	37%

[a] CLEAResult provided a list of distributors in contact with the program and selling equipment within AIC's service territory.

2.2.5 Impact Analysis

Gross Impact Analysis Approach

The evaluation team used the implementer's final program database extract to determine ex ante unit and gross savings. As described in the PY7 IPA evaluation plan, the team followed these steps to determine ex post gross savings:

- The team estimated ex post unit savings for each installed measure using the IL-TRM V2.0's parameters and algorithms, along with assumptions and SAG approved NTGRs provided by AIC.
  - Exception: The IL-TRM V2.0 did not include DMSHPs. Thus, AIC instructed the team to conduct the calculation using the IL-TRM V3.0 algorithm for DMSHPs.
- To determine ex post gross savings, the team summed the ex post unit savings over all measures recorded in the program database.

As described in the IPA evaluation plan, the team applied in-service rates (ISRs) from PY6 (100% for all measures). We also examined the implementer's ex ante savings calculations to explain differences in ex post results.

Net Impact Analysis Approach

The evaluation team calculated net impacts for PY7 using SAG-approved NTGRs for each measure.

2.2.6 Multifamily Metering Study

In June 2014, the evaluation team installed meters on PY6 multifamily ASHP and DMSHP units, with each meter in a different apartment. The team randomly selected apartment complexes participating in PY6 and, from each of those sites, randomly selected living units to participate in the study. Table 4 shows the sample by equipment types. The team retrieved meters in July 2015 and conducted the analysis in fall 2015.

Table 4. Metering Study Sampling

Equipment Type	PY6 Measure Installations	PY6 Units Metered
ASHP	615	40
DMSHP	351	39
Total	**966**	**79**

2.3 Sources and Mitigation of Error

Table 5 summarizes possible error sources associated with research tasks conducted for the AEH Program.

Table 5. Possible Sources of Error

Research Task	Survey Errors		Non-Survey Errors
	Sampling Errors	Non-Sampling Errors	
Trade Ally Survey	Yes	Non-Response	N/A
Invoice Reviews	N/A	N/A	Invoice inconsistencies
Impact Analysis	N/A	N/A	Analysis errors
Metering Analysis	Yes	N/A	Analysis errors

Throughout the planning and implementation of the PY7 evaluation, the evaluation team took a number of steps to mitigate potential error.

Survey Errors

- Sampling Errors
  - We surveyed trade allies to gather qualitative information about the program and did not design the sampling approach for the trade ally survey to achieve a specific level of confidence and precision. Since most AEH trade allies participate in other AIC and IPA programs, the evaluation team coordinated AEH survey questions on other program surveys to minimize the number of separate evaluation surveys administered to the limited trade ally population. The team conducted the HVAC survey by telephone and the HP survey online. It is possible that there will be some sample frame bias because our sampling approach includes only contractors participating in other programs, however CLEAResult indicated the majority of, if not all, contractors participating in AEH also participate in other programs. Sixteen trade allies responded to the survey out of a total of 40 AEH contractors who completed at least one project in PY7, resulting in a confidence/precision of 90%/17%.

- The evaluation team installed meters on 40 of 619 PY6 multifamily ASHP units and 39 of 351 PY6 multifamily DMSHP units, with each meter in a different apartment. In PY6, 22 multifamily properties participated in AEH; we sampled from seven different properties.

  Table 6 shows the anticipated precision estimates from the metering study at the 90% confidence interval. We present precision in terms of ASHP and DMSHP results combined and individually. We based precision estimates on an infinite population to be conservative.

Table 6. Confidence and Precision Estimates for Sample of DMSHPs and ASHPs

Parameter	Combined ASHP and DMSHP Results	Individual ASHP and DMSHP Results
Heating Energy Savings	90% confidence 13% Precision CV = 0.7	90% confidence 18% Precision CV = 0.7
Cooling Energy Savings	90% confidence 13% Precision CV = 0.7	90% confidence 18% Precision CV = 0.7
CF (summer peak)	90% confidence 9.2% Precision CV = 0.5	90% confidence 13% Precision CV = 0.5
CF (PJM)	90% confidence 7.4% Precision CV = 0.4	90% confidence 10.5% Precision CV = 0.4

Note: Coefficient of variance (CV) estimates are based on our experience metering these parameters, considering the expected variability of operation in multifamily homes.

- Non-Sampling Errors
  - **Non-Response:** To minimize non-response bias, the evaluation team fielded the HVAC and HP surveys over multiple weeks at different times of days and weeks, sending reminders or calling back multiple times.
  - **Metering Study:** We worked with the program implementation team to select a representative sample, and all but one of the initially selected buildings participated in the research study.[3]

[3] All facilities agreed to participate; however, one was unable to schedule a time with field staff, so we recruited a similar replacement site from the population of multifamily participants.

Non-Survey Errors

- **Analysis Errors:**
  - **Invoice Reviews:** The evaluation team reviewed 70 ASHP invoices and 66 DMSHP invoices. The team compared parameter values recorded in the tracking database (e.g., SEER, tons, model number) to values in the invoices. We compared analysis of invoice data against feedback from contractors and distributors to assess reasonableness. As each contractor used their own invoicing systems, we found inconsistencies in the availability of certain details, such as labor charges, numbers of indoor and outdoor DMSHP units, or auxiliary materials. To mitigate possible error due to the lack of transparency in invoices we interviewed distributors and requested cost estimates for different SEER levels, which were ultimately relied upon in our analysis.
  - **Impact Analysis:** To calculate gross impacts, the team applied the IL-TRM algorithms to participant data drawn from the tracking database. Separate staff reviewed calculations to verify that calculations were performed accurately.
  - **Metering Study:** To mitigate analysis errors, we used multiple reviewers within the evaluation team to independently verify the approach and calculations.

3. Detailed Evaluation Findings

3.1 Program Description

AEH began in PY6 (June 2013–May 2014) as a pilot offering. The program sought to increase energy savings in all-electric residences (single-family and multifamily), targeting customers with inefficient electric resistance heating that had already received shell improvements through other AIC programs, such as the HP Program or Multifamily Program. In PY7, CLEAResult modified the single-family[4] AEH offering to include a direct-install air-sealing measure and shell measures (insulation and air sealing) to shift the program towards a whole-house approach.[5] CLEAResult markets and administers the program, leveraging its existing ActOnEnergy program ally network to generate leads.

As part of the single-family program delivery, CLEAResult staff make the first visit to a potential participant's home at no charge to the customer, unless the customer requested direct-install air-sealing, which requires a small fee. Staff explain the program to the customer and make direct installations of lighting and hot water measures if the home has not previously been serviced by another ActOnEnergy program.

CLEAResult staff then examines the residence's existing shell and HVAC systems. Following this, staff provides a scope of work to the homeowner, including recommendations for eligible shell and HVAC measures along with a list of qualified program allies so homeowners may obtain estimates for retrofits. If the customer accepts and signs the scope of work, CLEAResult staff will arrange for HVAC and/or HP program allies to install the retrofits. Upon the work's completion, CLEAResult staff returns to verify the measure installations and to process incentive payments to program allies.[6]

A new offering in PY7 is the direct-install air sealing measure, which occurs during the initial energy audit. Customers can request this blower-door assisted air-sealing service for $50, performed by CLEAResult field staff.

Table 7 summarizes measures the program offered for each customer type.

Table 7. All-Electric Measures and Incentives, by Dwelling Type

Electric Measure	Single-Family	Multifamily	Incentive	Maximum per Unit
ASHP—Early Replacement	✓	✓	90% up to maximum	Single-family $4,800 Multifamily $4,200
DMSHP—Early Replacement	✓	✓	90% up to maximum	Single-family $16,000 Multifamily $8,000
Programmable Thermostat	✓	✓	$50/unit	Single-family $100 Multifamily $50
Low-Flow Shower Heads	✓		Direct-install	
CFLs	✓		Direct-install	
Specialty CFLs	✓		Direct-install	

[4] Up to two connected units.

[5] 2014 Ameren Illinois IPA Programs: All Electric Homes Program PY7 Implementation Plan. May 1, 2014.

[6] When customers receive their invoice from the trade ally(s), they will see an AEH program incentive automatically applied to the final amount due.

Electric Measure	Single-Family	Multifamily	Incentive	Maximum per Unit
Faucet Aerators	✓		Direct-install	
Water Heater Temp Adjustment	✓		Direct-install	
Air Sealing Audit	✓		Direct-install ($50 fee)	
Air Sealing	✓		$0.50 per CFM	NA
Ceiling Insulation	✓		$0.80 to $1.00 per SF	NA
Wall Insulation	✓		$1.30 per SF	NA
Rim Joist Insulation	✓		$2.00 per LF	NA
Crawl Space Insulation	✓		$6.00 per LF	NA

Note: CFM = Cubic foot per minute; SF = square feet; LF = linear feet

3.2 Program Goals and Participation

Table 8 shows program goals from the PY7 implementation plan, compared to achieved measure installations from the final database extract. AEH exceeded its installation goals for HVAC measures and certain direct-install and shell measures, including CFLs, air-sealing at audit, and crawl space insulation. Only one participant received a water heater temperature adjustment. CLEAResult staff indicated they stopped promoting this measure early in PY7 due to its impracticality,[7] not because of a lack of opportunities.

Table 8. PY7 Goals and Achievements

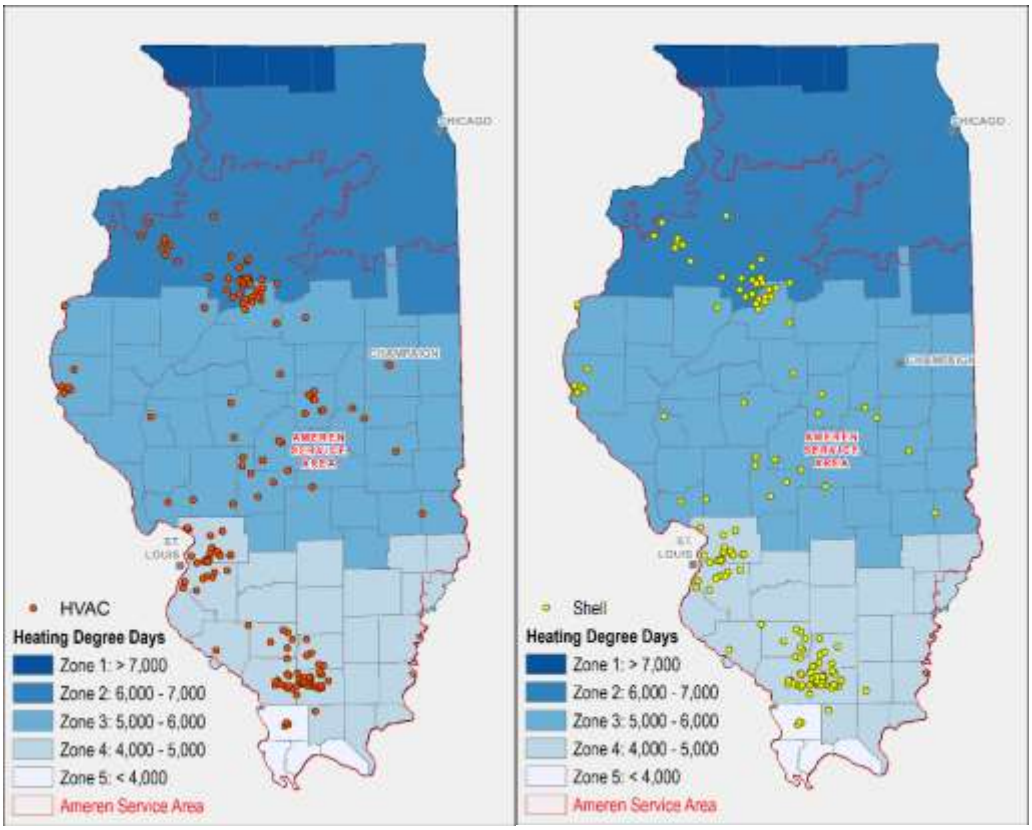
Electric Measure	Planned Goal		Achieved			
	Single-Family	Multifamily	Single-Family	Single-Family %	Multifamily	Multifamily %
ASHP	260	500	290	112%	570	197%
DMSHP[a]	20	60	20	100%	57	285%
Programmable Thermostat	147	225	145	99%	247	170%
Low-Flow Shower Head	176	NA	125	71%	NA	
CFL	1,404		1,563	111%		
Specialty CFL	4,641		991	21%		
Faucet Aerator	234		202	86%		
Water Heater Temp Adjustment	70		1	1%		
Air Seal at Audit (CFM)	18,800		19,800	105%		
Air Seal (CFM)	414,000		213,728	52%		
Ceiling Insulation (sqft)	319,570		261,772	82%		
Wall Insulation (sqft)	63,250		11,952	19%		
Rim Joist Insulation (feet)	21,235		13,576	64%		
Crawl Space Insulation (feet)	4,185		4,623	110%		

[a] DMSHP counts were based on number of residences receiving this measure, which usually consisted of one outdoor unit and multiple indoor units, although residences could receive multiple outdoor units for different parts of a home.

[7] CLEAResult staff said audit staff conducting the adjustment needed to remain at a residence until they could measure a drop in water temperatures.

Figure 1 shows the location of HVAC and shell installations within AIC's service territory (red outline); projects in climate zones 2 and 4 tended to be located in clusters, while projects in climate zone 3 were spread more evenly across the service territory. The majority (99% and 92%, respectively) of insulation and air-sealing (incentive) measures were installed in residences also receiving a new heat pump. A little over 40% of insulation projects included more than one insulation type (e.g., ceiling insulation with rim joist or crawl space insulation).

Figure 1. Location of HVAC and Shell Installations



According to CLEAResult staff, approximately 60% of participating single-family residences were professionally managed (i.e., renter occupied, with the landlord making installation decisions and paying for measures).

3.3 Process Assessment

3.3.1 Program Design and Implementation

Program Design Changes

In PY7, CLEAResult began offering single-family air sealing and shell measures to treat the whole house. The program also offered single-family owners an option to receive blower-door assisted air-sealing during the energy audit for a small fee. Single-family residences no longer needed to first receive shell improvements through other programs to be eligible for AEH. CLEAResult staff said shell and HVAC contractors often teamed to complete whole-house projects. Incentive payments only occurred once for each project, after inspection of

completed work and sign-off by the customer. CLEAResult noted shell measures often took longer to install than HVAC measures, leading to some impatience from HVAC contractors regarding payment. Overall, however, implementer staff said the PY7 program helped push the market towards whole-house retrofit projects and allowed them to continue developing relationships with ally contractors.

On the multifamily side, CLEAResult decided—based on feedback received from AIC to "spread the wealth" among more customers—to limit the number of heat pump incentives allotted to any one property manager to distribute program resources across more facilities. Measure limits varied by property size and distribution of eligible participants in the area.

Implementation

AIC and CLEAResult reported smooth program implementation over PY7. AIC staff did not report receiving complaints from trade allies or customers, but their involvement with the program was limited; staff primarily reviewed status reports or helped resolve issues or questions, as needed. CLEAResult staff anecdotally heard that customers were very satisfied with the program, and they also formally documented feedback through a homeowner and property manager survey that CLEAResult conducted.

CLEAResult said AEH experienced a strong start in PY7 due to a long waiting list of interested customers who could not be served in PY6 (due to oversubscription). PY6 trade allies also kept lists of customer leads, in case the program continued in PY7. Trade allies conducted all AEH marketing on the multifamily side and the majority of marketing to single-family homeowners.

Originally, the program was designed to target customers in southern Illinois who wanted a program tailored to their specific concerns (10 years ago, when these customers first complained, no efficiency programs were offered and customers experienced high electricity costs). AIC requested that CLEAResult collect participant feedback through a survey, seeking to determine if the AEH program was satisfying their needs.

Because IPA programs are approved in one-year increments,[8] the implementer must rebid programs each year. In PY8, AIC staff indicated AEH's cost-effectiveness fell below one. As a result, the program did not receive approval for PY8.

In its PY9 application, CLEAResult revised the program offerings, which is currently under review. AIC and CLEAResult staff said AEH is a very attractive program to eligible customers due to its high incentives. Customers interested but unable to participate in AEH during PY7 (because the program was fully subscribed) often were referred to another program for PY8 (e.g., the income-qualified program or the HVAC program). AIC staff said the "start-stop" nature of such IPA programs present challenges in managing customer and trade ally expectations; trade allies often increase hiring and equipment stock in anticipation of continuing programs.

3.3.2 Program Marketing

Although the AEH program employed minimal direct customer marketing efforts due to high demand generated by trade ally marketing and the waitlist from PY6, the evaluation team reviewed the PY7 marketing plan, customer-facing marketing materials used to generate program awareness, and a project tracking spreadsheet containing notes on each project (including projects that dropped out). Marketing materials

[8] The one-year duration allows different vendors to bid on program implementation.

developed in PY7 consisted of one direct-mail piece. Table 9 lists best practices[9] that guided the team's review and the extent that AEH achieved these elements. Although trade allies do not have program collateral, this is not an issue with AEH since the program implementer does the first visit to a potential participant's home.

Table 9. AEH Marketing Approach and Materials Review

Best Practices	Achieved
Marketing plan in place.	✓
Clearly defined marketing roles.	✓
Clearly defined marketing goals.	✓
Marketing plan leverages cross-promotional opportunities.	✓
Marketing plan takes advantage of existing partnerships.	✓
Marketing plan employs complementary multichannel approach.	✓
Program ambassadors received training.	✓
Supporting collateral available to trade allies (e.g., brochures, factsheets)	-
Marketing materials offer clear and comprehensive program details and benefits.	✓
Marketing materials offer clear messaging hierarchy with a direct call-to-action that provides sufficient information to take required next actionable steps.	✓
Program designed with measurable marketing metrics.	✓
Marketing metrics are tracked (e.g., source of lead).	○

Key: ✓=present, ○= partially present, - = not present

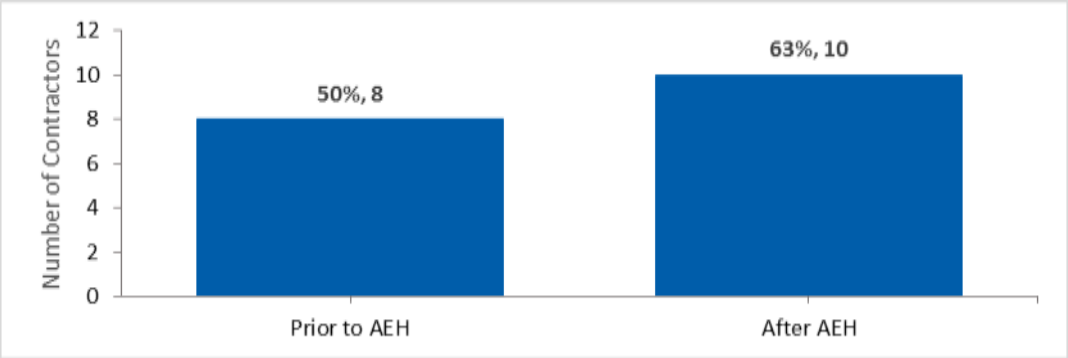
3.3.3 Trade Ally Experience and Satisfaction

Sixteen contractors provided the evaluation team with feedback about their participation in the AEH program, their satisfaction levels, and their interest in participating in future AEH programs.

Slightly over one-half (56%) of respondents said they participated in the AEH program starting in PY6—its first year—and 44% started in PY7. The AEH program encouraged HVAC and shell contractors to partner in delivering home performance projects, with 62% of contractors saying the program encouraged partnerships. When asked whether they partnered with other types of contractors prior to AEH, 50% said they did. Figure 2 shows the change in partnership rates before and after participating in AEH.

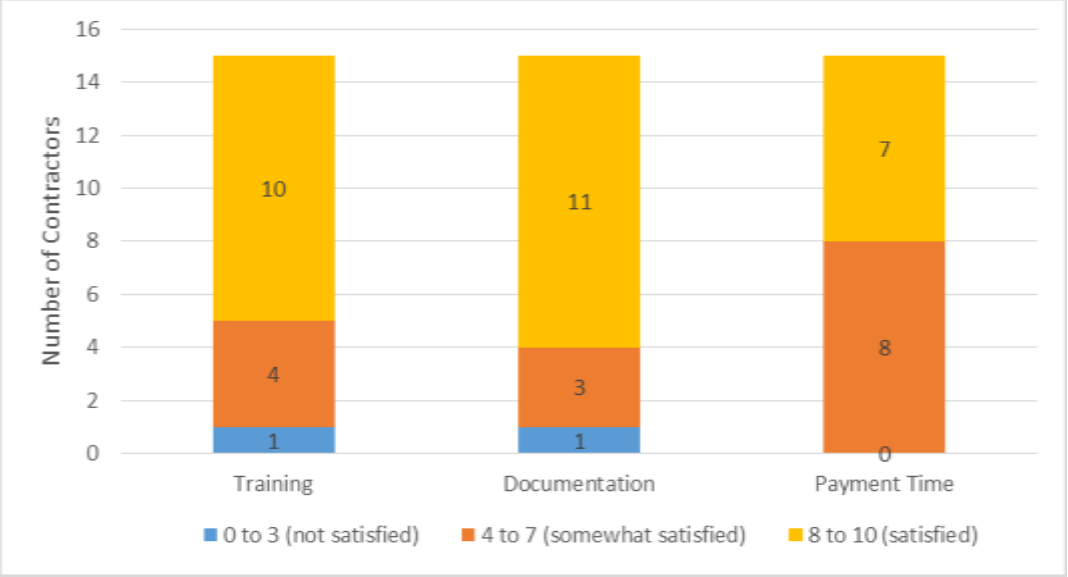
[9] Best practices developed by evaluation staff marketing experts

Figure 2. Percentage of Contractors Partnering Before and After AEH, n=16



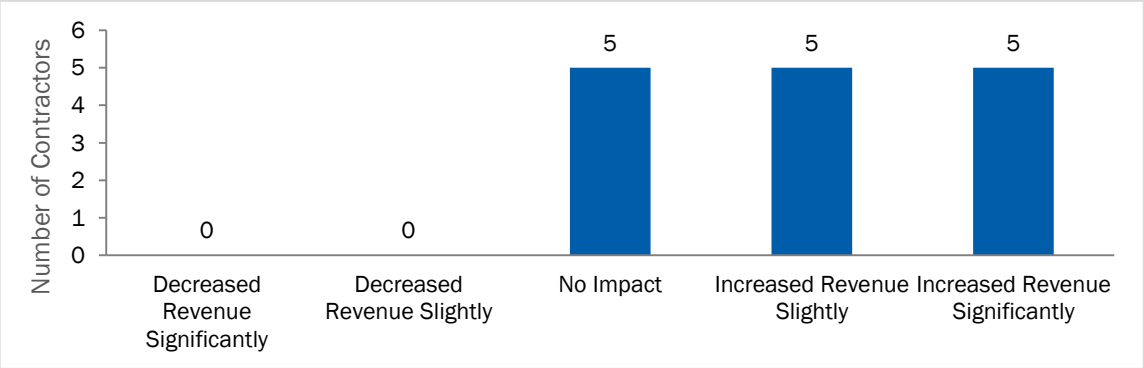
Surveyed contractors rated their satisfaction level on a 10 point scale (0: very dissatisfied; and 10: very satisfied) regarding training and other program support, clarity of program documentation, and payment times upon project completions. As shown in Figure 3, contractors indicated satisfaction (a rating of 8 or above) with program support and training (10) and with the clarity of program documentation (11). Fewer contractors expressed this satisfaction level with the time required to receive payment (7). All respondents, however, rated their satisfaction level a 4 or greater in terms of timely payments. Only one contractor rated satisfaction with training below a 4, saying he or she had not received training. One contractor not satisfied with the clarity of documentation explained there was "way too much paper work and regulations about the project."

Figure 3. Contractor Satisfaction with Training, Documentation Clarity, and Payment Time, n = 15



Respondents described changes in business revenues resulting from AEH participation. As shown in Figure 4, equal numbers of contractors experienced no impacts, slight increases, and significant increases to their business revenues. No contractor reported decreased revenue.

Figure 4. Revenue Change Before and After the Program, n = 15



While the majority of respondents (10) experienced an increase in revenue after participating in AEH, those reporting no impact indicated their involvement with AEH was limited. One contractor who said the program had no impact commented they "generally deal with gas [equipment]"; so the AEH program was not that applicable. Another said that he thought the program was "very smooth running," but he had only dealt with an AEH project once in the past two years, hence the program had little effect.

When asked how likely their company would be to participate in future AEH offerings, on a scale of 0 (not at all likely) to 10 (very likely), most contractors responded positively to the prospect. Twelve out of 16 respondents said they were very likely (score of 10) to participate in the program again; two contractors gave a score of 8; and two gave a score of 5. Note that all contractors answered this question, so even contractors not as satisfied with some program aspects would be somewhat likely to participate in the program again (score
of 5).

Respondents who took the online version of the survey (HP program contractors) also provided some firmographic data. Figure 5 shows the size distribution of respondents' companies. Most companies surveyed had one to 10 employees. The largest company had 35 employees; the smallest companies had two.

Figure 5. Number of Employees per Company, n = 10

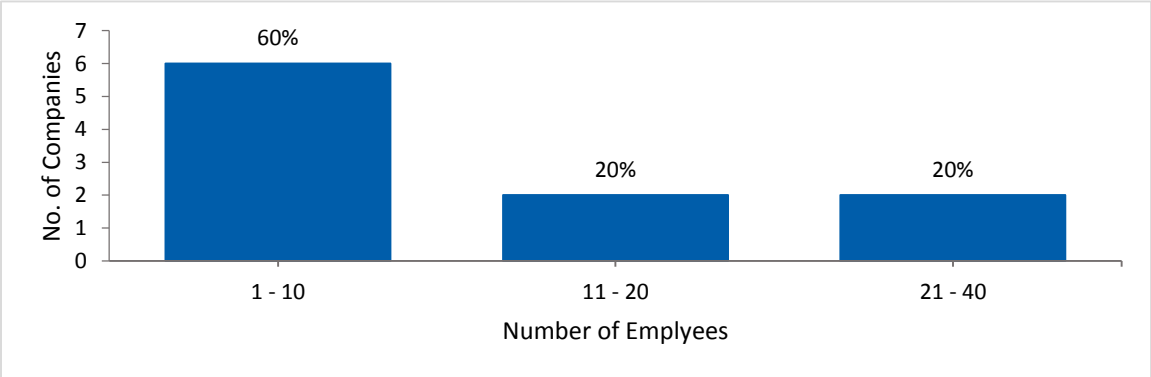
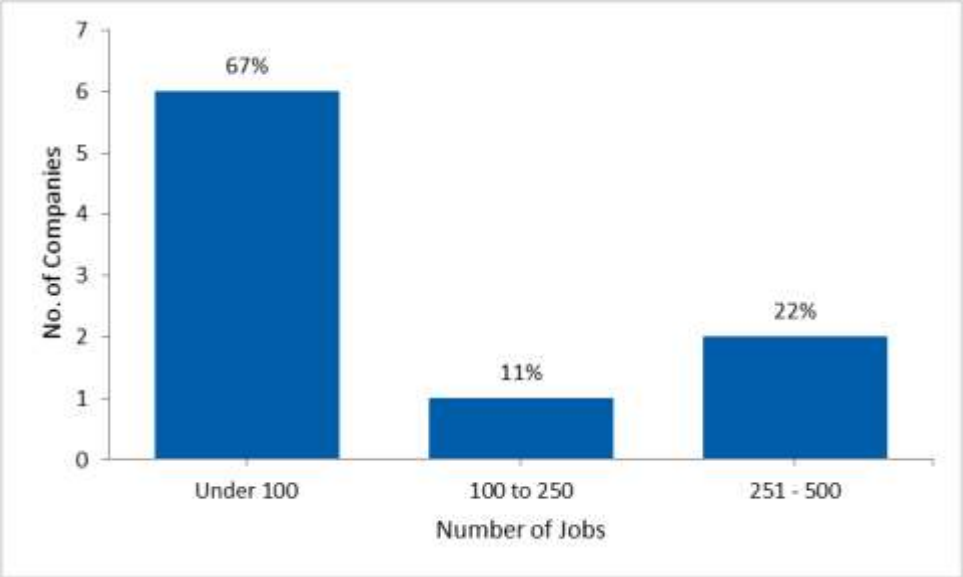


Figure 6 shows the number of jobs each company completed per year, with the majority of companies completing fewer than 100 jobs per year.

Figure 6. Number of Jobs Companies Complete per Year, n = 9



3.4 Impact Evaluation

3.4.1 Gross Impacts

The PY7 AEH Program produced ex post gross energy and demand impacts of 7,880 MWh and 0.914 MW, respectively. Table 10 shows measure-level impacts. Unless specified to use a different value by the IL-TRM, the evaluation team applied ISRs from the PY6 evaluation (100% for all measures) to calculate verified measure quantities. Note that units for building envelope measures vary by improvement type and not per project.

Table 10. AEH PY7 Gross Savings Impacts[a]

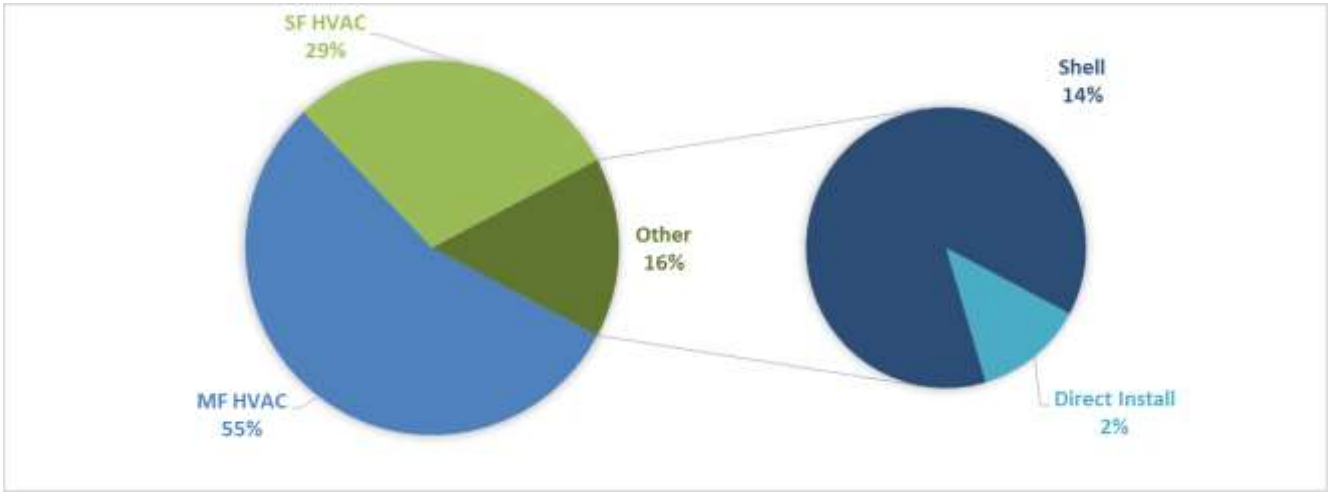
Electric Measure	Verified Measure Quantity[b]	Ex Ante Gross		Ex Post Gross		Realization Rate	
		MW	MWh	MW	MWh	MW	MWh
ASHP—Multifamily	570	0.607	5,681	0.448	4,044	74%	71%
DMSHP—Multifamily	57	0.066	564	0	203	0%	36%
Programmable Thermostat—Multifamily	247	n/a	76	n/a	99	n/a	130%
ASHP—Single-Family	290	0.397	3,764	0.227	2,132	57%	57%
DMSHP—Single-Family	20	0.030	254	0	99	0%	39%
Programmable Thermostat—Single-Family	145	n/a	59	n/a	78	n/a	131%
Low-Flow Shower Heads	125	0.003	45.98	0.003	46	100%	100%
CFLs	1,563	0.005	46.37	0.005	27	99%	57%
Specialty CFLs	991	0.005	46.23	0.005	27	100%	57%
Faucet Aerators	202	0.004	9	0.004	9	100%	100%
Water Heater Temp Adjustment	1	0.00001	0.1	0.00001	0.1	100%	100%
Air Seal at Audit (CFM)	19,800	0.018	64	0.014	47	81%	73%
Air Seal (CFM)	213,728	0.192	695	0.166	548	86%	79%
Ceiling Insulation (sqft)	261,772	0.026	354	0.032	368	123%	104%
Wall Insulation (sqft)	11,952	0.004	46	0.003	32	77%	70%
Rim Joist Insulation (linear feet)	13,576	0.003	53	0.0044	80	163%	152%
Crawl Space Insulation (linear feet)	4,623	0.002	47	0.0015	41	82%	87%
Total		**1.362**	**11,805**	**0.914**	**7,880**	**67%**	**67%**

[a] Measures grouped into three categories by color: HVAC (light grey), direct-install (white), and building envelope (blue).

[b] Source: Evaluation team application of 100% ISR to final AEH tracking data.

As shown in Figure 7, HVAC measures (ASHP, DMSHP, and thermostat) produced the majority of gross savings. Multifamily-specific HVAC projects contributed 55% of overall savings.

Figure 7. Distribution of Gross Electric Energy Savings by Measure Category



As shown in Table 10, the evaluation team calculated a 67% realization rate for the PY7 AEH programdue to the fact that ex ante savings assumed warmer climates and larger equipment sizes than actuals. The team calculated *ex post* unit and demand savings at the project level using the IL-TRM 2.0 algorithms.[10] Table 11 presents quantity weighted average unit savings values for each measure. The team calculated demand savings using AIC system peak coincidence factors. Engineering Algorithms) provides further details on the ex post unit savings calculations.

Table 11. AEH PY7 Unit Savings[a]

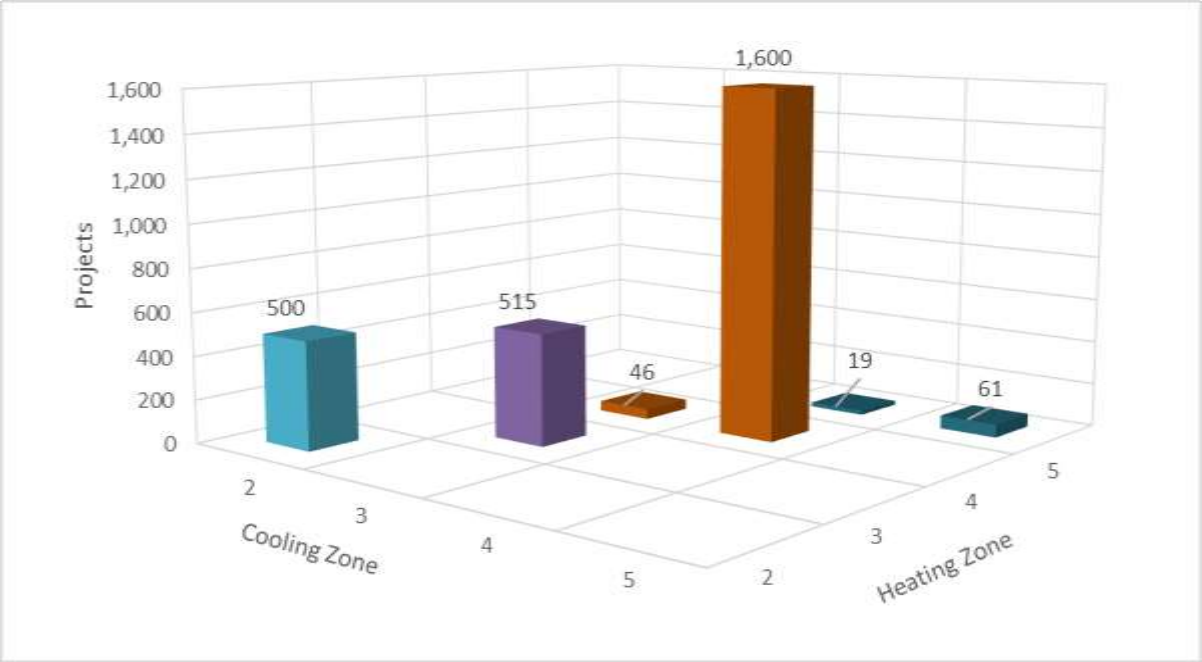
Electric Measure	Ex Ante Unit Savings		Average Ex Post Unit Savings	
	kW	kWh	kW	kWh
ASHP—Multifamily	1.0657	9,966	0.7861	7,096
DMSHP—Multifamily	1.1602	9,899	0	3,560
Programmable Thermostat—Multifamily	n/a	309	n/a	402
ASHP—Single-Family	1.3681	12,979	0.7828	7,353
DMSHP—Single-Family	1.4910	12,725	-0.0001	4,962
Programmable Thermostat—Single-Family	n/a	408	n/a	536
Low-Flow Shower Heads	0.0237	368	0.0237	368
CFL 43w to 14w—Post-EISA	0.0030	26	0.0030	15
CFL 53w to 19w—Post-EISA	0.0035	31	0.0035	18
CFL 72w to 23w—Post-EISA	0.0050	44	0.0050	25
CFL—Globe	0.0057	55	0.0057	32
CFL—Candelabra	0.0041	40	0.0041	23
CFL—Reflector	0.0051	45	0.0051	26
Faucet Aerators	0.0206	42	0.0206	42
Water Heater Temp Adjustment	0.0099	86	0.0099	86
Air Seal at Audit (CFM)	0.0009	3.3	0.0007	2.4
Air Seal (CFM)	0.0009	3.3	0.0008	2.6
Ceiling Insulation (sqft) R-11 to R-49	0.0001	1.8	0.0002	1.8
Ceiling Insulation (sqft) R-19 to R-49	0.0001	0.8	0.0001	0.9
Wall Insulation (sqft)	0.0003	3.8	0.0002	2.7
Rim Joist Insulation (feet)	0.0002	3.9	0.0003	5.9
Crawl Space Insulation (feet)	0.0004	10.3	0.0003	8.9

[a] Measures grouped into three categories by color: HVAC (light grey), direct-install (white), and building envelope (blue).

The majority of measures exhibited lower average ex post unit energy savings than ex ante unit savings. One reason for this discrepancy is the high number of measures in climate zones with lower heating requirements (climate zone 4), as shown in Figure 8 (colors correspond to different heating zones). The implementer's planning calculations used climate zone 3, a colder climate (i.e., Springfield) with higher heating loads.

[10] TRM 3.0 for DMSHPs.

Figure 8. Distribution of Project Locations by Climate Zone



The following section describes additional drivers for the difference in unit savings by measure type.

ASHP and DMSHP: The team compared three parameters in Table 12 to determine why ASHP and DMSHP ex ante unit savings were much greater than ex post average unit savings.

Table 12. ASHP and DMSHP Ex Ante vs. Ex Post Unit Savings and Input Parameters

Electric Measure	Ex Ante Unit Savings		Ex Post Unit Savings		Heating Capacity (btuh)		FLH Heat		HSPF EE	
	kW	kWh	kW	kWh	Ex Ante	Ex Post (Average)	Ex Ante	Ex Post (Average)	Ex Ante	Ex Post (Average)
ASHP - Multifamily	1.0657	9,966	0.7861	7,096	30,000	23,089	1,593	1,593	9.20	8.84
ASHP - Single-Family	1.3681	12,979	0.7828	7,353	36,000	25,143	1,754	1,380	9.10	8.94
DMSHP - Multifamily	1.1602	9,899	0	3,560	30,000	21,600	1,593	1,825	9.30	9.00
DMSHP - Single-Family	1.4910	12,725	-.0001	4,962	36,000	26,697	1,754	1,529	8.70	9.43

The discrepancy occurred for three reasons:

- First, the heating capacity of average PY7 installations were smaller than expected by the implementer.
- Second, heating full load hours were lower for single-family projects due to more installations in climate zone 4.

- Third, the average installed heating season performance factor (HSPF) was generally lower.[11]

For DMSHPs, the evaluation team used IL-TRM 3.0 to calculate savings.[12] The implementer's DMSHP ex ante calculation followed a different algorithm than that provided in IL-TRM 3.0.

Programmable Thermostat: For this measure, the team's calculation using the IL-TRM 2.0 algorithm resulted in higher savings than those estimated by the implementer. This discrepancy occurred due to the implementer calculating reduced electric heating consumption due to the installation of a new heat pump unit. IL-TRM 2.0 provided a table with heating loads for each climate zone; it did not provide instructions to calculate specific heating loads. While it is more accurate to calculate the heating consumption for a new heat pump (as the implementer did in its calculations), this approach is not consistent with instructions in the IL-TRM 2.0.

Air Sealing and Insulation: Differences in ex ante and ex post savings primarily resulted from differences in climate zones.

3.4.2 Net Impacts

The evaluation team calculated net ex ante and ex post savings by applying the SAG-approved NTGRs to the ex ante and ex post gross savings. Table 13 shows NTGRs by measure and net savings in MW and MWh. The AEH achieved net realization rates of 66% for demand and electric energy.

Table 13. AEH PY7 Program Net Savings Impacts

Electric Measure	NTGR	Ex Ante Net Savings		Ex Post Net Savings	
		MW	MWh	MW	MWh
ASHP—Multifamily	0.69	0.419	3,920	0.309	2,791
DMSHP—Multifamily	1.00	0.066	564	0	203
Programmable Thermostat—Multifamily	1.00	n/a	76	n/a	99
ASHP—Single-Family	0.69	0.274	2,597	0.157	1,471
DMSHP—Single-Family	1.00	0.030	254	0	99
Programmable Thermostat—Single-Family	1.00	n/a	59	n/a	78
Low-Flow Shower Heads	0.82	0.002	38	0.002	38
CFLs	0.88	0.005	41	0.005	23
Specialty CFLs	0.88	0.004	41	0.004	23
Faucet Aerators	0.73	0.003	6	0.003	6
Water Heater Temp Adjustment	1.00	0.00001	0.1	0.00001	0.1
Air Seal at Audit (CFM)	1.00	0.018	64	0.014	47
Air Seal (CFM)	0.80	0.154	556	0.133	438
Ceiling Insulation (sqft)	0.77	0.020	273	0.025	283
Wall Insulation (sqft)	0.77	0.003	35	0.002	25
Rim Joist Insulation (feet)	0.77	0.002	41	0.003	62
Crawl Space Insulation (feet)	0.77	0.001	36	0.001	32

[11] According to the program-tracking database provided by the implementer.

[12] DMSHP demand savings were small and negative due to errors in the TRM algorithm. The evaluation team submitted a TRM update for this measure, correcting the errors found.

Electric Measure	NTGR	Ex Ante Net Savings		Ex Post Net Savings	
		MW	MWh	MW	MWh
Total		1.001	8,602	0.659	5,719
			Net Realization Rate[a]	66%	66%

[a] Net realization Rate = ex post net value ÷ ex ante net value

4. Conclusions and Recommendations

The AEH program exceeded its HVAC measure installation goals, was fully subscribed, and received high satisfaction rankings from trade allies in PY7. The evaluation found the program encouraged HVAC and envelope contractors to continue or begin forming partnerships to complete whole-house projects, contributing to an increase in the delivery of whole-house energy efficiency services. However, as the program's future remains uncertain, the evaluation team provides recommendations that may be useful in future program planning.

- **Key Finding #1:** The program achieved lower ex post savings than those expected by the program implementer due to different assumptions regarding equipment capacity and climate zones.
  - **Recommendation #1:** To minimize discrepancies and maximize gross realization rates for programs implementing the PY7 program measures, planning assumptions should be tailored to expected participant characteristics. AEH's target customers are clustered in southern Illinois, and therefore we recommend basing ex ante savings calculations on climate zone 4 or 5 rather than climate zone 3 to better match forecasted project characteristics.
- **Key Finding #2:** The program only installed one water heater temperature adjustment measure out of 197 projects receiving direct-install measures as the implementer determined that supporting this measure proved too time consuming.
  - **Recommendation #2:** Instead of offering water heater temperature adjustment as a direct-install measure, consider including it as an energy saving tip provided through the Behavior Modification program, if it is not already part of the program.
- **Key Finding #3:** The one-year IPA program cycle can present planning/logistical challenges for trade allies and customers if programs, such as AEH, are constantly changing. This could lead to confusion and decreased satisfaction.
  - **Recommendation #3:** Prioritize program stability to allow efficient delivery of programs with high customer demand. AIC should consider how it might adjust its portfolio to provide consistency for trade allies and customers.

Appendix A. Incremental Cost Results

Forthcoming, based on discussions within the TAC.

Appendix B. Multifamily Metering Results

Forthcoming, based on discussions within the TAC.

Appendix C. Engineering Algorithms

The PY7 program evaluation estimated ex post gross savings impacts for AEH by applying savings algorithms from the Illinois Statewide TRM V2.0 (V3.0 for DMSHP) to information in the AEH program-tracking database. This section provides algorithms used along with all input assumptions.

Air Source Heat Pump

The evaluation team calculated unit savings for early replacement of an ASHP using the following equations from the IL-TRM 2.0.

Equation 1. Early Replacement ASHP Algorithms

Energy Savings:
ΔkWH for remaining life of existing unit (1st 6 years):
= *((FLH_cooling * Capacity_cooling * (1/SEER_exist - 1/SEER_ee)) / 1000) + ((FLH_heat *Capacity_heating * (1/HSPF_exist - 1/HSFP_ee)) / 1000)*

Demand Savings:
ΔkW for remaining life of existing unit (1st 6 years):
= *((Capacity_cooling * (1/EERexist - 1/EERee))/1000 * CF)*

Where:

FLH_cooling = Full load hours of air conditioning (dependent upon location)

Table 14 FLH_cooling Table for Different Cities and Sizes

Climate Zone (City Based Upon)	FLH_Cooling (Single-Family)	FLH_Cooling (Multifamily)
1. (Rockford)	512	467
2. (Chicago)	570	506
3. (Springfield)	730	663
4. (Belleville)	1,035	940
5. (Marion)	903	820
Weighted Average	629	564

Capacity_cooling = Cooling Capacity of Air Source Heat Pump (Btu/h)
= Actual (1 ton = 12,000Btu/h)

SEER_exist = Seasonal Energy Efficiency Ratio (SEER) of existing cooling system (kBtu/kWh)
= Use actual SEER rating where it is possible to measure or reasonably estimate.

SEER_ee = SEER of efficient Air Source Heat Pump (kBtu/kWh)
= Actual

FLH_heat = Full load hours of heating
= Dependent on location:

Table 15. FLH_cooling for Different Locations

Climate Zone (City Based Upon)	FLH_Cooling (Multifamily)
1. (Rockford)	1,969
2. (Chicago)	1,840
3. (Springfield)	1,754
4. (Belleville)	1,266
5. (Marion)	1,288
Weighted Average	1,821

Capacity_heating = Heating Capacity of Air Source Heat Pump (Btu/h)
= Actual (1 ton = 12,000Btu/h)

HSPF_exist = Heating System Performance Factor of existing heating system (kBtu/kWh)
= 3.41 (Electric Resistance)

HSFP_ee = Heating System Performance Factor of efficient Air Source Heat Pump (kBtu/kWh)
= Actual

EER_exist = Energy Efficiency Ratio of existing cooling system (kBtu/h / kW)
= Use actual EER rating where it is possible to measure or reasonably estimate

EER_ee = Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/h / kW)
= Actual

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 91.5%

Ductless Mini Split Heat Pumps

The evaluation team calculated unit savings for DMSHP using algorithms from the IL-TRM 3.0 as the IL-TRM 2.0 did not include this measure.

Equation 2. DMSHP Algorithms

$$\Delta kWh = \Delta kWhheat + \Delta kWhcool$$
$$\Delta kWhheat = PLD*AHHL*HF*(1/HSPFexist-1/HSPFee)*3.413$$
$$\Delta kWhcool = Capacitycool*HF*(1/SEERexist-1/SEERee)*EFLHcool$$
$$\Delta kW = (Capacity\_cooling *HF* (1/EER\_exist - 1/EER\_ee)) / 1000) * CF$$

Where:

PLD = Percent Load Displaced: the average total annual heating load displaced from an existing heating system and now provided by a ductless heat pump

Table 16. Estimate of PLD Based on Climate and Size

	PLD		
Climate zone	1-ton unit	1.5-ton unit	2-ton unit
Rockford	26%	39%	39%
Chicago	27%	40%	42%
Springfield	31%	47%	48%
Belleville	30%	45%	48%
Marion	31%	46%	50%

AHHL = Annual Household Heating Load in kWh for a household with electric resistance heat

Table 17. Estimate of Annual Household Heating Load

Climate Zone	Annual Household Heating Load Resistance (kWh)
1 (Rockford)	21,741
2 (Chicago)	20,771
3 (Springfield)	17,789
4 (Belleville)	13,722
5 (Marion)	13,966

HF = Household factor, to adjust heating consumption for non-single-family households

Table 18. Estimate of Household Factor

Household Type	HF
Single-Family	100%
Multifamily	65%
Actual	Custom

Capacitycool = The cooling capacity of the ductless heat pump unit in kBtu/hr
= Actual installed

HSPFee = HSPF rating of new equipment
= Actual installed

HSPFexist = HSPF rating of existing equipment = 3.41

SEERee = SEER rating of new equipment
= Actual installed

SEERexist = SEER rating of existing equipment
= Use actual value; if unknown, see table below

Table 19. Estimate of SEERexist by Equipment Type

Equipment Type	$SEER_{exist}$
PTAC	7.4 SEER
PTHP	7.4 SEER
SPVAC < 65kBtu/hr	9.0 SEER
SPVHP < 65 kBtu/hr	9.0 SEER
Room AC	7.0 SEER
Ducted ASHP	13.0 SEER
No existing system	No cooling savings.

EFLHcool = Equivalent full load hours for cooling; depends on location (see Table 20)

Table 20. Estimate of FLH_{RoomAC} by Climate Zone

Climate Zone (City based upon)	FLH_{RoomAC}
1 (Rockford)	220
2 (Chicago)	210
3 (Springfield)	319
4 (Belleville)	428
5 (Marion)	374
Weighted Average	248

EER_exist = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)
= Use actual EER rating otherwise

Table 21. Estimate of EERexist for Demand Savings

Equipment Type	EER_{exist}
PTAC	8.1EER
PTHP	8.1EER
SPVAC < 65kBtu/hr	9.9 EER
SPVHP < 65 kBtu/hr	9.9 EER
Room AC	7.7 EER
Ducted ASHP	11.2 EER
No existing system	

EER_ee = Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)
= Actual, If not provided convert SEER to EER using this formula:

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 72%

Programmable Thermostat

The evaluation team calculated the unit savings for a programmable thermostat using the IL-TRM 2.0.

Equation 2. Programmable Thermostat Unit Savings

$$\Delta kWh = \%ElectricHeat * Elec\_Heating\_Consumption * Heating\_Reduction * HF * Eff\_ISR$$

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric = 100%

Elec_Heating_Consumption = Estimate of annual household heating consumption for electrically heated family homes.

Table 22. Electric Heating Consumption

Climate Zone (City Based Upon)	Electric Heat Pump Elec_Heating_ Consumption (kWh)
1 (Rockford)	13,019
2 (Chicago)	12,438
3 (Springfield)	10,652
4 (Belleville)	8,217
5 (Marion)	8,363
Average	**11,822**

Heating_Reduction = Assumed percentage reduction in heating energy consumption due to programmable thermostat
= 6.2%

HF = Household factor, to adjust heating consumption for non-single-family households.

Table 23. Housing Factor for Programmable Thermostat

Household Type	HF
Single-Family	100%
Multifamily	65%
Actual	**Custom**

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and programmed effectively = 100%

Water Heating Measure Algorithms

The evaluation team determined ex post water heating conservation measure savings using the following algorithms.

Equation 1. Showerhead Algorithms

Energy Savings: $\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * SPCD * 365.25 / SPH) * EPG\_electric * ISR$

Demand Savings: $\Delta kW = \Delta kWh / Hours * CF$

Equation 2. Faucet Aerator Algorithms

Energy Savings: $\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * 365.25 * DF / FPH) * EPG\_electric * ISR$

Demand Savings: $\Delta kW = \Delta kWh / Hours * CF$

Where:

%ElectricDHW = 100% for electric water heater

GPM_base = Flow rate of the baseline showerhead/faucet aerator

GPM_low = As-used flow rate of the low-flow showerhead/faucet aerator

Table 24. GPM for Water Heating Measures

Measure	GPM_base	GPM_low
Faucet aerator	1.20	0.94
Showerhead	2.67	1.75

L_base = Average baseline length faucet use per capita for all faucets in minutes

Table 25. L_base for Water Heating Measures

Measure	Minutes
Faucet aerator	9.85
Showerhead	8.20

L_low = Average retrofit length faucet use per capita for all faucets in minutes (same as L_base)

Household = Average number of people in household = 2.56

SPCD = Showers Per Capita Per Day = 0.75

SPH = Showerheads Per Household = 1.79

DF = Drain Factor = 0.795 (unknown location)

FPH = Faucets Per Household = 3.83 (unknown location)

EPG_electric = Energy per gallon of hot water supplied by electric

Table 26. EPG for Water Heating Measures

Measure	EPG_Electric
Faucet Aerator	0.0894
Showerhead	0.1270

ISR = In-Service Rate

Table 27. ISR for Water Heating Measures

Measure	ISR
Faucet Aerator	95%
Showerhead	98%

Hours = Annual electric DHW recovery hours

Table 28. Hours for Water Heating Measures

Measure	Hours
Faucet Aerator[a]	45
Showerhead[b]	431
[a] Hours-of-use for single-family with unknown location. [b] Hours-of-use for single-family direct-install.	

CF = Coincidence Factor for electric load reduction

Table 29. CF for Water Heating Measures

Measure	CF
Faucet Aerator	0.0220
Showerhead	0.0278

Lighting Algorithms

The evaluation team determined ex post lighting savings using the following algorithms.

Equation 3. ENERGY STAR Standard and Specialty CFL Algorithms

Energy Savings: $\Delta kWh = ((WattsBase - WattsEE) / 1{,}000) * ISR * HOURS * WHF_e$

Demand Savings: $\Delta kW = ((WattsBase - WattsEE) / 1{,}000) * ISR * WHFd * CF$

Where:

WattsBase = Wattage of existing equipment

WattsEE = Wattage of installed equipment

Table 30. Wattages for Lighting Measures

Measure	Baseline Wattage	Efficient Wattage
CFL—Low 14W	43	14
CFL—Medium 19W	53	19
CFL—High 23W	72	23
Specialty CFL—9W Candelabra	40	9
Specialty CFL—14W Globe	60	14
Specialty CFL—15W Reflector	65	15

ISR = In-service rate = 96.9%

HOURS = Annual operating hours

Table 31. Annual Hours-of-use for Lighting Measures

Measure	Hours
Standard CFL (Spiral)	938
Specialty CFL (Globe)	1,240
Specialty CFL (Candelabra)	1,328
Specialty CFL (Interior Reflector)	938

WHF_e = Waste heat factor for energy (accounts for cooling savings from efficient lighting)
= 1.06

WHF_d = Waste heat factor for demand (accounts for cooling savings from efficient lighting)
= 1.11

CF = Summer Peak Coincidence Factor

Table 32. Coincidence Factors for Lighting Measures

Measure	CF
Standard CFL (Spiral)	0.095
Specialty CFL (Globe)	0.116
Specialty CFL (Candelabra)	0.122
Specialty CFL (Interior Reflector)	0.095

Lighting Measures Heating Penalty

The evaluation team determined heating penalties for electric-heated homes using the following algorithms.

Equation 4. Heating Penalty Algorithms

Heating Energy Savings: $\Delta kWh = -(((WattsBase - WattsEE) / 1{,}000) * ISR * HOURS * HF) / \eta Heat$

Where:

WattsBase = Wattage of existing equipment

WattsEE = Wattage of installed equipment

Table 33. Wattages for Lighting Measures

Measure	Baseline Wattage	Efficient Wattage
CFL - Low 14W	43	14
CFL - Medium 19W	53	19
CFL - High 23W	72	23
Specialty CFL – 9W Candelabra	40	9
Specialty CFL – 14W Globe	60	14
Specialty CFL – 15W Reflector	65	15

ISR = In-service rate = 96.9%

HOURS = Annual operating hours

Table 34. Annual Hours-of-use for Lighting Measures

Measure	Hours
Standard CFL (Spiral)	938
Specialty CFL (Globe)	1,240
Specialty CFL (Candelabra)	1,328
Specialty CFL (Interior Reflector)	938

HF = Heating Factor = .49

ηHeat = Efficiency of Heating equipment (Assumed 1.0 COP for electric resistance heating)

The evaluation team determined ex post water heating conservation measure savings using the following algorithms.

Equation 5. Showerhead Algorithms

Energy Savings: $\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * SPCD * 365.25 / SPH) * EPG\_electric * ISR$

Demand Savings: $\Delta kW = \Delta kWh / Hours * CF$

Therm Savings: $\Delta Therms = \%FossilDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * SPCD * 365.25 / SPH) * EPG\_gas * ISR$

Equation 6. Faucet Aerator Algorithms

Energy Savings: $\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * 365.25 * DF / FPH) * EPG\_electric * ISR$

Demand Savings: $\Delta kW = \Delta kWh / Hours * CF$

Therm Savings: $\Delta Therms = \%FossilDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * Household * 365.25 * DF / FPH) * EPG\_gas * ISR$

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 showerhead/faucet aerator

GPM_low = As-used flow rate of the low-flow showerhead/faucet aerator

Table 35. GPM for Water Heating Measures

Measure	GPM_base	GPM_low
Faucet aerator	1.20	0.94
Showerhead	2.67	1.75

L_base = Average baseline length faucet use per capita for all faucets in minutes

Table 36. L_base for Water Heating Measures

Measure	Minutes
Faucet aerator	9.85
Showerhead	8.20

L_low = Average retrofit length faucet use per capita for all faucets in minutes (same as L_base)

Household = Average number of people in household = 2.56

SPCD = Showers Per Capita Per Day = 0.75

SPH = Showerheads Per Household = 1.79

DF = Drain Factor = 0.795 (unknown location)

FPH = Faucets Per Household = 3.83 (unknown location)

EPG_electric = Energy per gallon of hot water supplied by electric

EPG_gas = Energy per gallon of hot water supplied by gas

Table 37. EPG for Water Heating Measures

Measure	EPG_electric	EPG_gas
Faucet Aerator	0.0894	0.0040
Showerhead	0.1270	0.0054

ISR = In-Service Rate[13]

Table 38. ISR for Water Heating Measures

Measure	ISR
Faucet Aerator	96%
Showerhead	96%

Hours = Annual electric DHW recovery hours

Table 39. Hours for Water Heating Measures

Measure	Hours
Faucet Aerator[a]	45
Showerhead[b]	431

[a] Hours-of-use for single-family with unknown location.
[b] Hours-of-use for single-family direct-install.

CF = Coincidence Factor for electric load reduction

[13] ISR calculated using PY6 survey data.

Table 40. CF for Water Heating Measures

Measure	CF
Faucet Aerator	0.0220
Showerhead	0.0278

Air Sealing Algorithms

The evaluation team determined ex post air sealing savings using the following algorithms.

Equation 7. Air Sealing Algorithms

Energy Savings: $\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating)$

$$\Delta kWh\_cooling = [(((CFM50\_existing - CFM50\_new)/N\_cool) * 60 * 24 * CDD * DUA * 0.018) / (1{,}000 * \eta Cool)] * LM$$

$$\Delta kWh\_heating\ (electric\ heat) = (((CFM50\_existing - CFM50\_new)/N\_heat) * 60 * 24 * HDD * 0.018) / (\eta Heat * 3{,}412)$$

Demand Savings: $\Delta kW = (\Delta kWh\_cooling / FLH\_cooling) * CF$

Where:

CFM_existing = Infiltration at 50 Pascals as measured by blower door before air sealing

CFM_new = Infiltration at 50 Pascals as measured by blower door after air sealing

N_Cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions = 18.5 for zones 1-2 and 21.5 for zones 3-5

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

Table 41. Cooling Degree Days by Climate Zone

Climate Zone	CDD 65
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

DUA = Discretionary Use Adjustment = 0.75

ηCool = SEER of cooling system

Table 42. ηCool for Air Sealing Measures

Age of Equipment	ηCool (Pre 2006)	ηCool (Post 2006)
SEER	10	13

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

Table 43. Latent Multiplier by Climate Zone

Climate Zone	Latent Multiplier
1 (Rockford)	8.5
2 (Chicago)	6.2
3 (Springfield)	6.6
4 (Belleville)	5.8
5 (Marion)	6.6

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions = 18.5 for zones 1-2 and 21.5 for zones 3-5

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

Table 44. HDD by Climate Zone

Climate Zone	HDD 65
1 (Rockford)	6,569
2 (Chicago)	6,339
3 (Springfield)	5,497
4 (Belleville)	4,379
5 (Marion)	4,476

ηHeat = Efficiency of heating system = 1

FLH_cooling = Full Load Hours of air conditioning (applied per participant based on project location)

Table 45. FLH_cooling by Climate Zone

Climate Zone	FLH_Cooling Single-Family
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Coincidence Factor = 0.915

Wall and Ceiling Insulation Algorithms

The evaluation team determined *ex post* ceiling and wall insulation savings using the following algorithms.

Equation 8. Ceiling and Wall Insulation Algorithms

Energy Savings: $\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating) * ADJ$

$\Delta kWh\_cooling = [((1/R\_old - 1/R\_wall) * A\_wall * (1\text{-}Framing\_factor) + (1/R\_old - 1/R\_attic) * A\_attic * (1\text{-}Framing\_Factor/2)) * 24 * CDD * DUA)] / (1{,}000 * \eta Cool)$

$\Delta kWh\_heating\ (electric\ heat) = [(1/R\_old - 1/R\_wall) * A\_wall * (1\text{-}Framing\_factor) + (1/R\_old - 1/R\_attic) * A\_attic * (1\text{-}Framing\_Factor/2)) * 24 * HDD] / (\eta Heat * 3{,}412)$

Demand Savings: $\Delta kW = (\Delta kWh\_cooling / FLH\_cooling) * CF$

Where:

ADJ = assumed to be 100%

R_wall = Total wall assembly R-value

R_attic = Total attic assembly R-value

R_old = R-value of existing attic or wall assembly and any existing insulation with a minimum of R-5

A_wall = Total area of insulated wall (ft^2)

A_attic = Total area of insulated attic (ft^2)

Framing_factor = Adjustment to account for area of framing = 0.15

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

Table 46. 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

ηCool = SEER of cooling system (actual if available, 10 SEER if unknown) (used age of existing equipment pre 2006)

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

Table 47. HDD by Climate Zone

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

Climate Zone	HDD
4 (Belleville)	3,378
5 (Marion)	3,438

HHeat = Efficiency of heating system (applied based on electric resistance heat type COP = 1)

FLH_cooling = Full Load Hours of air conditioning (applied per participant based on project location)

Table 48. FLH_cooling by Climate Zone

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

CF = Coincidence Factor = 0.915

Rim Joist Insulation Algorithms

The evaluation team calculated the ex post rim joist insulation savings using the following algorithms. As the IL-TRM does not include specific algorithms for rim joists, the team used basement sidewall insulation algorithms.

Equation 9. Rim Joist Insulation Algorithms

Energy Savings: $\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating) * ADJ$

$\Delta kWh\_cooling = (((1/R\_old\_AG - (1/(R\_added + R\_old\_AG))) * L\_rimjoist * H\_rimjoist * (1\text{-}Framing\_factor)) * 24 * CDD * DUA) / (1{,}000 * \eta Cool)$

$\Delta kWh\_heating\ (electric\ heat) = (((1/R\_old\_AG - (1/(R\_added + R\_old\_AG))) * L\_rimjoist * H\_rimjoist * (1\text{-}Framing\_factor)) * 24 * HDD) / (3{,}412 * \eta Heat)$

Demand Savings: $\Delta kW = (\Delta kWh\_cooling / FLH\_cooling) * CF$

Where:

ADJ = Assumed to be 100%

R_old_AG = R-value of existing foundation wall assembly above grade = R-2.25

R_new = R-value of added insulation (spray foam, rigid foam, cavity) = R-11

L_rimjoist = Total linear feet of installed rim joist insulation (ft)

H_rimjoist = Height of floor joist in which rim joist insulation is installed = 1.0 ft

Framing_factor = Adjustment to account for area of framing; FF = 0.0 for spray foam

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

Table 49. Cooling Degree Days by Climate Zone for Unconditioned Basement

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

DUA = Discretionary Use Adjustment = 0.75

ηCool = SEER of cooling system (10 SEER)

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

Table 50. HDD by Climate Zone for Unconditioned Basement

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

ηHeat = Efficiency of heating system (COP = 1)

FLH_cooling = Full Load Hours of air conditioning (applied per participant based on project location)

Table 51. FLH_cooling by Climate Zone

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

CF = Coincidence Factor = 0.915

Crawlspace Insulation Algorithms

The evaluation team calculated ex post crawlspace insulation savings using the following algorithms.

Equation 10. Crawlspace Insulation Algorithms

Energy Savings: $\Delta kWh = (\Delta kWh\_cooling + \Delta kWh\_heating) * ADJ$

$$\Delta kWh\_cooling = (((1/R\_old\_AG - (1/(R\_added + R\_old\_AG))) * LF * H\_AG * (1\text{-}Framing\_factor)) * 24 * CDD * DUA) / (1{,}000 * \eta Cool)$$

$$\Delta kWh\_heating\ (electric\ heat) = [(((1/R\_old\_AG - (1/(R\_added + R\_old\_AG))) * LF * H\_AG * (1\text{-}Framing\_factor)) + ((1/R\_old\_BG - (1/R\_added + R\_old\_BG))) * LF * H\_BG * (1\text{-}Framing\_Factor))) * 24 * HDD] / (3{,}412 * \eta Heat)$$

Demand Savings: $\Delta kW = (\Delta kWh\_cooling / FLH\_cooling) * CF$

Where:

ADJ = Assumed to be 100%

R_old_AG = Above grade existing R-value of crawlspace insulation = 2.25

R_old_BG = Below grade existing R-value of crawlspace insulation (assume 2' below grade) = 6.66

R_added = R-value of additional insulation (spray foam)

LF = Total linear feet of installed insulation (ft^2) (from database)

H_AG = Height of crawlspace wall above grade = 1 foot

H_BG = Height of crawlspace wall below grade = 2 feet

Framing_factor = Adjustment to account for area of framing = 0

CDD = Cooling Degree Days (assumed unconditioned (vented) crawlspace) (applied per participant based on project location)

Table 52. CDD by Climate Zone for Unconditioned (Vented) Crawlspace

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

DUA = Discretionary Use Adjustment = 0.75

ηCool = SEER of cooling system (10 SEER)

HDD = Heating Degree Days (assumed unconditioned (vented) crawlspace) (applied per participant based on project location)

Table 53. HDD by Climate Zone for Unconditioned (Vented) Crawlspace

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

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

ηHeat = Efficiency of heating system (COP = 1)

FLH_cooling = Full Load Hours of air conditioning (applied per participant based on project location)

Table 54. FLH_cooling by Climate Zone

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

CF = Coincidence Factor = 0.915

Water Heater Temperature Setback Algorithms

The evaluation team calculated ex post water heater temperature setback savings using the following algorithms.

Equation 11. Water Heater Temperature Setback Algorithms (Electric Water Heater)

Energy Savings: *ΔkWh = 86.4 kWh (Deemed value)*

*Demand Savings: ΔkW = ΔkWh / Hours * CF*

Where:

Hours = Annual Hours-of-use in which water heater is operating or idle = 8,766 hours

CF = Coincidence Factor = 1.0

Appendix D. Data Collection Instruments


AEH Data Collection.pdf

For more information, please contact:

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