Impact and Process Evaluation of 2012 (PY5) Ameren Illinois Company Home Energy Performance Program

Final

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TABLE OF CONTENTS

Table of Tables

TABLE OF FIGURES

1. Executive Summary

As a part of its residential ActOnEnergy portfolio, Ameren Illinois Company (AIC) administers the Home Energy Performance (HEP) Program, which includes a smaller component called the Electric Space Heat Pilot (ESHP). This report presents results from the evaluation of the fifth program year (PY5) (June 2012 to May 2013) of the HEP Program.[1]

The HEP Program is a home energy diagnostic offering audits to all AIC residential customers, and retrofits to customers with AIC heating fuel. . The Program offers audits, direct install measures, and incentives for additional energy efficiency opportunities. In PY5, the HEP Program reached a total of 4,152 participants[2]. The ESHP, a home diagnostic component of HEP focused on older homes with electric space heat, went on hiatus for much of PY5 because two Energy Advisors were assigned to Project Storm, a tornado restoration project that focused on home energy efficiency. In PY5, there were 26 ESHP participants.

Conservation Services Group (CSG) implements the program, which provides a small percentage of AIC's annual savings. The expected annual savings from this program were 1% of the overall portfolio of electric savings and 2% of the overall portfolio of therm savings (including both residential and commercial).

In PY5, we conducted an impact and a limited process evaluation. To support the process evaluation, we reviewed program materials and program-tracking data, and conducted interviews with implementation and AIC staff. Overall, the team used two approaches to estimate impacts: an engineering analysis for the determination of PY5 program impacts, and a billing analysis to provide information on the accuracy of engineering estimates in the TRM (2012).[3]

Impact Results

The primary objective of this evaluation was to estimate the energy-savings impacts from installing HEP measures. For the engineering analysis, we applied 2012 Technical Reference Manual (TRM) savings algorithms using program-tracking database inputs and the PY3 HEP Program measure-specific net-to-gross ratios (NTGRs) to determine PY5 net savings. Table 1 provides net impacts for the HEP program.

[1] While this is the fifth year of the program, the first year was very small, starting in March of 2009 with a few audits.

[2] The ESHP Program includes 26 households.

[3] State of Illinois: Energy Efficiency Technical Reference Manual. Final as of September 14, 2012. Effective June 1, 2012.

Table 1. PY5 HEP and ESHP Program Net Impacts

Program Component	# of Participants	Ex Ante Net			Ex Post Net		
		kWh	kW	Therms	kWh	kW	Therms
HEP Program	4,126	4,113,163	2,581	714,434	4,000,225	2,856	690,864
ESHP Program	26	50,111	2.03	19.15	41,610	9.64	18.91
Total	**4,152**	**4,163,274**	**2,583**	**714,454**	**4,041,835**	**2,866**	**690,883**
				Net Realization Rate	**97%**	**111%**	**97%**

Process Results

Overall, the HEP Program was implemented according to its design, with several minor changes in PY5. Some changes were the result of unprecedented program growth, while other changes reflected the program's long-term objective of becoming a Home Performance with ENERGY STAR® (HPwES) provider.

In PY5, the program moved closer toward its goal of becoming an HPwES program. In particular, the program underwent several minor implementation modifications, including providing HPwES certifications; rebranding program forms with HPwES logos and language; revising intake forms and incentive applications to gather data points to support HPwES qualifications; and changing measures and/or incentive levels to support HPwES standards.

According to program staff, the program experienced unanticipated and unprecedented program growth in terms of projects and measures installed. In PY5, the proportion of participants who retrofitted their homes via program ally-driven sales increased over the PY4 proportion, resulting in more envelope-measures installed than anticipated. In addition, PY4 measure and incentive levels were maintained moving into PY5, which proved to be more costly than the values used for PY5 planning purposes. This growth required program staff to change measure offerings and incentives midyear in an attempt to control program costs and stay within budget.

This unanticipated growth caused some challenges for trade allies and the AIC customers they serve, as program costs overtook expected budget. At first, program staff did not have a system in place to track pending projects and the associated incentive dollars. As such, staff were unable to communicate to program allies that limited incentive dollars were available, and program allies continued to sell retrofits as the year progressed. To manage program costs and pre-approve incentives before they are committed, program staff instituted a reservation system for incentives as well as monthly envelope-measure production caps to regulate this growth in program ally-driven sales. The new reservation system allows incentives to be tracked prior to approval and expenditure. In PY6, program staff anticipate using the reservation system to ensure that incentive status is clear for contractors and customers.

Recommendations

The evaluation team used two analytical approaches to derive program impacts. The first was an engineering analysis to estimate program impacts (Table 1), and the second was a billing analysis[4] to provide inputs for future planning efforts.

While the engineering estimates show realization rates very close to 100%, from the billing analysis we found that the HEP Program achieved approximately one-third of anticipated *ex ante* gas net savings, and approximately one-half of *ex ante* electric net savings.[5] We cannot state for certain why there is a discrepancy between the *ex ante* engineering estimates and the billing analysis. After exploring the *ex ante* data and looking closely at the TRM algorithms, we hypothesize that this occurred because of higher-than-expected efficiency in the heating units within homes, and differences in behavioral and household characteristics, including possible take-back (where the participant now has a less drafty home and therefore increases the use of their heating system). However, there is no way to pinpoint the reasons for these differences.

Given the unexpected and low results from the billing analysis, our recommendations are specific to next year's evaluation:

- Consider conducting a second year of billing analysis. A second year of billing analysis will provide additional observations and a wider range of participants from which to refine impact findings. More specifically, we expect that program participants, program offerings, and measure uptake all vary from year to year.
- If there is sufficient budget, a calibrated engineering model could be used in addition to the billing analysis as a second approach to estimating program impacts. Within this approach, an engineering prototypical home model is created that is then calibrated to the actual use of the HEP participants. It is a different approach than billing analysis, but both take advantage of actual data. Additionally, within a calibrated model, savings from individual measures can be drawn out of the overall results.
- The evaluation team is currently planning to perform in-home lighting audits this summer for a representative group of AIC customers. If that plan is agreed to and moves forward, we can expand our data collection to other pieces of equipment, such as furnaces, to support any explanation for the billing analysis results.

[4] The evaluation team conducted a fixed effects linear model incorporating a treatment group of PY4 program participants and a comparison group of PY5 program participants prior to their participation in the PY5 program.

[5] *Ex ante* net savings are based on TRM algorithms and the application of an NTGR.

2. INTRODUCTION

This report presents results from the evaluation of the fifth program year (PY5) of the AIC Home Energy Performance (HEP) Program. In PY5, we conducted impact evaluation, as well as a limited process evaluation. To support the process evaluation, we reviewed program materials and program-tracking data, and conducted interviews with implementation and AIC staff. Our impact analysis effort included an engineering desk review and billing analysis for HEP participants, which estimated program and measure category net electric and gas savings.[6]

Program Description

The HEP Program is a home energy diagnostic and retrofit program offered to AIC's residential customers. It offers audits, direct install measures, and incentives for additional energy efficiency opportunities. Customers can participate in the program either by receiving an audit from a HEP Energy Advisor (CSG-driven approach) and then engaging home contractor services, or by working with program allies outside of the program's audit process (program ally-driven approach).

In the CSG-driven approach, a CSG Energy Advisor conducts a "HEP audit" of the participant's home, and installs instant-savings measures (ISMs) such as CFLs and domestic hot water (DHW) measures. According to AIC staff, throughout the HEP audit, auditors educate the homeowner on savings possible through shell measures such as air sealing and wall and attic insulation, in addition to the overall energy-savings potential available through all ActOnEnergy incentive programs. Auditors also recommend HEP program allies (AIC-approved, Building Performance Institute (BPI)-certified insulation contractors) that offer incentives and install shell measures. In the program ally-driven approach, HEP program allies market the program to eligible customers, and then provide diagnostic testing to customers with recommendations for their home. Program allies then install selected energy efficiency measures (air sealing and insulation) in the customers' homes.

The HEP Program also focuses on developing a local home performance industry, and is in the process of transforming into a more comprehensive Home Performance with ENERGY STAR® (HPwES) program. This transformation included expanding services statewide, aligning measures offered to Department of Energy standards, and co-branding services. The HEP Program is further developing the local contractor network in Illinois by providing incentives for BPI certification of support staff of existing program allies.

The Electric Space Heat Pilot (ESHP), a home diagnostic program focused on older homes with electric space heat, was placed on hiatus in PY5 because two of the pilot's main Energy Advisors were assigned to Project Storm, a tornado restoration project that focused on home energy efficiency. As a result, 26 ESHP households completed projects in PY5. ESHP customers receive program services that are identical to non-electric space heating customers, with two exceptions. These customers have a dedicated program implementer in CSG, and—depending on homeowner eligibility and permission—are provided blower door-assisted air sealing of the home by a team of specially trained air-sealing technician.

[6] We conducted an engineering desk review only for ESHP participants given the small number of participants in PY5.

Table 2 below provides a summary of HEP and ESHP offerings.

Table 2. Summary of HEP and ESHP Offerings

Program Description	HEP	ESHP
Audit Description	Installation of CFLs and water conservation measures (high-efficiency showerheads and faucet aerators), a thermal scan of the house using an infrared camera, and development of a recommended work order	Energy audit and blower door-assisted air sealing—can include installation of CFLs and water conservation measures (high-efficiency showerheads and faucet aerators), a thermal scan of the house using an infrared camera, development of a recommended work order, and air sealing
Audit Duration	2 hours	3 to 3.5 hours
Audit Cost	$50	No cost, although in June raised cost to $50
Measures Installed during Audit	CFLs, faucet aerators, low-flow showerheads	CFLs, faucet aerators, low-flow showerheads, blower door-assisted air sealing
Measures recommended for incentives	All ActOnEnergy incentives are recommended as appropriate including HEP, HVAC, Appliance Recycling and EE rebates (these may include duct and air sealing, additional attic and/or wall insulation, programmable thermostats, HVAC equipment replacement, and water heater replacement)	All ActOnEnergy incentives are recommended as appropriate including HEP, HVAC, Appliance Recycling and EE rebates (these may include duct and air sealing, additional attic and/or wall insulation, programmable thermostats, HVAC equipment replacement, and water heater replacement
Target audience	Audits are offered to all residential customers. Shell measure incentives are offered only to customers heating with an AIC approved fuel.	AIC customers in existing homes with electric heat

Research Objectives

The objective of the PY5 Home Energy Performance Program evaluation is to provide estimates of gross and net electric and gas savings associated with the program. The evaluation team also explored a limited number of process-related research questions.

The impact evaluation answers the following research question:

1. What are the gross and net energy savings impacts from the programs?

In addition, the evaluation explores a limited number of process-related research questions:

1. Are the programs implemented according to design?
2. What implementation challenges have occurred in PY5 and how have they been overcome?
3. Have there been any changes to program design and implementation from PY4? If so, how, and why?

3. Evaluation Methods

In this section, we provide a summary of the evaluation activities conducted, and methods used, for the PY5 Home Energy Performance (HEP) Program and Electric Space Heat Pilot (ESHP). Our efforts included both a process and impact evaluation.

We evaluated the HEP and ESHP customers differently, given the limited number of ESHP participants (26 participants) and differences related to their household characteristics. For HEP customers, we conducted a billing analysis to quantify the effects of actions taken. For ESHP customers, we conducted an engineering desk review.

3.1 Data Sources and Analytical Methods

Table 3 provides a summary of the evaluation methods used for the PY5 evaluation.

Table 3. Summary of Evaluation Methods

Task	HEP	ESHP	Details
Program Materials Review	X	X	We reviewed program materials—including program design, implementation plans, marketing and outreach efforts, market actor training materials, and program databases—to assess program implementation and provide recommendations for improvement, where applicable.
Interviews with Program Staff and Implementers	X	X	We conducted interviews with the AIC program manager and CSG program manager in PY5 to understand the program's design, implementation, and evaluation priorities.
Participant Database Analysis	X	X	We assessed program participation and measure installation as an input to the impact evaluation.
Engineering Review	X	X	We conducted an engineering analysis for all participants.
Billing Analysis	X		For HEP participants, we conducted a billing analysis to quantify the effects of actions taken among the treatment and comparison group members.
Comparison Group Selection	X		We used PY5 participants as a comparison group for the billing analysis, assessing their equivalency as a comparison group prior to estimating net program impacts.

Data sources for evaluating the HEP Program and ESHP include:

- Information on key program efforts and dates gathered through stakeholder interviews
- Program-tracking databases and *ex ante* savings for PY4 and PY5 participants
- 2012 Illinois Statewide Technical Reference Manual (2012 TRM)[7]

[7] State of Illinois: Energy Efficiency Technical Reference Manual. Final as of September 14, 2012. Effective June 1, 2012.

- Electric and gas billing usage data for all PY4 treatment and PY5 comparison group customers
- Weather data (Heating Degree Days and Cooling Degree Days) from AIC as well as normalized weather for Springfield from the TRM (Version 1) to predict average daily net savings among PY4 participants in each billing analysis model
- Measure-specific net-to-gross ratios (NTGRs) from the evaluation of the PY3 HEP Program

3.1.1 Process Analysis

Process evaluation activities in PY5 were limited, as the primary evaluation task for this year was the impact analysis. The evaluation team conducted two in-depth interviews with program managers from CSG and AIC to help understand areas of success, challenges to success, and insights into the daily workings of the program. Interviews also sought to determine whether the programs were implemented according to design, if there had been any changes to program design and implementation from PY4, and if any implementation challenges occurred in PY5.

3.1.2 Impact Analysis

The primary objective of this evaluation was to estimate the energy-savings impacts from installing measures. Overall, the team used two approaches: one for the determination of PY5 program impacts, and a second to provide information on the accuracy of engineering estimates in the TRM. We outline these below.

Engineering Analysis and Application of Deemed Savings

To determine gross impacts associated with the Home Energy Performance Program, we conducted a review of the program-tracking database and verified the correct application of the Statewide TRM. The impact evaluation efforts estimated gross impact savings for the HEP participants by applying savings algorithms from the 2012 Illinois Statewide TRM to the information in the program-tracking database. The algorithms used to calculate all evaluated program savings are outlined in Appendix B, along with all input variables. We applied the PY3 HEP Program measure-specific net-to-gross ratios (NTGRs) to the gross savings to obtain PY5 HEP Program net savings. Note that the engineering review and application of deemed savings was conducted for both HEP and ESHP[8] participants.

Billing Analysis

We conducted a billing analysis of HEP program savings to estimate net program impacts. Given that the evaluation research design supported a billing analysis that directly yielded net impacts, no NTGR was involved in determining net impacts. This approach provides context to the engineering values calculated from assumptions in the TRM and NTGRs, helping to identify areas where further primary data collection efforts can improve accuracy of underlying engineering

[8] We applied the PY3 HEP Program measure-specific net-to-gross ratios (NTGRs) to the ESHP gross savings to obtain PY5 net savings. We decided to apply these ratios because ESHP had no primary data collection and is embedded within HEP.

assumptions.[9] Due to the small population of ESHP participants (26 homes), we did not include them in the billing analysis. Rather, the evaluation team incorporated them into the engineering desk review.

Because a billing analysis is best conducted on both a complete year of billing data before the installation of measures and a complete year of billing data after the installation of measures, the evaluation team conducted the analysis in PY5 using PY4 participants as the treatment group. As such, the evaluation effort focused on estimating PY4 impacts, and applying those findings to PY5 participants. In addition, given that some customers are dual-fuel customers, the evaluation estimated both electric and gas savings.

[9] Note that this analysis excludes ESHP participants given the low number of households (n=26) and their unique household characteristics.

4. Results and Findings

4.1 Process Findings

The process evaluation effort explored the following research objectives: 1) whether the program was implemented according to design; 2) what changes, if any, occurred to program design and implementation compared to PY4; and 3) whether there were any implementation challenges in PY5.

Program Design Changes

Overall, the HEP Program was implemented according to its design. The program made several minor design changes in PY5. Some changes were the result of unprecedented program growth, while other changes reflected the program's long-term objective of becoming a Home Performance with ENERGY STAR® (HPwES) provider.

In PY5, the program moved closer toward its goal of becoming an HPwES program. In particular, the program underwent several minor implementation modifications, including providing HPwES certifications; rebranding program forms with HPwES logos and language; revising intake forms and incentive applications to gather data points to support HPwES qualifications; and changing measures and/or incentive levels to support HPwES standards. Other minor program design changes included revising contractor training efforts by removing building envelope and audit training, and offering Building Performance Institute (BPI) certification incentives exclusively to existing allies who add additional staff. The incentives do not apply to existing staff recertification or to new program allies. In addition, customer targets shifted away from recruiting for the Electric Space Heat Pilot (ESHP), as two Energy Advisors were assigned to Project Storm, a tornado restoration project focused on home energy efficiency.

According to program staff, the HEP Program experienced unanticipated and unprecedented program growth in terms of projects and measures installed. In PY5, the proportion of participants (39%) who participated in the program by working directly with a program ally (1,500 retrofit-only participants) increased over the PY4 proportion (30%, 1,398 retrofit-only participants). Notably, program ally-driven participants install envelope measures, while CSG-driven participants may only install instant-savings measures (ISMs). In addition, PY4 measure and incentive levels were maintained moving into PY5, which proved to be more costly than the values used for PY5 planning purposes. This growth required program staff to change measure offerings and incentives midyear in an attempt to control program costs and stay within budget.

This unanticipated growth caused some challenges for trade allies and the AIC customers they serve, as program costs overtook expected budget. At first, program staff did not have a system in place to track pending projects and the associated incentive dollars. As such, staff were unable to communicate to program allies that limited incentive dollars were available, and program allies continued to sell retrofits as the year progressed. To manage program costs and pre-approve incentives before they are committed, program staff instituted a reservation system for incentives as well as monthly envelope-measure production caps to regulate this growth in program ally-driven sales. The new reservation system allows incentives to be tracked prior to approval and expenditure. In PY6, program staff anticipate using the reservation system to ensure that incentive status is clear for contractors and customers.

In keeping with our research objectives defined above, we use Table 4 to note implementation changes from PY4 to PY5.

Table 4. Program Design and Implementation Changes in PY5

Design Element	Description [(a)]	Overview of PY5 Change
Transform into a Comprehensive HPwES Program	<u>Moving Toward HPwES:</u> Since program inception, CSG has focused on developing a local home performance industry and transforming the program into a more comprehensive HPwES program. <u>Program Ally-Driven Sales</u>: Program allies may recruit and provide retrofit services to AIC customers outside of the audit component. In these cases, the contractors contact the program to pre-qualify the customers and confirm eligibility. Contractors then discount the relevant incentives from the work invoice. <u>HPwES Training:</u> In PY4, the HEP Program focused on developing the local contractor network in Illinois through facilitating BPI certification and other whole-building science training. In PY4, the program provided incentives of $750 to trade allies who became BPI-certified.	<u>Moved Closer to HPwES Program:</u> In PY5, the program moved closer to being an HPwES program and was approved as a HPwES certificate provider.[(b)] As program allies further developed their home performance capacity in PY5, the program took several steps in preparation for transitioning to an HPwES program in PY6, including: • Providing HPwES certifications through sponsors Midwest Energy Efficiency Association and the Illinois Department of Commerce and Economic Opportunity [(c)] • Rebranding program forms with HPwES logos and language • Revising intake forms and incentive applications to gather data points to support HPwES qualifications • Changing measures/incentive levels to support HPwES standards during PY5 • Orienting and facilitating training of allies on the HPwES program <u>Increased Program Ally-Driven Sales</u>: In PY5, there was a significant influx of non-audit projects submitted by HEP program allies. This is consistent with the program's long-term goal of establishing a local home performance industry and transforming the program into a more comprehensive HPwES program. <u>Supported Trade Ally BPI Certification:</u> In PY5, the program adopted a "depth over breadth" approach and only offered the incentive to additional staff of existing BPI-certified trade allies. In doing so, the program sought to assist allies in adding certified staff.
Measures Offered and Incentive Levels	<u>Measures Offered</u>: The program offers a $50 energy audit to customers. The audit includes a thermal scan, and during the audit the Energy Advisor may install free CFLs and/or water conservation measures. The audit produces a list of recommended and incented retrofit measures, including duct and air sealing; additional attic, wall, and /or rim joist insulation; programmable thermostats; and HVAC equipment and water heater replacement.	<u>Changed Measure Mix:</u> Due to unanticipated program growth and an attempt to control program costs, the program made slight measure changes midyear (as indicated in the program's amended implementation plan, including removing the R19 to R49 attic insulation and adding rim joist insulation). <u>Decrease in Incentive Levels:</u> Due to unanticipated program growth and an attempt to control program costs, the program twice decreased incentive levels—once on September 1, 2012, and again on December 15, 2012. By the end of PY5, both the number of incentive dollars per unit and the maximum incentives for

Design Element	Description (a)	Overview of PY5 Change
		air sealing and insulation measures decreased compared to initial PY5 levels. In addition, CSG implemented an incentive reservation system. On-Bill Financing: Beginning in PY5, participants could use on-bill financing (OBF) to fund their home efficiency retrofits, an option AIC began offering customers across all ActOnEnergy programs.[d]
Contractor Training	Description of Trade Ally Development: CSG approves contractors who meet several professional criteria (e.g., licenses, insurance, etc.); provides them program orientation training and home performance training; requires BPI-certified technicians (building analysts and envelope professionals); and provides incentives for those who add BPI-certified staff. Building Envelope Training: A PY4 offering for less-experienced contractors, covering air and duct sealing, measurement and reporting on air leakage reduction with a blower door, and proper use of dense-packing equipment for wall insulation. (PY4) Audit Training: A PY4 offering covering program audit procedures, CSG's audit software, data collection, and customer service, in a one-week training curriculum followed by a mentoring program.	Notably, Program staff and staff account managers continually work to facilitate training by working with local training providers to promote upcoming training opportunities to trade allies. In addition account managers often attend portions of the class to promote ActOnEnergy programs. • Removed Building Envelope Training • Removed Audit Training
Target Market	Customer Targets: AIC customers in existing homes heated by electricity or natural gas. For ESHP, the implementation team targets customers living in older, electrically heated homes located in the southern portion of the AIC service territory.	Placed ESHP on Hiatus: ESHP went on hiatus because two Energy Advisors were assigned to Project Storm, a tornado restoration project that focused on home energy efficiency. As a result, only 26 ESHP projects were completed.

[a] Source: Amended Program Implementation Plan "2011-2014 Ameren Residential Programs Home Energy Performance Program PY5 Implementation Plan, Submittal Date: 06/01/12, Amendment 01: 1/25/13."
[b] Source: Program portfolio reports: "HEP PY5 Portfolio Reports."

[c] The Illinois Home Performance is a version of the national Home Performance with ENERGY STAR Program. Gold certificates are awarded for homes retrofitted by participating contractors that meet ASHRAE 62.2 ventilation requirements, decreased infiltration rates, and four of five of metrics related to duct sealing, wall insulation, attic insulation, basement/crawlspace insulation, and heating and cooling equipment. Silver certificates are awarded for decreased infiltration rates, and attic insulation. (As retrieved on 11/14/2013 from source: http://www.actonenergy.com/portals/0/forms/IHPflyer.pdf.)
[d] Source: Interviews with implementation team.

Participation and Conversion Rates

In PY5, the HEP Program reached 4,152 participants, including ESHP participants.[10] Table 5 provides an overview of participation by services received.

Table 5. Overview of PY5 Only Participation by Household and Services Received

Approach	Participant Type	Number of Participants	% of Participants
CSG-Driven	CSG Audit & Program Ally Retrofit	353	9%
	CSG Audit Only	2,041	49%
Program Ally-Driven	Program Ally Retrofit	1,758	42%
	Total	**4,152**	**100%**

In Table 6, we compare conversion rates between PY4 and PY5. Given program design, participants may enter the program in one program year and continue their participation in a following year.

Table 6. PY4 and PY5 Conversion Rates

Approach	Participant Type	PY4 Participants	PY5 Participants
CSG-Driven	CSG Audit & Program Ally Retrofit	321	353
	CSG Audit Only	2,908	2,041
Program Ally-Driven	Program Ally Retrofit	1,398	1,758
	Total	**4,627**	**4,152**
	Conversion Rate [a]	**10%**	**15%**

[a] The conversion rate is calculated by dividing the number of participants who received a retrofit following an audit by the number of participants who received an audit.

Measures Installed

Table 7 below provides an overview of households that received measures and the total number of measures received. Notably, air sealing was the most frequently installed measure, reflecting the high number of program ally-driven projects in which ISMs are typically not installed.

[10] This excludes participants who entered the program in PY4, but installed measures in PY5 as these participants (n=293) were included in the PY4 report.

Table 7. Overview of Participation by PY5 Measure Category
(includes the 26 ESHP Participants)

Measure	Total in PY5 Participant Database		
	Unique Households	Number of Units	Unit
CFL	2,923	17,777	Bulb
Air Sealing	1,984	3,142,321	CFM
Attic Insulation	1,781	2,314,561	SF
Wall Insulation	1,413	1,092,126	SF
Faucet Aerator	1,405	3,291	Aerator
Showerhead	1,377	2,061	Showerhead
Rim Joist Insulation	787	115,101	SF

Program Tracking

As noted above, program incentives were revised midyear in an effort to control program costs. According to program staff, a planning decision was made to move to the TRM algorithms instead of applying evaluated savings values for PY5. However, because the completion of the TRM was delayed and air sealing savings algorithms were not in place until late June/early July, the program maintained PY4 measures and incentives moving into PY5. As a result, per-unit savings values were revised at varied times for different measures, as shown in Table 8.

Table 8. PY5 HEP Measure and Incentive Level Changes

<table>
<tr><th rowspan="2">Measure</th><th colspan="2">Incentive Levels through September 15, 2012</th><th colspan="2">Incentive Levels September 15 – December 15, 2012</th><th colspan="2">Incentive Levels December 15, 2012, Onward</th></tr>
<tr><th>Incentive Rate</th><th>Maximum</th><th>Incentive Rate</th><th>Maximum</th><th>Incentive Rate</th><th>Maximum</th></tr>
<tr><td>Air Sealing</td><td>$0.50 per CFM</td><td>$1,200</td><td>$0.50 per CFM</td><td>$1,200</td><td>$0.30 per CFM</td><td>$600</td></tr>
<tr><td>Attic Insulation R-11 or Less Improved to R-38 or Greater</td><td>$0.70 per SF</td><td rowspan="2">$1,400</td><td>$0.50 per SF</td><td rowspan="2">$1,400</td><td>$0.40 per SF</td><td>$600</td></tr>
<tr><td>Attic Insulation R-12 to R-19 Improved to R-49 or Greater</td><td>$0.50 per SF</td><td>$0.50 per SF</td><td colspan="2">Not offered</td></tr>
<tr><td>Wall Insulation</td><td>$1.20 per SF</td><td>$2,400</td><td>$1.00 per SF</td><td>$2,400</td><td>$0.80 per SF</td><td>$1,000</td></tr>
<tr><td>Rim Joist</td><td colspan="2">Not offered</td><td>$1.00 per LF</td><td>$400</td><td>$1.00 per LF</td><td>$320</td></tr>
<tr><td>Maximum Incentive</td><td colspan="2">$5,000</td><td colspan="2">$5,400</td><td colspan="2">$2,520</td></tr>
<tr><td colspan="7">Source: Amended Program Implementation Plan “2011-2014 Ameren Residential Programs Home Energy Performance Program PY5 Implementation Plan, Submittal Date: 06/01/12, Amendment 01: 1/25/13.”</td></tr>
</table>

In addition, we compared the *ex ante* PY3 net-to-gross ratio (NTGR) (i.e., values that AIC expected to apply to PY5 measures) to *ex ante* NTGRs found in the program-tracking database. We found minor differences in the gas NTGR for faucet aerators, showerheads, air sealing, and wall insulation (see Table 9 below).

Table 9. PY5 and Program Database NTGR, by Measure

Measure Description	PY5 Electric		PY5 Gas	
	NTGR*	Program Database NTGR	NTGR*	Program Database NTGR
CFL - 13 to 15 Watt	0.75	0.75	N/A	N/A
CFL - 18 to 20 Watt	0.75	0.75	N/A	N/A
CFL - 23 to 25 Watt	0.75	0.75	N/A	N/A
Faucet Aerators	0.99	0.99	0.99	0.97
Low-Flow Showerheads	0.97	0.97	0.97	0.99
Air Sealing	1	0.995	1.00	1.04
Attic Insulation	N/A	0.93	N/A	0.97
Wall Insulation	0.93	0.93	0.63	0.97
Rim Joist Insulation	N/A	0.93	N/A	0.97
*Source: Electric NTGRs sourced from PY3 HEP Report Table ES-2; Gas NTGRs sourced from PY3 HEP Gas Memo Table 4.				

4.2 Impact Findings

The evaluation team conducted an engineering analysis to derive gross PY5 HEP and ESHP impacts and adjusted these impacts using the PY3 NTGR. The results are provided below.

Table 10. PY5 HEP and ESHP Program Net Impacts

Program Component	# of Participants	Ex Ante Net			Ex Post Net		
		kWh	kW	Therms	kWh	kW	Therms
HEP Program	4,126	4,113,163	2,581	714,434	4,000,225	2,856	690,864
ESHP Program	26	50,111	2.03	19.15	41,610	9.64	18.91
Total	**4,152**	**4,163,274**	**2,583**	**714,454**	**4,041,835**	**2,866**	**690,883**
				Net Realization Rate	**97%**	**111%**	**97%**

Below we provide gross and net impacts by measure and program.

Gross Impacts

We calculated *ex post* gross savings using inputs and algorithms from the 2012 TRM. CSG provided the evaluation team with documentation of the inputs and algorithms that were used to calculate *ex ante* savings (see Table 11 below). The gross realization rate was 97% for electric savings, 111% for demand savings, and 100% for gas savings.

Table 11. PY5 HEP Program Gross Impacts by Measure (Includes ESHP Participants)

Measure	*Ex Ante* Gross Impacts			*Ex Post* Gross Impacts [a]			Gross Realization Rate [b]		
	kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
CFL - 13 to 15 Watt	538,444	57	-	538,988	57	-	100%	100%	NA
CFL - 18 to 20 Watt	170,212	18	-	170,399	18	-	100%	100%	NA
CFL - 23 to 25 Watt	116,750	12	-	116,869	12	-	100%	100%	NA

Measure	*Ex Ante* Gross Impacts			*Ex Post* Gross Impacts [a]			Gross Realization Rate [b]		
	kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
Faucet Aerator - Electric	25,796	3	-	25,794	3	-	100%	100%	NA
Faucet Aerator - Gas	-	-	5,065	-	-	5,062	NA	NA	100%
Showerhead - Electric	146,036	9	-	146,036	9	-	100%	100%	NA
Showerhead - Gas	-	-	26,025	-	-	26,026	NA	NA	100%
Air Sealing	2,473,994	2,124	347,909	2,382,409	2,287	355,275	96%	108%	102%
Attic Insulation	491,617	169	129,160	544,787	259	175,369	111%	154%	136%
Wall Insulation	435,257	238	185,515	392,196	280	152,966	90%	118%	82%
Rim Joist Insulation	60,602	17	20,062	1,235	0.13	-	2%	1%	0%
Total	**4,458,711**	**2,647**	**713,735**	**4,318,714**	**2,926**	**714,698**	**97%**	**111%**	**100%**

Note: Numbers may not total due to rounding.
[a] *Ex post* gross impacts are based on the application of TRM derived savings values to verified participation numbers.
[b] Gross Realization Rate = *ex post* gross value / *ex ante* gross value.

Based on our understanding of the agreement between the ICC and AIC to not count heating penalties in impacts toward electric goals, interactive effects were not included in *ex post* savings calculations of lighting measures. Because there were few electrically heated homes, when the heating penalties are applied, the CFL per-unit values decrease slightly. We provide impacts, including heating penalties, in Appendix B for use in cost-effectiveness calculations.

Ex post gross savings differ from *ex ante* gross savings for the following reasons:

- Air sealing, attic insulation and wall insulation all have differences in realization rates due to the following:
  - Variable assumptions in the savings algorithm calculations.
  - The *ex ante* per unit deemed kW value for participants with electric resistance heating and air conditioning was 0 kW whereas the *ex post* calculations, based on the Illinois TRM, includes kW savings for the cooling season for air conditioning equipment.
- Rim joist *ex post* savings are significantly different from *ex ante* for the following reasons:
  - For ESHP participants, one customer received *ex ante* savings for installing rim joist insulation. However, the evaluation team did not find any evidence of installation in the program database and as such no *ex post* savings were applied for this installation.
  - For HEP participants, the evaluation team had difficulty determining the needed details for this measure. We did discuss how to look for information within the program database with CSG, but found little evidence of specifics for rim joist insulation. The program database lists 787 households with rim joist installations. Rim Joist insulation is recorded as an "Other" type of wall insulation in the database, with specifications provided in the notes section. However, the database showed few participants who received *ex ante* savings for rim joist insulation included rim joist details in the notes section (91 of the 787). Additionally, only one of these participants had specific details (such as the linear feet of installed rim joist, existing R-value, and installed R-value) included in the database. As such, the

evaluation team was unable to calculate savings for the remaining participants who received *ex ante* savings for installing rim joist insulation.

Net Impacts

Following the NTGR framework, we applied the NTGR values available prior to the start of the program year (PY3).[11] *Ex post* net savings were calculated by applying the PY3 HEP measure-specific NTGRs to obtain PY5 net savings (see Table 12 below).[12]

Table 12. PY5 HEP and ESHP Net Impacts by Measure

Measure	*Ex Ante* Net Impacts			*Ex Post* Net Impacts [a]			Net Realization Rate [b]		
	kWh	kW [c]	Therms	kWh	kW	Therms	kWh	kW	Therms
CFL - 13 to 15 Watt	403,833	42.8	-	404,241	42.87	-	100%	100%	NA
CFL - 18 to 20 Watt	127,661	13.5	-	127,799	13.6	-	100%	100%	NA
CFL - 23 to 25 Watt	87,564	8.7	-	87,652	9.3	-	100%	107%	NA
Faucet Aerator - Electric	25,539	2.8	-	25,536	2.9	-	100%	100%	NA
Faucet Aerator - Gas	-	-	4,912	-	-	5,011	NA	NA	102%
Showerhead - Electric	141,656	9.1	-	141,655	9.1	-	100%	100%	NA
Showerhead - Gas	-	-	25,765	-	-	25,246	NA	NA	98%
Air Sealing	2,461,631	2,114	360,086	2,382,409	2,287	355,275	97%	108%	99%
Attic Insulation	455,729	156	124,897	506,652	241	163,093	111%	154%	131%
Wall Insulation	403,484	220	179,393	364,742	260	142,258	90%	118%	79%
Rim Joist Insulation	56,178	15.9	19,400	1,149	0.12	-	2%	1%	0%
Total	**4,163,274**	**2,583**	**714,454**	**4,041,835**	**2,866**	**690,883**	**97%**	**111%**	**97%**

Note: Numbers may not total due to rounding.
[a] *Ex post* net impacts are based on the application of TRM derived savings values to verified participation numbers.
[b] Net Realization Rate = *ex post* net value / *ex ante* net value.

Ex post net savings differ from *ex ante* net savings for lighting and DHW measures for the following reasons (differences in building shell measures explained in the section above):

- CFL - 23 to 25 watt has a 107% demand savings realization rate as the *ex ante* net kW used a NTGR of 0.70instead of the 0.75 specified for CFLs.[13]
- Faucet Aerators and Showerheads – The gas NTGR for these two measures appeared to have been flipped, causing slight differences in these two measures.

[11] Source: Electric NTGRs sourced from PY3 HEP Report Table ES-2; Gas NTGRs sourced from PY3 HEP Gas Memo Table 4.

[12] We applied these ratios to ESHP as well, as the program had no primary data collection and is embedded within HEP.

[13] Source: Electric NTGRs sourced from PY3 HEP Report Table ES-2; Gas NTGRs sourced from PY3 HEP Gas Memo Table 4.

4.3 Inputs for Future Program Planning

The use of a billing analysis for estimation of net savings for this type of program is new for Illinois. At the time that our results were available, discussions were occurring within the technical advisory committee (who closely discuss all aspects of the Technical Reference Manual) about use of billing analysis to adjust engineering results. Ultimately, for PY5, we recommend that another year of billing data accumulate before consideration of application of Illinois specific billing analysis values within any TRM adjustment. However, we provide the full reporting of our billing analysis in Appendix B.

A. Appendix: Billing Analysis Methods & Results

In this section, we provide our results of this year's billing analysis, but ultimately recommend that another year of billing analysis occur before consideration of application of Illinois specific billing analysis values within any TRM adjustment. Table 13 provides engineering and billing analysis results for the PY5 HEP program.

Table 13. PY5 HEP and ESHP Program Net Impacts, by Estimation Method

Analytical Approach	Ex Ante Net			Ex Post Net		
	kWh	kW	Therms	kWh	kW	Therms
Engineering Analysis with PY3 NTGR*	4,113,163	2,581	714,434	4,000,2255	2,856	690,864
			Net Realization Rate	97%	111%	97%
Billing Analysis	4,113,163	2,581	714,434	2,161,445	1,356	251,568
			Net Realization Rate	53%	53%	35%
*Excludes ESHP.						

As can be seen, the two approaches produce different realization rates. In general, different methodological approaches will produce different results, although not always so starkly different. In particular, engineering algorithms apply estimates based on the physical energy changes expected from various inputs whereas a billing analysis incorporates actual customer usage. Actual customer usage takes into account interactive effects of the measures installed, behavioral changes post installation, and other factors that effect energy use but are not captured in an engineering algorithm.

However, in this case, the realization rates are substantially different across the two approaches. Because the billing analysis results indicate that the HEP Program achieved approximately one-third of anticipated *ex ante* gas savings, and approximately one-half of *ex ante* electric savings, we explored the *ex ante* and billing analysis data in an effort to understand why. The following items may be affecting *ex post* savings:

- Gas savings are driven relatively equally by air sealing (51% of *ex ante* savings) and insulation (44% of *ex ante* savings). Water measures accrue savings year-round, but with only 5% of gas savings coming from DHW measures, this points to the heating season as the area where discrepancies between the engineering estimates and billing analysis show up. Electric savings are driven by air sealing measures, which represent 71% of savings.

- When including only homes with electric heat, the billing analysis shows that electric savings from envelope measures (which include air sealing) have a 33% realization rate. Envelope measures for gas show a similar realization rate to electric space heating results (at 34%). However, electric savings that are cooling only show a 41% realization rate. This further supports the idea that some of the larger discrepancies between the engineering algorithms and billing analysis may be showing up on the heating side.

Because the data suggests that air sealing and the heating season are areas where substantial differences may occur, we conducted a sensitivity analysis to explore what could be driving lower realization rates for air sealing during the heating season.[14] Based on this sensitivity analysis, we hypothesize that some of the differences between the engineering algorithms and billing analysis are because of higher-than-expected efficiency in the heating units within homes and differences in behavioral and household characteristics, including possible take-back (because the home now costs less to heat, a customer can now afford to turn up the thermostat). We outline these possible reasons for the differences in greater detail below. However, there is no way, given the available data and budget to confirm the reasons for these differences.

- **Higher-Efficiency Heating Units within Homes:** Our sensitivity analysis indicates that increasing the efficiency of heating units reduces the engineering estimates, and may be one reason for why we see the billing analysis results. However, we recommended confirming this hypothesis through on-site research.

- **Differences in Behavioral and Household Characteristics:** The TRM algorithms are engineering-based and cannot adjust for behavioral differences in how people use their equipment (i.e., set thermostats). Behavioral aspects could include how people adjust thermostats, the duration with which they use heating and cooling equipment, or other factors. For air sealing, there is some ability to adapt the engineering savings to account for wind factors, but there is no wind data available from each of the sites that could be used to determine an appropriate value. As such, the engineering algorithms have little ability to vary potential savings based on actual structural differences from home to home. Both of these areas are strong candidates for why we see differences between the billing analysis results and engineering estimates.

- **Possible Take-Back Effect**: A component of behavior that has been called out by many is “take-back” or “the rebound effect.” Essentially, it suggests that when participants experience lower costs for energy due to, in this case, their home’s retrofit, they may adjust their temperature set points to increase their comfort. As a result, one could hypothesize that HEP participants may increase their use of heating or cooling equipment after retrofitting their household. Again, while this is a possibility, we have no direct way to test this hypothesis with the data available.

- **Specification Error:** There could have been various changes within the home from the pre to the post period that could have affected energy use. For example, the addition of an air

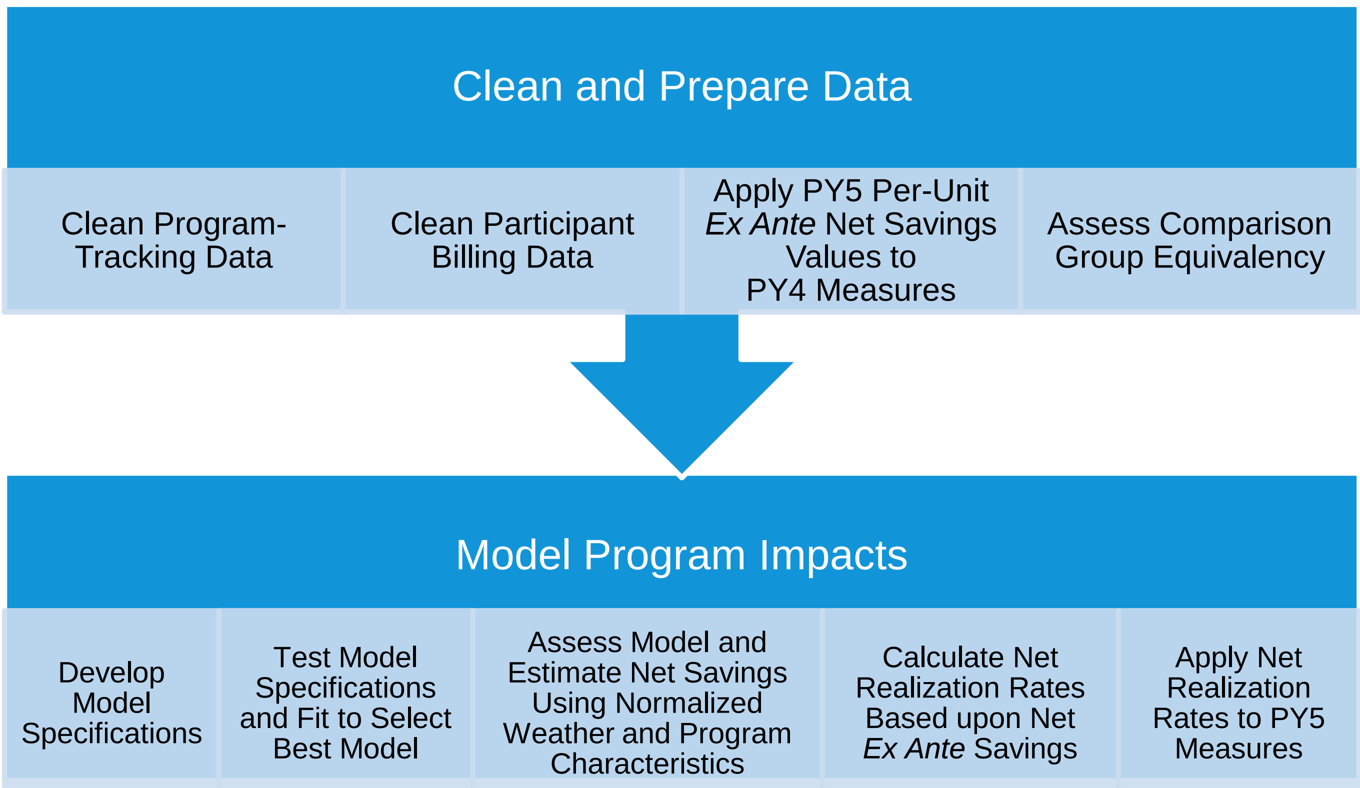
[14] The sensitivity analysis took the example in the Version 1 TRM for air sealing measure and adjusted the algorithm input values of CDD and HDD, Latent Multiplier, and efficiency of heating units.

conditioner, a second refrigerator, or another room after participating in the program would reduce the savings estimated in a regression model. Because such information was not collected, it was not included in the models.

A.1 SUMMARY OF APPROACH

The primary objective of this evaluation was to estimate the energy-savings impacts from installing HEP measures. To address this, we conducted a one-way[15] fixed effects linear model incorporating a comparison group of PY5 program participants to estimate program impacts. Because a billing analysis is best conducted on a complete year of billing data before the installation of measures and a complete year of billing data after the installation of measures, the evaluation team conducted the analysis in PY5 using PY4 participants as the treatment group. As such, the evaluation effort focused on estimating PY4 impacts, and applying those findings to PY5 participants. In addition, given that some customers are dual-fuel customers, the evaluation estimated both electric and gas savings. Figure 1 provides a summary of the billing analysis approach.

Figure 1. Billing Analysis Approach to Estimating Net Impacts



Below we provide details regarding the billing analysis approach.

[15] The analysis was in essence a 2-way fixed-effects panel model because in addition to using customer-specific intercepts, we also included a set of month-year dummies over the entire evaluation period. However, while a two-way fixed effects model would normally absorb both the customer coefficients and the time coefficients, we kept the time coefficients and used them in the model evaluations by multiplying them by the proportion of observations that were present in each month.

A.2 CLEAN AND PREPARE DATA

This section summarizes how we cleaned and prepared the PY4 and PY5 HEP Program participant databases and billing data for the billing analysis.

A.2.1 CLEAN PROGRAM-TRACKING DATA

To conduct the billing analysis, we prepared a master participant database that combined both PY4 and PY5 program-tracking databases. We received both PY4 and PY5 HEP Program tracking databases from AIC. Each of the individual databases had multiple datasets that we merged and appended together. The datasets used in our analysis included:

- **Project List:** Used this dataset as a basis for any sequential merges.
- **Electric Audit, Gas Audit**: Contains instant-savings measures (i.e. lighting, low-flow showerheads, and faucet aerators) that were installed as part of the audit component of the program.
- **Electric Incentive, Gas Incentive**: Contains all measures that were installed as part of the incentive component of the program.
- **Building Characteristics**: Used this dataset to determine the primary heating fuel of the home. This dataset was supplemented with another dataset (Annual Seasonal Consumption) to complete the heating fuel type designation for each home.
- **Unit Savings Values**: Used to verify and determine the underlying assumptions regarding the heating and cooling system combinations of the home that the program used to assign per-unit kWh and therm savings.

Because the data structure is the same in the PY4 database as it is for the PY5 database, we cleaned both in the same manner. We merged by account the projects lists and the measure-level datasets from the two program years before cleaning the file.

We encountered several minor data issues and took careful measures to address and correct each one to ensure that the billing analysis was not biased by these issues.

- **Identifiers for Unique Sites:** The identifiers for unique sites are different for PY4 and PY5. PY4 uses a field called "Site ID," and PY5 uses "Premise ID." If the same person participated in PY4 and PY5, they might have different Site/Premise IDs. Sometimes the same person participating twice in a program year could get different Site/Premise IDs (in many cases the other ID is missing). ***Solution:*** We generated a new site identifier (ODCID) that assigned the same number to the same participant. We thoroughly checked this assignment using name, address, and account number[16] matching and regular expression comparisons.

[16] The obvious question here is: Why not use account numbers as the unique identifier for all merges? The reason is because accounts are divided into electric account and gas accounts, which are not identical. The account numbers are populated based on the type of savings of the measure that the participant installed.

- **Negative Values:** We found negative quantities, savings, and incentive values in the data to correct for or to update previous values. Often, these corrections were made with a different project ID, made on a different date, misplaced in separate datasets, or a combination of the three. Because of these issues, it made it impossible to detect all duplicate entries. *Solution:* The quantities, savings, and incentives were collapsed and summed in *pairs* by ODCID (Site Identifier), measure description, and a date variable[17] to make sure that each of the negative values had a corresponding positive value for which the sum becomes zero.[18]

- **Incorrectly Matched Project IDs:** Six project IDs were incorrectly matched between the project list and the measure installed. For example, an audit project on the project list is an incentive in the measure installed data, and vice versa. *Solution:* When looking at all the cases at once, the number of occurrences for the two types of errors is exactly the same. Upon a closer look at names and measure descriptions, it seems that the project IDs were swapped, so we switched them back.

- **Project IDs with Different Names and Addresses:** A few project IDs have completely different names and addresses in the project list and the measures-installed dataset. *Solution:* We determined the correct name and address for those project IDs by looking at all of the audits and installations by both of the name and address combinations.

- **Missing, Faulty, and Overlapping Dates:** There are some missing, faulty, and overlapping dates between PY4 and PY5, meaning that some PY4 projects have event dates in PY5 and vice versa. *Solution:* Usually, this could be fixed by simply assigning the event date to the date of measure installation. The program year for PY4 projects with installation dates in PY5 and vice versa were left unchanged.

After correcting the initial data issues, we merged the project list with measure installation data to get a master measure-level tracking data file.

We extracted the primary heating type flag from the building characteristics data and from annual seasonal consumption data. We merged this flag into the master tracking data using the *old* Site ID/Premise ID, and then checked and adjusted to be consistent with the new ODCID.

The breakdown of the drops and counts are detailed in Table 14 below.

As such, participants who installed only gas-saving measures will not have an electric account number in the file. In addition, electric accounts are sometimes different from gas accounts, such that one observation from a gas installation dataset would not map to an observation from an electric installation dataset, even though the measures might be installed by the same person.

[17] This could be any variable that separates multiple installations by the same participant. Using a date was a check to see that corrections are paired with an observation that was entered before the correction.

[18] However, sometimes even though the quantities might sum up to be zero, the savings might not. This discrepancy does not happen very often, but those savings values are set to zero if the quantity summed to zero.

Table 14. Participant Database Cleaning Results, Step 1

Participant Database	Sites	Unique Electric Accounts	Unique Gas Accounts	Projects
Initial # (combined PY4 and PY5 participants)	8,484	7,314	6,768	9,483
Quantity and savings corrected through another project, rendering the first project number invalid	0	0	0	6
# After Adjustment	8,484	7,314	6,768	9,477
Projects not on projects list and also had measure quantity = 0	11	11	11	11
# After Adjustment	8,473	7,303	6,757	9,466
Projects on projects list but measure quantity = 0	3	2	3	3
# After Adjustment	8,470	7,301	6,754	9,463
No measure data for project	361	315	274	458
# After Adjustment	8,109	6,986	6,480	9,005
% After Adjustment	**96%**	**96%**	**96%**	**95%**

We then divided the data into those accounts with electric savings and those with gas savings. We dropped observations based on the following criteria:

- On the electric side, we dropped observations if electric accounts had no electric measures installed, or the electric measure installed had no electric savings value.
- On the gas side, we dropped observations if gas accounts had no gas measures installed, or the gas measure installed had no savings value.
- We dropped all households who participated in the Electric Space Heating Pilot (ESHP) in PY4 and PY5. These customers were dropped from both the electric and gas billing analyses.

During this stage, we also defined participants as PY4 or PY5 for billing analysis purposes. In the following tables, PY4 participants (the treatment group) include any participants who initiated participation or installed fuel-specific measures in PY4, including participants who may have participated or had an audit in PY4 but installed fuel-specific measures in PY5.

Table 15 below shows these cleaning results.

Table 15. Participant Database Cleaning Results, Step 2

Participant Database	Unique Electric Accounts			Unique Gas Accounts		
	PY4	PY5	Total	PY4	PY5	Total
Initial #	3,805	3,386	6,986	3,577	3,124	6,480

Participant Database	Unique Electric Accounts			Unique Gas Accounts		
No Electric Measures Installed	343	3	316	0	0	0
# After Adjustment	3,462	3,383	6,670	3,577	3,124	6,480
No Gas Measures Installed	0	0	0	650	14	601
# After Adjustment	3,462	3,383	6,670	2,927	3,110	5,879
0 kWh Savings or 0 Therm Savings	4	0	4	0	0	0
# After Adjustment	3,458	3,383	6,666	2,927	3,110	5,879
Air Sealing Pilot Measures	3	0	3	2	0	2
# After Adjustment	3,455	3,383	6,663	2,925	3,110	5,877
% After Adjustment	91%	100%	95%	82%	100%	91%
No Overlap with Clean Billing Data (see Table 16)	605	618	1,076	818	563	1,285
# After	2,850	2,765	5,587	2,107	2,547	4,592
Participant Overlaps PY4 and PY5 (classified as PY4 participant for analysis; removed from PY5 accounting)	0	28	0	0	62	0
# After Adjustment	2,850	2,737	5,587	2,107	2,485	4,592
Accounts with any participation in ESHP	278	19	297	13	1	14
# After Adjustment	2,572	2,718	5,290	2,094	2,484	4,578
Accounts with thermostat installation (not a PY5 measure)	0	0	0	2	0	2
# After Adjustment	**2,572**	**2,718**	**5,290**	**2,092**	**2,484**	**4,576**
% After Adjustment	**68%**	**80%**	**76%**	**58%**	**80%**	**71%**

A.2.2 Clean Participant Billing Data

The participant billing data used in the billing analysis comes from monthly billing data from June 2010 to May 2013, obtained directly from AIC. To develop the dataset used for the statistical analysis, the evaluation team conducted the following data-processing steps:

- Removed customers based on the following criteria:

    - Customer not found in the program-tracking database (and therefore had no PY4 or PY5 participation flag)
    - All usage data fields missing
    - Extremely high or low kWh average daily usage (<2 kWh or >300 kWh)
    - Extremely low average daily therm usage (<.07 therms) over a nine-or-more-month period

- Checked for data issues such as negative usage, billing dates out of range, duplicate billing periods, overlapping billing periods, and long billing durations (greater than six months). We found no issues on these grounds.
- Assigned each meter read cycle to a calendar month based on the midpoint of the read cycle (so that the month-year assignment reflects the calendar month in which the majority of days fell), and determined average usage for each observation (based on usage and number of billing days)
- Linked usage data with the customer-specific (account level) measure installation dates, to identify the first and last measure installation dates. We then assigned pre- and post-treatment billing periods based on those dates: We assigned billing periods before the first installation date to the pre-period, all bills following the last installation date as the post-period, and any bills occurring between installation dates (or in the month of the audit and ISM installations) to a deadband period, that was not included in analysis.
- Assigned seasonal dummy variables to each of the monthly observations:
    - Winter: January, February, March, November, December
    - Shoulder: April, May, September, October
    - Summer: June, July, August
- Using the pre-period, post-period, and seasonal indicators, we removed additional customers based on the following criteria:
    - No pre-period billing data
    - Less than two months of pre-period data in the summer and winter periods, respectively
    - Less than two months of post-period data in the summer and winter periods, respectively (PY4 customers only)
    - Less than nine billing periods in the pre-period
    - Less than nine billing periods in the post-period (PY4 customers only)

Table 16 provides the results of the data cleaning effort for the billing analysis.

Table 16. Data Cleaning Results: Electric and Gas Participants

Data Cleaning	Electric Customers	Gas Customers

	PY4 (Treatment)	PY5 (Comparison)	PY4 %	PY4 (Treatment)	PY5 (Comparison)	PY4 %
Unique Accounts[19]	**7,611**			**7,235**		
Account not in participant data	949			1,363		
# accounts remaining	3,454	3,208	100%	2,923	2,949	100%
No usage data	4	2	0.1%	3	1	0.1%
# accounts remaining	3,450	3,206	100%	2,920	2,948	100%
Negative usage	0	0	0.0%	0	0	0.0%
# accounts remaining	3,450	3,206	100%	2,920	2,948	100%
Billing dates out of range	0	0	0.0%	0	0	0.0%
# accounts remaining	3,450	3,206	100%	2,920	2,948	100%
Duplicative billing dates	0	0	0.0%	0	0	0.0%
# accounts remaining	3,450	3,206	100%	2,920	2,948	100%
Overlapping billing periods	0	0	0.0%	0	0	0.0%
# accounts remaining	3,450	3,206	100%	2,920	2,948	100%
High ADC overall	0	1	0.0%	Not Applied[20]		
High ADC in the pre-period only	0	0	0.0%			

[19] Because the billing data does not contain any participant information, such as program year, the program year is not known until the billing data is merged with the participant data. Therefore we do not show counts of unique participants in the billing data by program year until after the second step, when indicators from the participant data (such as program year) is matched with billing data.[20] We did not apply a cutoff for high gas usage because (a) the distribution of gas usage did not show any cause for alarm (e.g., clear outliers), and (b) applying a similar Btu consumption threshold as we used for electric (300 kWh) would have resulted in many accounts being dropped.[21] Summer season drops were not applied to customers in the gas billing analysis because we would not expect summer-specific savings from gas measures (which affect heating load and base load, which are covered in other drops).

[20] We did not apply a cutoff for high gas usage because (a) the distribution of gas usage did not show any cause for alarm (e.g., clear outliers), and (b) applying a similar Btu consumption threshold as we used for electric (300 kWh) would have resulted in many accounts being dropped.[21] Summer season drops were not applied to customers in the gas billing analysis because we would not expect summer-specific savings from gas measures (which affect heating load and base load, which are covered in other drops).

Data Cleaning	Electric Customers			Gas Customers		
High ADC in the post-period only	0	0	0.0%			
# accounts remaining	3,450	3,205	100%			
Low ADC overall	10	9	0.3%	1	4	0.0%
Low ADC in the pre-period only	1	2	0.0%	1	0	0.0%
Low ADC in the post-period only	1	0	0.0%	2	0	0.1%
# accounts remaining	3,438	3,194	100%	2,916	2,944	100%
Extremely long duration	0	0	0.0%	0	0	0.0%
# accounts remaining	3,438	3,194	100%	2,916	2,944	100%
No pre-program billing data	20	31	0.6%	27	36	0.9%
# accounts remaining	3,418	3,163	99%	2,889	2,908	99%
Insufficient data in pre-period summer	208	264	6.0%	Not Applicable[21]		
# accounts remaining	3,210	2,899	93%			
Insufficient data in post-period summer	247	N/A[22]	7.2%	Not Applicable		
# accounts remaining	2,963	2,899	86%			
Insufficient data in pre-period winter	46	118	1.3%	140	265	4.8%
# accounts remaining	2,917	2,781	84%	2,749	2,643	94%
Insufficient data in post-period winter	16	N/A	0.5%	262	N/A	9.0%
# accounts remaining	2,901	2,781	84%	2,487	2,643	85%

[21] Summer season drops were not applied to customers in the gas billing analysis because we would not expect summer-specific savings from gas measures (which affect heating load and base load, which are covered in other drops).

[22] Post-period drops are not applicable to the comparison group of PY5 customers because their post-period consumption data is not used in analysis.[23] The difference in unit values within certain measures is solely dependent on the underlying heating and cooling type of the home.

Data Cleaning	Electric Customers			Gas Customers		
Insufficient pre-program billing data (less than 9 observations in pre-period)	36	44	1.0%	147	158	5.0%
# accounts remaining	2,865	2,737	83%	2,340	2,485	80%
Insufficient post-program billing data (less than 9 observations in post-period)	15	N/A	0.4%	233	N/A	8.0%
# accounts remaining	2,850	2,737	83%	2,107	2,485	72%
Accounts with any participation in ESHP	278	19	8.0%	13	1	0.4%
# accounts remaining	2,572	2,718	74%	2,094	2,484	72%
Accounts with thermostat installation (not a PY5 measure)	0	0	0	2	0	0.1%
# accounts remaining	2,572	2,718	74%	2,092	2,484	72%

In summary, we retained approximately 72% to 74% of PY4 participants and 80% of PY5 participants, as shown in Table 17 below.

Table 17. Summary of Participants Used in Billing Analysis

Sample for Analysis	Electric Customers		Gas Customers	
	PY4 (Treatment)	PY5 (Comparison)	PY4 (Treatment)	PY5 (Comparison)
Initial Participant Count (from participation database)[a]	3,458	3,383	2,927	3,110
Total Drops	886	665	835	626
Final N	2,572	2,718	2,092	2,484
% Remaining	74%	80%	72%	80%

[a] These are the counts of unique accounts with electric or gas measures respectively with *ex ante* savings in the project data (as reflected in the third step of Table 15).

A.2.3 Apply PY5 Per-Unit Values to PY4 Measures

The HEP Program claimed savings based on different savings assumptions in PY4 and PY5 due to changes in the Illinois Statewide TRM. As such, if we used the per-unit values that were not the same as for PY5 participants, any realization rate we might calculate based on savings observed through billing analysis of PY4 customers would not be immediately applicable to PY5 *ex ante* savings. Therefore, to ensure that the realization rates we derive through billing analysis could be applied to PY5 *ex ante* savings, we recalculated PY4 *ex ante* savings for the billing analysis treatment group (PY4 participants) in terms of PY5 savings assumptions (per-unit savings). To do this, the evaluation team applied PY5 per-unit *ex ante* savings and PY5 ex ante NTGRs for equivalent measures installed in PY4 to recalculate net realization rates for PY4 participants in PY5 terms. Specifically, we performed the following steps:

- Calculated PY5 per-unit *ex ante* savings, for each measure, for unique combinations of heating and cooling type, based on per-unit savings assumptions calculated from the PY5 program-tracking database. We used unique measure descriptions and unit savings to determine the heating and cooling combination[23] that was used for each per-unit value. We then divided PY4 and PY5 records by measure and heating/cooling combination, calculated PY5 per-unit values, and applied them to PY4 measure records. For some PY5 measures, the unit savings value is dependent on the period within a calendar year that the measure was installed (mostly a change from calendar year 2012 to 2013). To assign a value to PY4 participants, we took the weighted average of PY5 per-unit savings, depending on the quantity that was installed in each period of the year. For the few values that did not exactly match, the closest approximation was used.

- Calculated the measure-level NTGRs based on the *ex ante* net savings and *ex ante* gross savings in the PY5 database and applied these values to PY4 measure records within the billing analysis. We calculated what measure-level NTGR values had been used in PY5 using the PY5 database for two reasons: (1) to ensure that we applied the same values that the program used to claim savings, so that the realization rates would be comparable, and (2) for ease of analysis – it is easier to apply values using the same measure descriptors/parameters that were already in the PY4 and PY5 data. The NTGR values in the program database were generally similar to the *ex ante* values (from PY3) that AIC expected to apply to the PY5 data, with a few exceptions noted in Table 9.

We then applied these PY5 per-unit values to PY4 participants as the basis for calculating realization rates.

A.2.4 Assess Comparison Group Equivalency

After cleaning the data, and to evaluate the impact of the program net of the impact of any external stimuli, the evaluation team identified a reasonable comparison group to represent counterfactual energy use. Because of the non-random design of the program and data limitations, our best option for a comparison group was PY5 participants, since they will mitigate any self-selection bias that may be present in the evaluated group (PY4 participants). It is important that PY5 participants are equivalent on as many dimensions as possible. Based on the information at our disposal, we specifically looked at three criteria to determine that PY5 participants were equivalent to the PY4 participants, and could be used as a valid comparison group. The three criteria are listed below:

- **Heating Fuel Type** – The type and magnitude of savings for several measures is directly related to the heating fuel type of the home. As such, we reviewed the proportion of households by heating fuel type across PY4 and PY5 participants.

[23] The difference in unit values within certain measures is solely dependent on the underlying heating and cooling type of the home.

- **Measure Mix** – We assessed the similarity in the distribution and variety of measures that were installed in PY4 and PY5 participant households.
- **Baseline Period Average Daily Consumption (ADC)** – Similarity in average daily consumption before engaging with the program might be a general proxy for behavioral similarities. As such, the evaluation team compared the baseline monthly ADC of PY4 and PY5 participants.

As a result of the equivalency check, we determined that the PY4 and PY5 participant groups were comparable for analyzing the impacts of the HEP Program. We document our findings below.

Heating Fuel Type

We found that the PY4 and PY5 participant groups are fairly equivalent in the proportion of homes that are heated by electric resistance heating and the types of measures that were installed in them across the program years (see Table 18 below). A similar percentage of participants with electric measures in PY5 and PY4 had electric heat (13%). Because of differences in annual consumption and expected differences in electrically-heated and gas-heated homes' response to colder weather, we ran separate overall savings models for electric participants with electric vs. non-electric space heat. For the same reason, we included indicators and appropriate interactions for homes with electric heating space heat within models for building envelope savings.

Table 18. Heating Fuel Type in PY4 and PY5

Heating Fuel Type	Participants with Electric Measures		Participants with Gas Measures	
	PY4 Participant Group (n=2,572)	PY5 Participant Group (n=2,718)	PY4 Participant Group (n=2,092)	PY5 Participant Group (n=2,484)
Gas	85%	84%	99%	99%
Electric	13%	13%	0.5%	1%
Other/Missing	2%	2%	0%	0%

Note: May not total 100% due to rounding.

Measure Category Mix

As can be seen in the tables and figures below, the measure mixes between PY4 and PY5 cohorts are fairly similar. Notably, a sizable proportion of participants within each fuel-specific analysis received only one type of measure for that fuel type. In Table 19, the percentages of these within-fuel "single measure category" households are shown in the first three rows (Lighting Only, Envelope Only, and DHW Only). For example, for 43% of PY5 participants with electric savings, CFLs were the only measure with electric savings they installed. For PY4, that rate was 44%. These high proportions of participants with only one measure category installed per fuel type enabled us to conduct "single measure category" models to get a cleaner read on measure category-specific savings.

Table 19. Percent of Participants in Billing Analysis that Installed Each Measure Type

Within-Fuel Measure Mix [a]	Electric Accounts		Gas Accounts	
	PY4 Participant Group (n=2,572)	PY5 Participant Group (n=2,718)	PY4 Participant Group (n=2,092)	PY5 Participant Group (n=2,484)
Lighting Only	44%	43%	–	–
Envelope Only	36%	39%	45%	49%
DHW Only	2%	3%	45%	43%

Lighting and Envelope	8%	6%	–	–
Lighting and DHW	8%	7%	–	–
DHW and Envelope	0%	0%	10%	8%
Lighting, Envelope, and DHW	1%	1%	–	–

[a] The measure mix distribution reflects the distribution within each of the two fuel types we analyzed – for example, while 44% of PY4 electric participants received lighting measures as the only measure category with electric savings in the tracking database, they may have also installed gas envelope or DHW measures.

The figures below show the percentage of participants in each billing analysis (electric and gas) that installed each measure category.

Figure 2. Percent of Accounts in Electric Billing Analysis that Installed Each Measure

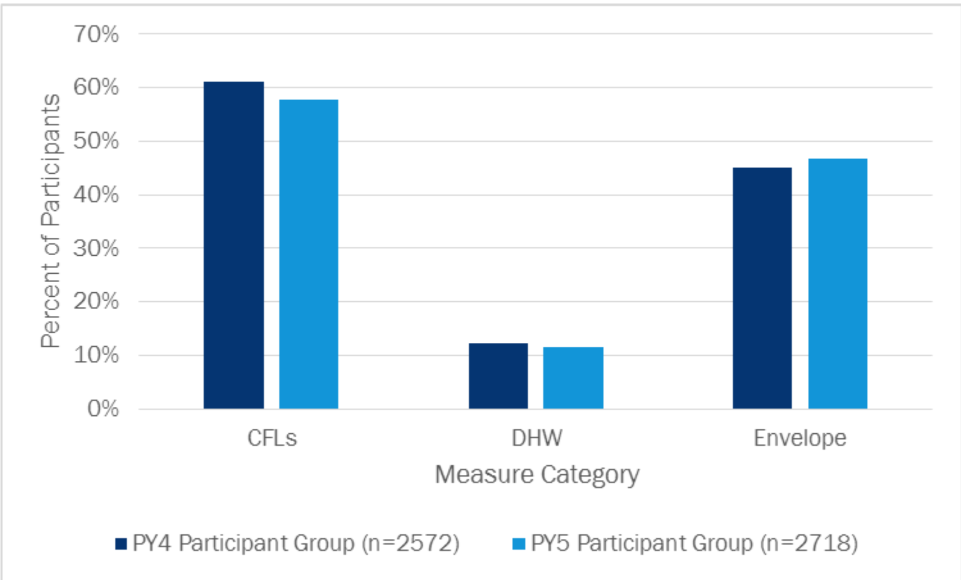
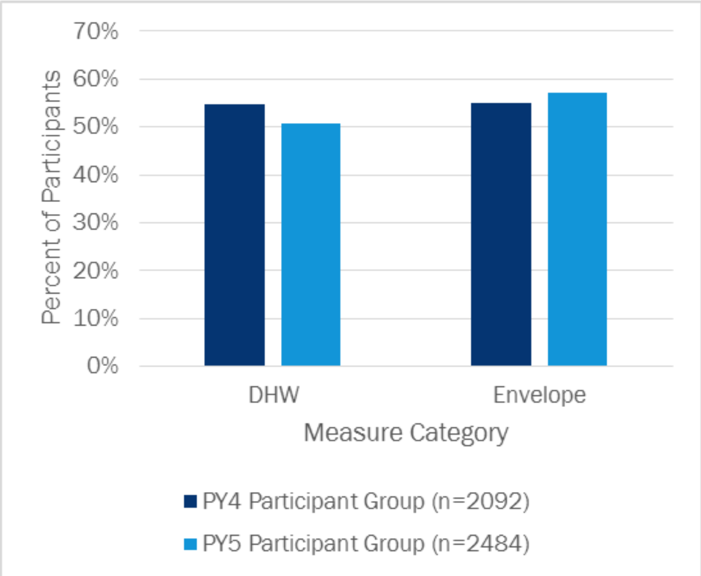


Figure 3. Percent of Accounts in Gas Billing Analysis that Installed Each Measure



Baseline Average Daily Energy Consumption

Finally, we looked at average daily consumption in our standardized (June 1, 2010, through May 31, 2011) pre-program period – PY3 – to determine how similar households may be in terms of energy consumption patterns. Table 20 below shows that within each fuel type, the treatment and comparison groups were fairly equivalent based on the average daily consumption in the baseline period.

Table 20. Baseline Period Average Daily Consumption, kWh and Therms

Fuel Type	PY4 Participants	PY5 Participants
Baseline Period (PY3)	June 1, 2010 – May 31, 2011	
Average Daily kWh (among Electric Participants)	38.2 (sd: 21.7)	37.8 (sd: 21.3)
Average Daily kWh (among Electric Participants with Electric Space Heating)	67.3 (sd: 26.7)	63.8 (sd: 24.1)
Average Daily kWh (among Electric Participants with Non-Electric Space Heating)	34.1 (sd: 17.3)	33.7 (sd: 17.6)
Average Daily Therms (among Gas Participants)	2.47 (sd: 1.07)	2.41 (sd: 1.07)

[a] Billing analysis participants with less than 9 months of data in PY3 were excluded from these calculations.

Figure 4 below shows the comparison of baseline period electric consumption by month for treatment and comparison groups, and Figure 5 below shows the same for gas consumption.

Figure 4. Comparison of Average Baseline Monthly kWh Consumption between Treatment and Comparison Customers in Electric Billing Analysis

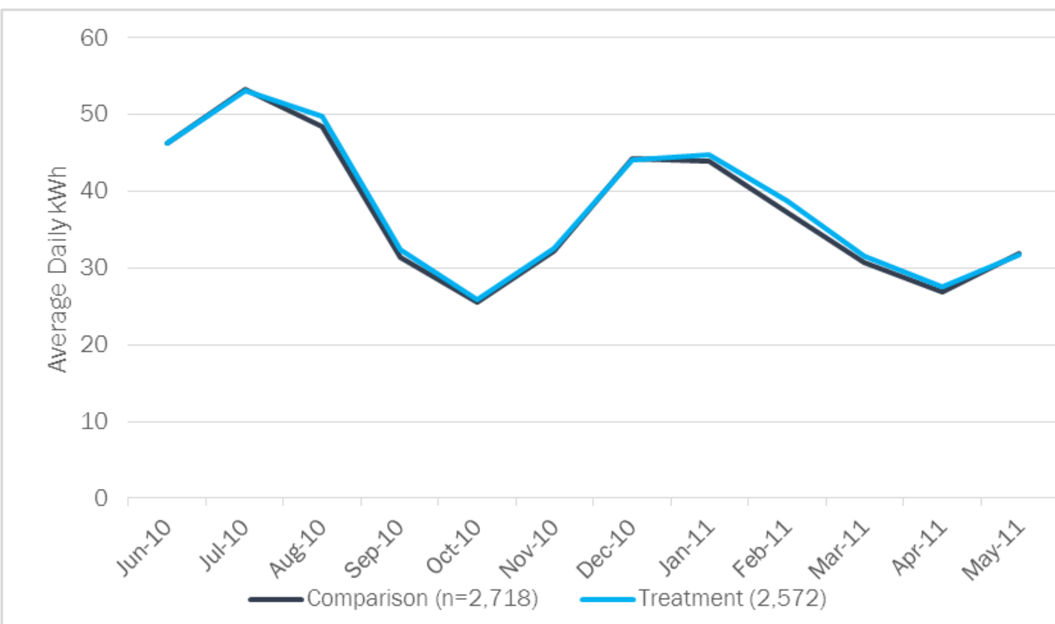
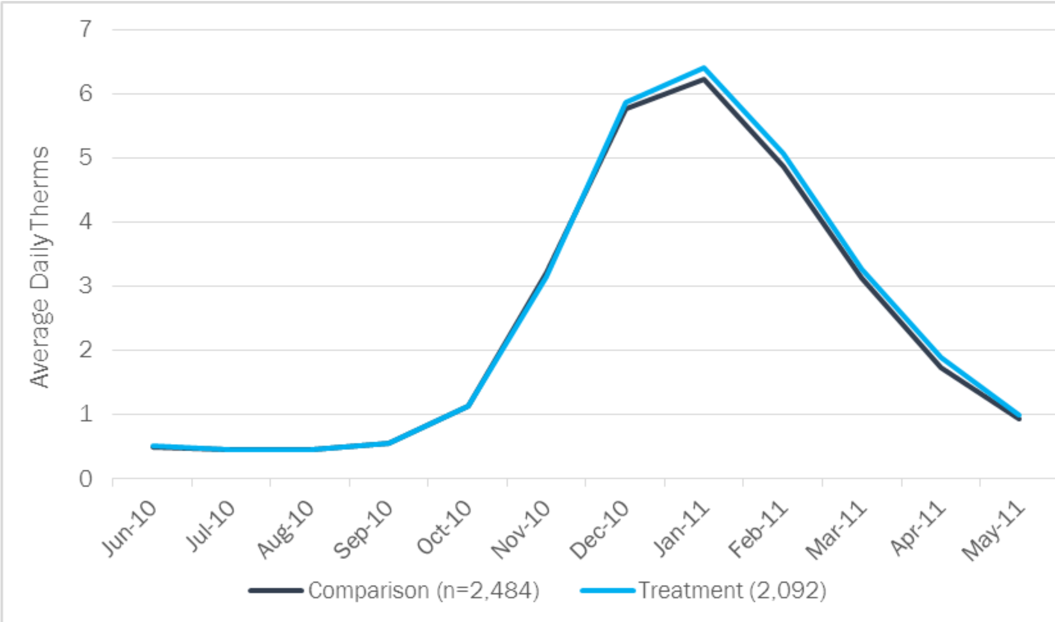


Figure 5. Comparison of Average Baseline Monthly Therm Consumption between Treatment and Comparison Customers in Gas Billing Analysis



A.3 Model Program Impacts

Given that some HEP customers are dual-fuel customers, the HEP evaluation estimated both electric (breaking out non-electric space heat and electric space heat) and gas savings. We developed overall and measure-specific models for gas and electric participants, and we collapsed several measure types into broader categories, including CFLs, domestic hot water (DHW)[24], and envelope measures. In total, we developed four electric models and three gas models, with each providing savings estimates and realization rates, as shown in Table 21 below.

Table 21. Overview of HEP Program Billing Analysis Models

Fuel Type	Customer Type	Model
Electric	Electric Space Heat (ESH)	Overall savings for all measures [a]
	Non-Electric Space Heat (non-ESH)	Overall savings for all measures [a]
	Electric Accounts	CFL savings based on customers who only installed CFLs
	Electric Accounts [b]	Envelope savings based on customers who only installed envelope measures
Gas	Gas Accounts	Overall savings for all measures
		Envelope savings based on customers who only installed envelope measures

[24] Note that the team was unable to produce a reliable electric model for DHW measures.

Fuel Type	Customer Type	Model
		DHW savings based on customers who only installed DHW measures
[a] Includes DHW measures effects. [b] Includes ESH terms so savings and realization rates are produced for households with ESH and non-ESH within the same model.		

A.3.1 DEVELOP AND TEST MODEL SPECIFICATIONS

For modeling purposes, we collapsed several measure types into broader categories. This helps to keep measure-specific estimates from being based on small groups of households, and also increases the likelihood of finding savings for specific measure types. It is unlikely that sink faucet aerators, for example, would produce savings large enough to be detected by a billing analysis. The categories that we used for modeling are CFLs, envelope (related to space conditioning), and domestic hot water (DHW). The list of measure categories and how they compared between PY4 and PY5 is shown in Table 19.

Knowing that AIC would benefit from savings estimates and realization rates by measure type as well as overall, our initial approach was to estimate several models that incorporated terms for each of the three measure categories. This preferred approach would allow us to use the same model to generate savings estimates overall and by measure category. We pursued this approach for both gas and electric models, though ultimately selected separate models for overall savings (including savings among electric space and non-electric space heat electric participants) and specific measure categories. In addition to estimating models with measure categories incorporated, it is important to take into account whether each household heating system is fueled by gas or electricity.

Our method of selecting models focused on several factors. We estimated several models beginning with the specification we thought most appropriate given the research questions and the data available. After eliminating models that produced implausible results (e.g., a realization rate of 500%, or measure savings estimates from measure-specific models that add up to more than the total savings from an overall savings model, etc.), we compared models based on the stability of the savings estimates over a number of specifications. We also considered the Akaike Information Criterion[25] as a measure of model relative fit.[26] After concluding that the models were generally stable, our team selected the model with the best fit. The team encountered some issues in evaluating the HEP models, and these issues will be described in following sections separated by savings fuel type.

As described earlier, our models included a comparison group consisting of households that participated in PY5. The point of the PY5 comparison group is to represent the counterfactual for the treatment group (PY4 participants) in the post-period. Up until the date on which each PY5 participant entered the PY5 Program, their billing data can be compared to the billing data of the PY4 participants. As a result, for PY5 participants, there is no "post" participation period for the

[25] Akaike, Hirotugu (1974), "A new look at the statistical model identification", *IEEE Transactions on Automatic Control* **19** (6): 716–723. This approach trades off model complexity against model fit. It does not tell us whether model fits, but which of several models fits the data more efficiently than the others.

[26] Significance testing was not a focus of decision-making because we were analyzing the whole population of participants, thus making sampling error a non-issue.

comparison group because each PY5 participants' billing data is dropped from the analysis on the date when they enter the PY5 program.

To improve our estimate of the counterfactual (what PY4 participants would have done during the post period absent the program), we added dummy variables for each month of the evaluation period. The monthly dummy variables provide information on time trends not related to the comparison group per se. This method "allows" the comparison group to represent something closer to the counterfactual, i.e. what PY4 participants would have done during the post-period absent the program.

We also entered weather terms in the model, as well as interaction terms between weather and the post-period for the treatment group, to account for appreciable differences in weather across years (see Table 22 below), and the possibility that the relationship between weather and consumption might change following treatment.

Table 22. Average Daily HDD (Base 65) and CDD (Base 65) for Records in Billing Analysis

Program Year	Records in Electric Billing Analysis		Records in Gas Billing Analysis	
	HDD	CDD	HDD	CDD
PY3	13.4	3.5	13.5	3.4
PY4	12.8	3.8	13.0	3.8
PY5	17.8	2.8	18.0	2.8
Average	*14.6*	*3.4*	*14.7*	*3.3*

Electric Models

As noted earlier, our preferred modeling approach was to include in the model each measure category installed by each customer. However, none of these models produced usable results. While the overall program savings were quite stable, some of the measure-specific coefficients were not. This was true of estimates for CFLs and for domestic hot water measures. We tried many models in an effort to solve the problem, but it remained obdurate. We have concluded that there may be some specification errors that could not be corrected with the available data.

Our revised approach takes advantage of two factors: (1) the overall savings estimates were stable, and (2) there were enough customers who installed only one measure category with electric savings, thus allowing single-measure models for CFLs and envelope measures. Whatever challenges existed in the multiple-measure data were not a problem in the single-measure groups. There were sufficient numbers of households who installed CFLs only and envelope measures only to provide confidence in single-measure estimates in these categories. In addition, multiple specifications within those measure groups provided stable estimates of savings and realization rates for them. The one measure type that we could not produce estimates for based on single-measure installation households was the DHW category. There were not enough households where that was the only measure type to support an estimate.

One option for a DHW-specific estimate was to analyze the group of customers who installed only two measures, including DHW. The one combination that produced enough households for analysis was the DHW and CFL combination. Our team attempted many models with terms for this measure combination, but the results for CFLs and DHW were still not stable when analyzed in combination. Thus, DHW-specific estimates of savings and realization rates are not reported.

For the overall savings model and the models for envelope-only measures, it was important to incorporate heating fuel type into the analysis. We found that this was best done by running the overall model separately for electric heating households (ESH) and non-electric heating households (non-ESH).

For the envelope-only models, the heating fuel type was entered into the model as an interaction with the treatment variable since the models show better fit (using the Akaike Information Criterion) when incorporating space heating type and realization rates can then be applied separately for ESH and non-ESH households.

The CFL savings, being less sensitive to heating fuel, was estimated for customers regardless of heating fuel. Our approach has produced four models for electric savings, with each providing savings estimates and realization rates:

1. Overall savings for customers with ESH. The savings estimated from this model cover all program measures in aggregate (including DHW measure effects). This model was used for reporting overall program savings and realization rates for Electric Space Heat customers.
2. Overall savings for customers without ESH. The savings generated from this model cover all program measures in aggregate (including DHW measure effects). This model was used for reporting overall program savings and realization rates for non-Electric Space Heat customers.
3. CFL savings based on customers who had only CFLs installed (according to electric program tracking data). This model was developed for informational purposes only.
4. Envelope-related savings based on customers who had only envelope measures installed (according to electric program tracking data). This model included the ESH terms so savings and realization rates could be produced for households with ESH or non-ESH from the same model.[27] This model was developed for informational purposes only.

Our final electric models were fixed effects linear models with the specifications shown below. The models include dummies for each calendar month covered by the evaluation period because this helps to control for time-related trends beyond weather, such as economic, historical, and political conditions. This approach allows the comparison group to more precisely represent the counterfactual. As noted above, the analysis was in essence a 2-way fixed-effects panel model because in addition to using customer-specific intercepts, we also included a set of month-year dummies over the entire evaluation period. However, while a two-way fixed effects model would normally absorb both the customer coefficients and the time coefficients, we kept the time coefficients and used them in the model evaluations by multiplying them by the proportion of observations that were present in each month.

[27] Note that using the same model assumes that the random component follows the same distribution for both groups. To make sure that this is a reasonable assumption, we checked the random component of the residuals for ESH vs. non-ESH households and found that both were mean-zero, though they did not follow an identical distribution (neither distribution was perfectly normal, and the distribution for ESH households had a larger standard deviation). While this difference may affect our standard error estimates, we wouldn't expect it to affect our coefficient estimates. Since we are assuming no sampling error for this population-level analysis, we are not using standard errors to calculate confidence levels or precision. Still, we reported "robust" standard errors that cluster by household.

The estimating equations were the same for overall impacts and measure-specific impacts. We ran separate models with the same model specification for each of the following sets of customers: (1) those with ESH, (2) those without ESH, and (3) those who installed CFLs only:

$$ADC_{it} = B_0 + B_1 Post_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_4 Post \cdot HDD_{it} + B_5 Post \cdot CDD_{it} + B_t MY + \varepsilon_{it}$$

Where:

ADC_{it} = Average daily consumption (in kWh) for the billing period

$Post$ = Indicator for treatment group in post-period (coded 0 if treatment group in pre-period or comparison group in all periods)

HDD = Average daily Heating Degree Days provided by AIC

CDD = Average daily Cooling Degree Days provided by AIC

MY = Month-Year dummies for all time periods in the model

B_0= Average household-specific constant

B_1=Main program effect (change in ADC associated with being a participant in the post period)

B_2=Increment in ADC associated with one unit increase in HDD

B_3=Increment in ADC associated with one unit increase in CDD

B_4=Increment in ADC associated with each increment increase of HDD for participants in the post period. (The additional program effect due to HDD)

B_5=Increment in ADC associated with each increment increase of CDD for participants in the post period. (The additional program effect due to CDD)

B_t=Coefficients for each month-year period

ε_{it} = Error term

We ran a slightly different model for envelope-only households. Notably, this model was not used for reporting overall billing analysis savings. The estimates for envelope-only households were built on the model above, but included terms to account for ESH homes[28]:

$$ADC_{it} = B_0 + B_1 Post_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_4 Post_{it} \cdot HDD_{it} + B_5 Post_{it} \cdot CDD_{it} +$$

$$B_6 ESH_i \cdot Post + B_7 ESH_i \cdot HDD_{it} + B_t MY + \varepsilon_{it}$$

Where:

[28] The ICC reviewers suggested including interaction terms for all month year dummies with the ESH variable. The evaluation team did not run this specification as incorporating this set of interactions would essentially mean that the model is no longer a two-way fixed effect model and we would lose the benefits of that type of model.

ADC_{it} = Average Daily Consumption

$Post$ = Indicator for treatment group in post period (coded 0 if treatment group in pre-period or comparison group in all period)

HDD = Heating Degree Days provided by AIC

CDD = Cooling Degree Days provided by AIC

ESH = Electric Space Heating (Coded 1 if electric space heating household, 0 if non-ESH)

MY = Month-Year dummies for all time periods in the model

B_0= Average household-specific constant

B_1=Main program effect (change in ADC associated with being a participant in the post period)

B_2=Increment in ADC associated with one unit increase in HDD

B_3=Increment in ADC associated with one unit increase in CDD

B_4=Increment in ADC associated with each increment increase of HDD for participants in the post period. (The additional program effect due to HDD)

B_5=Increment in ADC associated with each increment increase of CDD for participants in the post period. (The additional program effect due to CDD)

B_6=Increment in ADC due to being a household with electric space heating and in the participant group during the post period

B_7= Increment in ADC due to being a household with electric space heating, in the participant group during the post period, for each increment in HDD

B_t=Coefficients for each month-year period

ε_{it} = Error term

Gas Models

Only two measure types were pertinent for gas models: envelope measures and DHW measures. Our approach to the gas models was the same as for the electric models, insofar as we developed one overall savings model without measure terms, and developed measure category savings estimates from models with households who installed only one gas measure category. Since nearly all households with gas savings had gas heat, there was no need for separate models based on heating fuel. We used a simple model for overall savings, including only terms for treatment and weather, and applying the same model to households that installed envelope measures only, and to households that installed DHW only. This was possible because there were sufficient households that received only one measure of these two types. The result is three gas models estimating:

1. Overall savings for all customers (includes all measure types in aggregate). No heating fuel terms were entered because there were virtually no measures installed in ESH households that had gas savings values in the gas cohort.
2. Envelope measure savings based on customers who installed only envelope measures.

3. DHW measure savings based on customers who installed only DHW measures.

All three gas estimates were made with same specification, just applied to different groups: (1) all customers with gas measures installed, (2) customers with only gas envelope measures installed, and (3) customers with only gas DHW measures installed for gas savings.

$$ADC_{it} = B_0 + B_1 Post_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_4 Post_{it} \cdot HDD_{it} + B_5 Post_{it} \cdot CDD_{it} + B_t MY + \varepsilon_{it}$$

Where:

ADC_{it} = Average Daily Consumption

$Post$ = Indicator for treatment group in post period (coded 0 if treatment group in pre-period or comparison group in all period)

HDD = Heating Degree Days provided by AIC

CDD = Cooling Degree Days provided by AIC

MY = Month-Year dummies for all time periods in the model

B_0= Average household-specific constant

B_1=Main program effect (change in ADC associated with being a participant in the post period)

B_2=Increment in ADC associated with one unit increase in HDD

B_3=Increment in ADC associated with one unit increase in CDD

B_4=Increment in ADC associated with each increment increase of HDD for participants in the post period. (The additional program effect due to HDD)

B_5=Increment in ADC associated with each increment increase of CDD for participants in the post period. (The additional program effect due to CDD)

B_t=Coefficients for each month-year period

ε_{it} = Error term

A.3.2 Assess Models, Estimate Savings, and Calculate Realization Rates

This section contains model coefficients and realization rates resulting from the billing analysis for PY4 participants.

Electric Model Results

As described in Section A.2.2, we used separate models to estimate overall savings for customers with and without electric space heat. The regression model results for customers with electric space heat (approximately 21% of PY4 customers in billing analysis) is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 23. Regression Model Results for Electric Heat Customers (among Electric Participants)

(Dependent variable is average daily kWh consumption.
Number of customers = 685, Number of observations = 20,230, R^2 = 0.704)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	-6.040	1.634	-3.7	0
postXhdd	0.141	0.090	1.56	0.119
postXcdd	0.396	0.139	2.85	0.005
Hdd	0.206	0.069	3	0.003
Cdd	0.667	0.116	5.77	0
Constant	38.622	0.890	43.38	0

The regression model results for customers without electric space heat (approximately 79% of PY4 customers in billing analysis) is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 24. Regression Model Results for Non-Electric Heat Customers (among Electric Participants)

(Dependent variable is average daily kWh consumption.
Number of customers = 4,605, Number of observations = 135,657, R^2 = 0.750)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	-1.444	0.443	-3.26	0.001
postXhdd	0.015	0.021	0.71	0.475
postXcdd	0.022	0.051	0.43	0.669
Hdd	0.062	0.012	5.06	0
Cdd	0.943	0.038	25.13	0
Constant	27.787	0.247	112.57	0

To understand savings for CFLs, we developed a separate model to look at electric savings among electric customers whose *only* electric measure in the tracking data was CFLs. These customers comprised 44% of PY4 participants and 43% of PY5 participants in the billing analysis. Further, these customers comprised 72% of all PY4 participants in the billing analysis who installed CFLs, and 75% of all PY5 participants in the billing analysis who installed CFLs. In other words, of all customers in PY4 who installed CFLs, 72% of them installed only that measure. The results of the "CFLs Only" model is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 25. Regression Model Results for Electric Participants who installed CFLs only (in electric tracking data)

(Dependent variable is average daily kWh consumption.
Number of customers = 2,309, Number of observations = 68,820, R^2 = 0.716)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	-1.313	0.563	-2.33	0.02
postXhdd	0.018	0.029	0.63	0.53
postXcdd	0.116	0.062	1.87	0.062
Hdd	0.069	0.024	2.92	0.003
Cdd	0.924	0.056	16.42	0
Constant	28.750	0.382	75.17	0

To understand savings from envelope measures (insulation and air sealing), we developed a separate model to look at electric savings among electric customers whose *only* electric measures in the tracking data were envelope measures (insulation, air sealing, or both). These customers comprised 36% of PY4 participants and 39% of PY5 participants in the billing analysis. Further, these customers comprised 80% of all PY4 participants in billing analysis who installed envelope measures, and 83% of all PY5 participants in billing analysis who installed envelope measures. The results of the "Envelope Only" model is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 26. Regression Model Results for Electric Participants who installed Envelope Measures only (in electric tracking data)

(Dependent variable is average daily kWh consumption.
Number of customers = 1,988, Number of observations = 58,116, R^2 = 0.749)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	-2.023	0.503	-4.03	0
postXhdd	0.028	0.023	1.2	0.232
postXcdd	0.053	0.063	0.85	0.398
Hdd	-0.089	0.031	-2.88	0.004
Cdd	0.968	0.060	16.02	0
eshXhdd	1.525	0.087	17.58	0
postXesh	-2.994	1.557	-1.92	0.055
Constant	27.804	0.393	70.67	0

Using the coefficients from the models, we estimated savings using normalized weather and relevant measure categories. We used the weather normals for Springfield from the PY5 TRM[29] to

[29] Weather normals for Springfield in the PY5 TRM are 5,497 HDD using a base temperature of 65° and 1,108 CDD using a base temperature of 65°.

predict expected average daily net savings among PY4 participants in each model, applying the average normal weather values to all model terms containing HDD or CDD.

Then we calculated realization rates based on expected *ex ante* savings. To calculate realization rates that could be applied to PY5 participants, we recalculated net *ex ante* savings for PY4 participants using PY5 savings assumptions (PY5 per-unit gross savings and PY5 NTGR). We compared evaluated net savings with net *ex ante* savings (using PY5 per-unit assumptions) for customers in the same model, to calculate realization rates. Realization rates for electric participants and measures that can be applied to PY5 savings are shown in Table 27 below.

Table 27. Electric Realization Rates from PY4 Electric Billing Analysis

Model	Treatment and Post-Period Observations	*Ex Ante* Net Savings (kWh)		Observed Net Savings (kWh)		Realization Rate
		Average Daily Savings	Annual Average Savings	Average Daily Savings	Annual Average Savings	
Electric Space Heat Participants (Table 23)	4,809	5.03	1,836	2.72	993	54%
Non-Electric Space Heat Participants (Table 24)	33,293	2.21	808	1.15	419	52%
CFLs Only Participants (Table 25)	17,562	0.89	326	0.69	252	77%
Envelope Only Participants (Table 26)	13,230	4.19	1,530	1.65	602	39% [a]
Envelope Only w/ Electric Heat	902	13.6	4,974	4.44	1,621	33%
Envelope Only w/ Non-Electric Heat	12,328	3.5	1,278	1.44	527	41%

[a] The overall "Envelope Only" realization rate reflects the PY4 proportions of Electric Space Heat and Non-Electric Space Heat customers with envelope measures. To calculate the PY5 overall realization rate for envelope measures, we apply the realization rates specific to each heating type.

In Section A.2.3, we show PY5 *ex post* savings results that incorporate these realization rates.

Gas Model Results

As described in Section A.2.1, we used an overall model to estimate savings among all gas participants, and then developed separate models for each measure category. The overall savings model is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 28. Regression Model Results for Overall Gas Savings (among All Gas Participants)

(Dependent variable is average daily therm consumption.
Number of customers = 4,576, Number of observations = 132,806, R^2 = 0.804)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	-0.181	0.029	-6.32	0
postXhdd	-0.001	0.002	-0.78	0.436

Variable	Coefficient	Robust SE	t-statistic	p-value
postXcdd	0.010	0.002	5.89	0
Hdd	0.023	0.001	15.79	0
Cdd	-0.001	0.002	-0.75	0.454
Constant	0.701	0.017	41.35	0

To understand savings from envelope measures (insulation and air sealing), we developed a separate model to look at gas savings among gas participants whose *only* gas measures in the tracking data were envelope measures (insulation, air sealing, or both). These customers comprised 45% of PY4 participants and 49% of PY5 participants in the billing analysis. Further, these customers comprised 82% of all PY4 participants in billing analysis who installed envelope measures, and 86% of all PY5 participants in billing analysis who installed envelope measures. The results of the "Envelope Only" model is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 29. Regression Model Results for Gas Participants who installed Envelope Measures only (in gas tracking data)

(Dependent variable is average daily therm consumption.
Number of customers = 2,172, Number of observations = 62,430, R^2 = 0.809)

Variable	Coefficient	Robust SE	t-statistic	p-value
post	-0.196	0.039	-5.06	0
postXhdd	-0.010	0.002	-4.24	0
postXcdd	0.015	0.003	5.83	0
hdd	0.029	0.002	12.74	0
cdd	-0.003	0.003	-1.05	0.295
constant	0.667	0.026	26	0

To understand savings for domestic hot water (DHW) measures, we developed a separate model to look at gas savings among gas participants whose *only* gas measures in the tracking data were DHW (faucet aerators and low-flow showerheads). These customers comprised 45% of PY4 participants and 43% of PY5 participants in the billing analysis. Further, these customers comprised 82% of all PY4 participants in the billing analysis who installed DHW measures, and 85% of all PY5 participants in the billing analysis who installed DHW measures. The results of the "DHW Only" model is shown below. Note that we have included t-statistics, but they have little meaning given that these models were estimated on populations, not samples. Thus, there is no sampling error.

Table 30. Regression Model Results for Gas Participants who installed DHW measures only (in gas tracking data)

(Dependent variable is average daily therm consumption.
Number of customers = 2,005, Number of observations = 59,183, R^2 = 0.801)

Variable	Coefficient	Robust SE	t-statistic	p-value
post	-0.196	0.046	-4.26	0
postXhdd	0.009	0.003	3.11	0.002
postXcdd	0.011	0.003	4.19	0
hdd	0.020	0.002	9.63	0
cdd	0.001	0.003	0.49	0.622
constant	0.719	0.025	28.49	0

Using the coefficients from the models, we estimated savings using normalized weather and program characteristics. We used the weather normals for Springfield from the PY5 TRM[30] to predict expected average daily net savings among PY4 participants in each model, by applying the average normal weather values to all model terms containing HDD or CDD.

Then we calculated realization rates based on the *ex ante* savings. To calculate realization rates that could be applied to PY5 participants, we recalculated net *ex ante* savings for PY4 participants using PY5 savings assumptions (PY5 per-unit gross savings and PY5 NTGR). We compared evaluated net savings with net *ex ante* savings (using PY5 per-unit assumptions) for customers in the same model, to calculate realization rates. Realization rates for gas participants and measures that can be applied to PY5 savings are shown in the table below.

Table 31. Gas Realization Rates from PY4 Gas Billing Analysis

Model	Treatment and Post-Period Observations	*Ex Ante* Net Savings (therms)		Observed Net Savings (therms)		Realization Rate
		Average Daily Savings	Annual Average Savings	Average Daily Savings	Annual Average Savings	
All Participants (Table 28)	30,467	0.49	177	0.17	62	35%
Envelope Only Participants (Table 29)	13,385	0.88	321	0.30	109	34%
DHW Only Participants (Table 30)	14,501	0.06	20	0.02	7	36%

In Section A.2.2, we provide PY5 *ex post* savings results that incorporate these realization rates.

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30 Weather normals for Springfield in the PY5 TRM are 5,497 HDD using a base temperature of 65° and 1,108 CDD using a base temperature of 65°.

A.3.3 Apply Results to PY5 Measures

Table 32 below summarizes net *ex ante* and net *ex post* electric and demand savings for the PY5 HEP Program.

Table 32. PY5 Electric *Ex Post* Savings

Primary Space Heating Fuel and Measure Category	Number of Electric Accounts [a]	PY5 Ex Ante Net Savings [b]		Realization Rate [c]	PY5 Ex Post Net Savings [d]	
		Total kWh	Total kW		Total kWh	Total kW
Electric Space Heat						
Overall	427	1,186,372		54%	641,842	
CFLs	218	70,293		77%	54,414	
Envelope Measures	176	1,025,111		33%	333,768	
Non-Electric Space Heat			2,581.00			1,356.30
Overall	2,930	2,926,791		52%	1,519,603	
CFLs	1,534	541,476		77%	419,163	
Envelope Measures	1,566	2,316,052		41%	954,451	
Overall HEP Savings	**3,357 [c]**	**4,113,163**		**53%**	**2,161,445**	

[a] Reflects number of electric accounts in PY5 where any measure was installed.
[b] Source: PY5 program-tracking database.
[c] We calculated overall *ex post* HEP savings by applying realization rates from the Electric Space Heat model (among all ESH customers) and the Non-Electric Space Heat model (among all ESH customers) rather than applying measure-specific realization rates. The realization rate is calculated as the PY4 *ex post* net divided by the PY4 *ex ante* net (using PY5 per-unit savings assumptions).
[d] PY5 ex post net savings is calculated as the *ex ante* savings for all PY5 HEP electric accounts where any measure was installed multiplied by the estimated realization rate.
[e] Represents the total number of unique PY5 electric accounts with any claimed electric savings and project-level data, excluding ESHP participants. Note that these include participants who enrolled in the program in PY4, and installed measures in PY5.
Note: Values may not total due to rounding.

Table 33 summarizes net *ex ante* and net *ex post* savings for the PY5 HEP Program.

Table 33. PY5 Gas *Ex Post* Savings

Measure Category	Number of Gas Accounts [a]	PY5 *Ex Ante* Net Savings (Therms) [b]	Realization Rate [c]	PY5 *Ex Post* Net Savings (Therms) [d]
Envelope Measures	1,904	683,776	34%	232,557
DHW Measures	1,427	30,659	36%	11,113
Overall HEP Program Savings [e]	**3,109 [f]**	**714,434**	**35%**	**251,568**

[a] Reflects number of gas accounts in PY5 where any measure was installed.
[b] Source: PY5 program-tracking database.
[c] Realization Rate = *ex post* net value / *ex ante* net value among PY4 participants (using PY5 per-unit savings assumptions).
[d] PY5 ex post net savings is calculated as the ex ante savings for all PY5 HEP gas accounts where any measure was installed multiplied by the estimated realization rate.
[e] Overall *ex post* HEP savings are calculated by applying the overall realization rate (from PY4 billing analysis) to PY5 *ex ante* savings, rather than applying measure-specific realization rates.
[f] Represents the total number of unique PY5 gas accounts with any claimed gas savings and project-level data, excluding ESHP participants. Note that these include participants who enrolled in the program in PY4, and installed measures in PY5.

Measure Category	Number of Gas Accounts [a]	PY5 *Ex Ante* Net Savings (Therms) [b]	Realization Rate [c]	PY5 *Ex Post* Net Savings (Therms) [d]
Note: Values may not total due to rounding.				

B. Appendix: Engineering Analysis Algorithms

In PY5, the impact evaluation efforts estimated gross impact savings for the ESHP participants by applying savings algorithms from the 2012 Illinois Statewide Technical Reference Manual (2012 TRM)[31] to the information in the program-tracking database. The algorithms used to calculated all evaluated program saving are presented below, along with all input variables. We applied the PY3 HEP measure-specific NTGRs to the ESHP gross savings to obtain PY5 net savings.

B.1 Lighting Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to determine *ex post* lighting savings.

Equation 1. Interior Hardwired CFL Algorithms

Energy Savings: $\Delta kWh = ((WattsBase - WattsEE) / 1000) * ISR * HOURS * WHF_e$

Demand Savings: $\Delta kW = ((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF$

Where:

WattsBase = Wattage of existing equipment

WattsEE = Wattage of installed equipment

ISR = In-service rate or the percentage of units rebated that get installed = 97%[32]

HOURS = Annual operating hours = 938 hours

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 = .095

B.2 Lighting Measures Heating Penalty

The evaluation team used the algorithms below, from the 2012 TRM, to determine heating penalty for electric and gas heated homes.

[31] State of Illinois: Energy Efficiency Technical Reference Manual. Final as of September 14, 2012. Effective June 1, 2012.

[32] ISR calculated for the ESHP program in PY4 are used for PY5 participants.

Equation 2. Heating Penalty Algorithms

Heating Energy Savings: *ΔkWh = -(((WattsBase - WattsEE) / 1000) * ISR * HOURS * HF) / ηHeat*

Heating Therm Savings: *Δtherms = -(((WattsBase – WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat*

Where:

WattsBase = Wattage of existing equipment

WattsEE = Wattage of installed equipment

ISR = In-service rate or the percentage of units rebated that get installed = 97%[33]

HOURS = Annual operating hours = 938 hours

HF = Heating Factor = .49

ηHeat = Efficiency of Heating equipment (Assumed COP 2.0 for heat pumps and AFUE 0.8)

Table 34. Heating Penalty

Lighting Measure	Heating Equipment	ΔkWh	ΔkW	Δtherms
CFL - Low 13 to 15 Watt	Heat Pump (htg only)	-10.25	n/a	n/a
CFL - Medium 18 to 20 Watt	Heat Pump (htg only)	-12.48	n/a	n/a
CFL - High 23 to 25 Watt	Heat Pump (htg only)	-10.92	n/a	n/a
CFL - Low 13 to 15 Watt	Electric Resistance	-20.51	n/a	n/a
CFL - Medium 18 to 20 Watt	Electric Resistance	-24.97	n/a	n/a
CFL - High 23 to 25 Watt	Electric Resistance	-21.85	n/a	n/a
CFL - Low 13 to 15 Watt	Gas Heating	n/a	n/a	-0.87
CFL - Medium 18 to 20 Watt	Gas Heating	n/a	n/a	-1.06
CFL - High 23 to 25 Watt	Gas Heating	n/a	n/a	-0.93

B.3 Water Heating Measure Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to determine *ex post* water heating measure savings.

Equation 3. Showerhead Algorithms

Energy Savings: *ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR*

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[33] ISR calculated for the ESHP in PY4 are used for PY5 participants.

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

Therm Savings: *ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_gas * ISR*

Equation 4. Faucet Aerator Algorithms

Energy Savings: *ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_electric * ISR*

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

Therm Savings: *ΔTherms = %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	1.2	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	8.2

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 = .795 (unknown location)

FPH = Faucets Per Household = 2.83 (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	0.004
Showerhead	0.127	0.0054

ISR = In-Service Rate[34]

Table 38. ISR for Water Heating Measures

Measure	ISR
Faucet Aerator	95%
Showerhead	98%

Hours = Annual electric DHW recovery hours

Table 39. Hours for Water Heating Measures

Measure	Hours
Faucet Aerator	197
Showerhead	431

CF = Coincidence Factor for electric load reduction

Table 40. CF for Water Heating Measures

Measure	CF
Faucet Aerator	0.0220
Showerhead	0.0278

B.4 Air Sealing Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to determine *ex post* air sealing savings.

Equation 5. Air Sealing Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

*ΔkWh_cooling = [(((CFM50_existing - CFM50_new)/N_cool) * 60 * 24 * CDD * DUA * 0.018) / (1000 * ηCool)] * LM*

*ΔkWh_heating (electric heat) = (((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018) / (ηHeat * 3,412)*

Demand Savings: *ΔkW = (ΔkWh_cooling / FLH_cooling) * CF*

[34] ISR calculated for the ESHP in PY4 are used for PY5 participants.

Gas Savings (gas heat): $\Delta Therms = (((CFM50\_existing - CFM50\_new)/N\_heat) * 60 * 24 * HDD * 0.018) / (\eta Heat * 100{,}000)$

$\Delta kWh\_heating$ (gas heat furnace fan run time reduction) $= \Delta Therms * F_e * 29.3$

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[35]

CDD = Cooling Degree Days

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 = Seasonal Energy Efficiency Ratio (SEER) of cooling system

Table 42. ηCool for Air Sealing Measures

Measure	ηCool
Central Air Conditioner	10
ASHP	10
GSHP	16.9

LM = Latent Multiplier to account for latent cooling demand

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

[35] Assumed Zone 2 Normal Exposure.

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions = 15.75[36]

HDD = Heating Degree Days

Table 44. Heating Degree Days 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

Table 45. ηHeat for Air Sealing Measures

Measure	ηHeat
Gas Furnace	0.7
Electric Resistance	1.0
Air Source Heat Pump (ASHP)	1.7
GSHP	3.6

FLH_cooling = Full Load Hours of air conditioning

Table 46. 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

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

B.5 Attic and Wall Insulation Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to determine *ex ante* attic and wall insulation savings.

[36] Applied average of 1, 1.5, 2 and 3 story homes for homes with normal exposure in Zone 2.

Equation 6. Attic Insulation Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

*ΔkWh_cooling = (((1/R_old - 1/R_new) * A_attic * (1-Framing_Factor/2)) * 24 * CDD * DUA) / (1000 * ηCool)*

*ΔkWh_heating (electric heat) = (((1/R_old - 1/R_new) * A_attic *(1-Framing_Factor/2))) * 24 * HDD) / (ηHeat * 3412)*

Demand Savings: *ΔkW = (ΔkWh_cooling / FLH_cooling) * CF*

Gas Savings (gas heat): *ΔTherms = (((1/R_old - 1/R_new) * A_attic * (1-Framing_Factor/2)) * 24 * HDD) / (ηHeat * 100,067 Btu/therm)*

*ΔkWh_heating (gas heat furnace fan run time reduction) = ΔTherms * F_e * 29.3*

Equation 7. Wall Insulation Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

*ΔkWh_cooling = (((1/R_old - 1/R_new) * A_wall * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool)*

*ΔkWh_heating (electric heat) = (((1/R_old - 1/R_new) * A_wall* (1-Framing_factor))) * 24 * HDD) / (ηHeat * 3412)*

Demand Savings: *ΔkW = (ΔkWh_cooling / FLH_cooling) * CF*

Gas Savings (gas heat): *ΔTherms = (((1/R_old - 1/R_new) * A_wall * (1-Framing_factor)) * 24 * HDD) / (ηHeat * 100,067 Btu/therm)*

*ΔkWh_heating (gas heat furnace fan run time reduction) = ΔTherms * F_e * 29.3*

Where:

R_new = Total attic or wall assembly R-value after the installation of additional insulation (see Equation 8 for assembly R-value algorithms)

R_old = R-value of existing attic or wall assembly and any existing insulation with a minimum of R-5 (see Equation 8 for assembly R-value algorithms)

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 (Framing Factor included in the assembly R-value algorithms; see Equation 8)

CDD = Cooling Degree Days

Table 47. Cooling Degree Days by Climate Zone

Climate Zone	CDD
1 (Rockford)	820
2 (Chicago)	842

Climate Zone	CDD
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

DUA = Discretionary Use Adjustment = 0.75

ηCool = Seasonal Energy Efficiency Ratio of cooling system = 10 SEER

HDD = Heating Degree Days

Table 48. 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

ηHeat = Efficiency of heating system

Table 49. Assumed ηHeat by Heat Type

Measure	ηHeat
Gas Furnace	0.7
Electric Resistance	1.0
Air Source Heat Pump (ASHP)	1.7
GSHP	3.6

FLH_cooling = Full Load Hours of air conditioning

Table 50. 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

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

Because the R-values in these algorithms are stated to be assembly R-values, our engineering calculations deviated somewhat from the TRM as follows:

- We determined the assembly wall value using the ASHRAE Isothermal Planes method (page 27.3, ASHRAE Fundamentals, 2013).

- This method includes the IL TRM framing factor within the calculations as shown below
- Equation 8 was not applied to calculate assembly R-values for pre-existing attic or wall insulation for those with R-values less than 5. These cases were assigned an assembly R-value of 5 for both attic and wall insulation.

The following algorithms were used to calculate the assembly R-values for attic insulation and wall insulation:

Equation 8. Attic and Wall Assembly R-value Algorithms

$$\text{Attic Assembly R-value} = ((1/\text{R-value}_{database}) * \% \text{ of Assembly} + 1/\text{R-value}_{Joist} * \text{Framing\_Factor} /2) + (\text{R-value}_{indoor\ air\ film} + \text{R-value}_{plywood} + \text{R-value}_{gypsum} + \text{R-value}_{indoor\ air\ film})$$

$$\text{Wall Assembly R-value} = ((1/\text{R-value}_{database}) * \% \text{ of Assembly} + 1/\text{R-value}_{WoodStud2x4} * \text{Framing\_Factor}) + (\text{R-value}_{outdoor\ air\ film} + \text{R-value}_{claytile} + \text{R-value}_{rigid\ foam} + \text{R-value}_{gypsum} + \text{R-value}_{indoor\ air\ film})$$

Where:

$\text{R-value}_{database}$ = Pre or post insulation R-value found in the database (for R-values that are greater than 5)

Framing_factor = Adjustment to account for area of framing = 0.15

Figure 6. Engineering Factors Used within Attic Insulation Calculations

No Insulation				With Insulation			
N	Element	R	R	N	Element	R	R
1	indoor air film, still air		0.68	1	indoor air film, still air		0.68
2	air[a]	0.86	0.92	2	mineral fiber batt insulation	19	16.22
3	Joist (nominal 5.5") - southern pine	5.78		3	Joist (nominal 5.5") - southern pine	5.8	
4	plywood, 5/8", douglas fir		0.85	4	plywood, 5/8", douglas fir		0.85
5	gypsum wallboard, 0.5 inch		0.45	5	gypsum wallboard, 0.5 inch		0.45
6	indoor air film, still air		0.68	6	indoor air film, still air		0.68
	R value		3.6		R value		18.9
	U value		0.28		U value		0.05
	% of assembly	0.925	0.075		% of assembly	0.925	0.075
	U of assembly	0.28			U of assembly	0.05	
	R of assembly	3.58			R of assembly	18.88	

[a]horizontal position, up heat flow, 50 degree mean with 30 degree difference, emissivity of 0.82 for building materials, 5.5" air space

Figure 7. Engineering Factors Used within Wall Insulation Calculations

No Insulation				With Insulation			
N	Element	R	R	N	Element	R	R
1	Outdoor Air film, 15 mph wind		0.17	1	Outdoor Air film, 15 mph wind		0.17
2	clay tile, 1 cell deep, 4", no insulation		1.11	2	clay tile, 1 cell deep, 4", no insulation		1.11
3	rigid foam insulating sheathing		4	3	rigid foam insulating sheathing		4
4	air[a]	1.25	1.40	4	mineral fiber batt insulation	13	10.04
5	Wood stud (nominal 2 x 4)	4.38		5	Wood stud (nominal 2 x 4)	4.38	
6	gypsum wallboard, 0.5 inch		0.45	6	gypsum wallboard, 0.5 inch		0.45
7	indoor air film, still air		0.68	7	indoor air film, still air		0.68
	R value		7.8		R value		16.5
	% of assembly	0.85	0.15		% of assembly	0.85	0.15
	R of assembly	7.81			R of assembly	16.45	

[a]vertical position, horizontal heat flow, 50 degree mean with 30 degree difference, emissivity of 0.82 for building materials

B.6 Rim Joist Insulation Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the *ex post* rim joist insulation savings. The TRM does not have algorithms specifically for rim joist, therefore the basement sidewall insulation algorithms were used. It was verified that the *ex ante* savings were calculated using the same algorithms from the 2012 TRM.

Equation 9. Rim Joist Insulation Algorithms

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

$$\Delta kWh\_cooling = (((1/R\_old\_AG - (1/(R\_new + R\_old\_AG))) * L\_rimjoist * H\_rimjoist * (1-Framing\_factor)) * 24 * CDD * DUA) / (1000 * \eta Cool)$$

$$\Delta kWh\_heating\ (electric\ heat) = (((1/R\_old\_AG - (1/(R\_new + R\_old\_AG))) * L\_rimjoist * H\_rimjoist * (1-Framing\_factor)) * 24 * HDD) / (3412 * \eta Heat)$$

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

Gas Savings (gas heat): $\Delta Therms = (((1/R\_old\_AG - (1/(R\_new + R\_old\_AG))) * L\_rimjoist * H\_rimjoist * (1-Framing\_factor)) * 24 * HDD) / (100{,}067 * \eta Heat)$

$$\Delta kWh\_heating\ (gas\ heat\ furnace\ fan\ run\ time\ reduction) = \Delta Therms * F_e * 29.3$$

Where:

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

R_new = R-value of new rim joist insulation

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 = 0.0 for spray foam

CDD = Cooling Degree Days (assumed unconditioned basement)

Table 51. 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 = Seasonal Energy Efficiency Ratio of cooling system = 10 SEER

HDD = Heating Degree Days (assumed unconditioned basement)

Table 52. Heating Degree Days 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

Table 53. Assumed ηHeat by Heat Type

Measure	ηHeat
Gas Furnace	0.7
Electric Resistance	1.0
Air Source Heat Pump (ASHP)	1.7

FLH_cooling = Full Load Hours of air conditioning

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

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

C. Appendix: Cost-Effectiveness Inputs

Table 55 presents net impacts for AIC cost-effectiveness calculations. These values differ from those included in the main report due to the inclusion of heating penalties. This approach was taken based on discussions with AIC, and past agreement between AIC and ICC staff that heating penalties would not be included in savings calculations for goal attainment.

Table 55. PY5 HEP Net Impacts (Including Heating Penalties)

Component	Electric Savings (MWh)	Demand Savings (MW)	Gas Savings (Therms)
HEP	3,811.50	2.86	690,864
ESHP	39.36	0.01	18.91
Total	**3,850.86**	**2.87**	**690,882.72**