Impact and Process Evaluation of 2012 (PY5) Ameren Illinois Company Warm Neighbors Cool Friends (Moderate Income) Program

Draft

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1. EXECUTIVE SUMMARY

This report presents results from the evaluation of the second program year of Ameren Illinois Company's (AIC's) ActOnEnergy Moderate Income or Warm Neighbors Cool Friends (WNCF) Program for PY5 (June 2012 to May 2013). The program began as a pilot in PY3.

Implemented by Conservation Services Group (CSG), the WNCF program is a home diagnostic and whole-house retrofit program that focuses on serving AIC customers who do not qualify for low-income weatherization assistance, but cannot afford to pay market prices for energy efficiency retrofit improvements to their homes. The target market is existing homes heated by a fuel source (electricity or natural gas) provided by AIC and owned by customers with a household income between 200% and 300% of the federal poverty level guidelines for household size.

This evaluation reviews the program's performance in Program Year 5 (PY5), which began in June 2012 and ended in May 2013. The expected savings from this program is less than 1% of the overall PY5 portfolio of electric savings and 2% of the overall portfolio of therm savings.

In PY5, we conducted an impact evaluation 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 another estimate of the savings using customer bills. We applied a NTGR of 1.0 to gross savings to obtain PY5 WNCF program net savings. As a result, ex post gross and net impacts are identical.

Impact Results

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

Table 1. PY5 WNCF Program Net Impacts

Number of Participants	Ex Ante Net[a]			Ex Post Net		
	kWh	kW	Therms	kWh	kW	Therms
260	568,260	441	134,700	534,471	473	123,521
			Net Realization Rate[b]	94%	107%	92%

[a] Source of ex ante savings: PY5 program-tracking database.
[b] The realization rate is calculated as the PY5 net ex post savings divided by the PY5 ex ante net savings.

Process Results

Overall, program staff implemented the WNCF program according to its design with minor changes and a few challenges. Despite meeting its PY5 participation goal of reaching 260 participants,

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

program staff noted that it is an ongoing challenge to effectively market to potential WNCF participants. Given that participation is limited by eligibility criteria and grant funding, marketing and outreach activities are also limited. Program staff described having reached a balance in PY5 between filling the pipeline with interested customers and providing audits one to two weeks later.

Similar to PY4, program staff state that about 20% of applicants are disqualified because their homes include such items as knob and tube wiring, vermiculite, and holes in the roof. It is often difficult for customers with modest incomes to remediate the problems before they can be accepted into the program. Project coordinators who interface with these customers during the audit to provide references to contractors who can remediate disqualifying features.

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[2] to provide inputs for future planning efforts. The billing analysis included a comparison group,[3] providing net savings.

While the engineering estimates show realization rates very close to 100%, from the billing analysis, we found that the WNCF program achieved a little over one third of anticipated *ex ante* electric and gas net savings.[4] We cannot state for certain why there is such a large 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 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 WNCF participants. It is a different approach than billing analysis, but both take

[2] The evaluation team conducted a one-way fixed effects linear model incorporating a treatment group of PY4 program participants and a comparison group of PY5 program participants.

[3] Inclusion of a comparison group acts as the counterfactual and provides what would have occurred absent the program. For this analysis, the PY4 WNCF participants were the treatment group, and the PY5 WNCF participants were the comparison group. Once customers participated in the PY5 WNCF Program, they were dropped from the model.

[4] Ex ante net savings are based on TRM algorithms.

advantage of actual data. Additionally, within a calibrated model, savings from individual measures can be drawn out of the overall results.

2. INTRODUCTION

This report presents results from the evaluation of the second program year of the Ameren Illinois Company (AIC) ActOnEnergy Residential Warm Neighbors Cool Friends (WNCF) Program for PY5 (June 2012 to May 2013). The program began as a pilot in PY3. To support the evaluation we reviewed program materials and program-tracking data, and conducted interviews with implementation and AIC staff. Our impact analysis effort included an engineering review and application of savings, as well as a billing analysis to serve as an input for program planning.

Program Description

The WNCF program is a home diagnostic and whole-house retrofit program that serves AIC residential customers who do not qualify for low-income weatherization assistance, but cannot afford energy efficiency retrofit improvements to their homes. The target market is existing homes heated by a fuel source (electricity or natural gas) provided by AIC and owned by customers with a household income between 200% and 300% of the federal poverty level guidelines for household size.

There are two main firms involved in implementing this program. The Conservation Services Group (CSG) the program performs no-cost energy audits for targeted customers. The Energy Assistance Foundation (EAF)[5] refers customers to CSG as well as contributing funding to help defray costs not covered by the program. The program requires customers to pay a small portion of the overall project cost (the greater of $500 or 10% of the total project cost, in addition to any amount not covered by program incentives). After determination of what the customer should pay based on program incentives, EAF grants additional funds up to $3,000 to cover the remainder of the project cost.

EAF is involved in participant outreach and intake, differentiating the Program from other home performance offerings. In particular, customers who are interested in participating in the program submit their application to the foundation, which screens customers for eligibility. If the customers are eligible, EAF shares this information with CSG to schedule an appointment.

Once a participant enters the program, several measures are installed at the time of the on-site audit. These instant savings measures (ISMs) include CFLs and/or water conservation measures. Audits include the installation of ISMs, a comprehensive energy evaluation utilizing a blower door and a thermal scan of the house using an infrared camera. Homeowners then receive a custom report with a work order of recommended energy efficiency improvements that they are encouraged to install by contracting with CSG. CSG then subcontracts the work to selected Home Energy Performance (HEP) allies. Retrofit measures installed after the audit include insulation, air sealing and heating and cooling equipment replacements.

Research Objectives

The objective of the PY5 WNCF 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.

[5] A nonprofit organization funded through donations by AIC employees and customers.

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 explored 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 detail the evaluation activities conducted for the PY5 WNCF Program, along with the methods used. The assessment of the PY5 AIC WNCF program included both process and impact analyses.

3.1 DATA SOURCES AND ANALYTICAL METHODS

Table 2 presents the evaluation activities we conducted for the PY5 evaluation.

Table 2. Summary of WNCF Evaluation Activities

Activity	PY5 Impact	PY5 Process	Details
Program Material Review		X	Included review of 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	The evaluation team conducted interviews with the AIC WNCF program manager and CSG program manager in PY5 to understand the program's design, implementation, and evaluation priorities.
Participant Database Analysis	X	X	The evaluation team assessed program participation and measure installation as input to impact evaluation.
Engineering Review	X		We conducted an engineering analysis for all WNCF PY5 participants.
Billing Analysis	X		Conducted a billing analysis to quantify the actions taken among the treatment and comparison group members.
Comparison Group Selection	X		For the billing analysis, the evaluation team used PY5 participants as a comparison group for the PY4 participants; we assessed the equivalency of these two groups prior to estimating net program impacts.

The evaluation team used the following data sources in evaluating the WNCF Program:

- 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)[6]
- Electric and gas billing usage data for all PY4 treatment and PY5 comparison group customers
- Weather data (heating degree days (HDD) and cooling degree days (CDD)

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

3.1.1 PROCESS ANALYSIS

Process evaluation activities in PY5 were limited, as the primary evaluation task for this year was the impact analysis. As a result, the process analysis is based largely on in-depth interviews. In particular, the evaluation team conducted interviews with program managers from CSG and AIC to determine whether the program was implemented according to design, if there had been any changes to program design and implementation from PY4, and any implementation challenges that have occurred in PY5.

3.1.2 IMPACT ANALYSIS

The primary objective of this evaluation was to estimate the energy savings impacts from installing measures. 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 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 WNCF 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 A, along with all input variables.

We applied a NTGR of 1.0 to gross savings to obtain PY5 WNCF program net savings. In PY3, the evaluation team discussed and reached agreement with the ICC and AIC staff given our understanding of program design and targeted customers. This is due to the fact that the program is targeted to participants who fall within 200% and 300% of the federal poverty level guidelines for household size. As such, participants are unlikely to have installed many of the measures offered through the program without assistance. As a result, ex post gross impacts and ex post net impacts are identical.

Billing Analysis

We conducted a billing analysis[7] of 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 provided in the TRM and NTGRs, helping to identify areas where further primary data collection efforts can improve accuracy of underlying engineering assumptions.

Because a billing analysis is best conducted on a complete year of billing data before and a complete year of billing data after 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

[7] The evaluation team conducted a one-way fixed effects linear model incorporating a comparison group of PY5 program participants.

the majority of participants are dual fuel customers with a mix of electric and gas measures, the evaluation estimated both electric and gas savings.

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 & Challenges

Overall, the WNCF program was implemented according to its design. The program made the following minor design changes in PY5.

- **Changed Measure Mix:** The program made slight measure changes midyear. These changes included: offering electronically commutated motors (ECMs) for furnaces, replacing 95% Annual Fuel Utilization Efficiency (AFUE) boilers with 90% AFUE boilers (which was partly due to controlling program costs and partly due to a change in Department of Energy testing protocols in which 95% AFUE boilers no longer achieved the stated Air-Conditioning, Heating, and Refrigeration Institute (AHRI) efficiency), and offering incentives for basement wall and crawl space insulation.
- **Removed EAF Funding for Central Air Conditioning:** The program removed EAF funding (but kept AIC funding) for central air conditioning (CAC) replacements as it was deemed non-essential equipment that added to the cost per project. By removing EAF funding, program staff were able to provide services to additional households within the project budget.

According to program staff, changes in measure offerings were made for a number of reasons. Program staff anticipated replacing per-unit savings and incentive values from evaluated savings to TRM algorithms in PY5. However, due to delays in the TRM, PY4 measure and incentive levels were maintained moving into PY5, which proved to be more costly than the values used for PY5 planning purposes. In addition, the major measure mix installed in PY5 was different than planned, which led to more expensive gas savings and overall less electric savings.

Other program changes included moving QA/QC procedures in-house by using the CSG's project coordinators, account managers and QA inspectors from the WNCF program to perform QA and QC on all projects. In addition, the WNCF program became an approved Illinois Home Performance with ENERGY STAR® (HPwES) provider. Since program inception, CSG has focused on developing a local home performance industry and transforming the program into a more comprehensive HPwES program. The program became an approved HPwES provider in PY5. By the end of PY5, about 10% of the homes were HPwES, with 16 Gold and 13 Silver Illinois HPwES certificates.

Program staff indicated that the program continues to have challenges finding opportunities to market to this hard to reach population as well as finding customers who qualify for services.

While the program met its PY5 participation goal, program staff noted that it is an ongoing challenge to effectively market to potential WNCF participants. Given that participation is limited by eligibility criteria and grant funding, marketing and outreach activities are also limited. Program staff described having reached a balance in PY5 between filling the pipeline with interested customers and providing audits one to two weeks later. They also stated that the most effective PY5 marketing channel continues to be word of mouth referrals. Similar to PY4, PY5 marketing and outreach efforts included letters to WNCF audit customers who are eligible for the program (i.e., income profile),

referrals from AIC program ally contractors, outreach to organizations that serve participants (i.e., churches, senior centers, community programs), and word of mouth from program participants to friends, family, and colleagues. In PY5, the implementation team expanded marketing to churches and libraries using existing program flyers.

Similarly to PY4, program staff state that about 20% of applicants are disqualified because their homes include such items as knob and tube wiring, vermiculite, and holes in the roof. Such disqualification often occurs in the St. Louis Metro East area. Project coordinators who interface with these customers during the audit and test-in provide references to contractors who can remediate disqualifying features. It is often difficult for customers with modest incomes to remediate the problems before they can be accepted into the program.

Participation & Conversion Rates

In PY5, the program reached 260 participants, surpassing their goal of 250 retrofit projects. Notably, 40 participants had enrolled and participated in PY4, but then went on to install measures and claim savings in PY5.

Participation is limited to the amount of grant funds available. In PY5, the participation experience varied somewhat across the 260 participants based on the services received. As shown in Table 3, the team grouped participants based on whether they received an audit or retrofit alone, or both services. Overall, a little over half of the participants (53%) received an on-site audit where they received Instant Savings Measures (ISMs) and installed retrofit measures through a participating contractor. Notably, a little under a third of participants received "Retrofit Only" services. According to program staff, these customers were either 1) referrals from an HEP program audit if income qualified, or 2) disqualified WNCF audit recipients who remediated disqualifying features.

Table 3. Overview of PY5 Participation by Services Received

Participant Type	Number of Participants	% of Participants [a]
Audit & Retrofit	138	53%
Retrofit Only	74	28%
Audit Only (received ISMs)	48	18%
Total	**260**	**100%**

[a] Sub totals do not sum to 100% due to rounding.

The conversion rate, a key metric of program performance, is calculated by dividing the number of participants who received a retrofit following an audit by the number of participants who received an audit, a key metric of program performance. In Table 4, we compare conversion rates between PY4 and PY5. Across PY4 and PY5, the conversion rate increased in PY5, however, this may be due to fluctuations that occur year over year rather than changes to program delivery and implementation.

Table 4. PY4 and PY5 Conversion Rates

Participant Type	PY4 Participants	PY5 Participants
Audit & Retrofit	171	138
Audit Only	99	48
Total	**270**	**186**
Conversion Rate	**63%**	**74%**

Measures Installed

Program participants install a variety of measures through the program. Table 5 provides an overview of households that received measures and the total number of measures received based on program-tracking data.

Table 5. Overview of PY5 WNCF Participation by Measure Category

Measure Category	Measure	Unique Households[a]	# of Measures	Unit
Lighting	CFL - Low 13 TO 15 Watt	111	864	Bulb
	CFL - Medium 18 to 20 Watt	53	344	Bulb
	CFL - High 23 to 25 Watt	49	297	Bulb
Domestic Hot Water (DHW)	Faucet Aerators	91	133	Aerator
	Showerheads	130	146	Showerhead
HVAC	Air Heat Pump Replacement	3	3	Heat pump
	Central AC Replacement	67	67	CAC
Boiler/Furnace	Furnace >95	190	192	Furnace
	Gas Boiler >90	8	8	Boiler
Envelope	Air Sealing	223	376,418	CFM
	Attic Insulation	192	192,265	Sqft or Lf
	Wall Insulation	143	125,266	Sqft or Lf
	Rim Joist Insulation	107	11,669	Lf
	Crawl Space Insulation	49	10,894	Sqft or Lf
	Basement Wall Insulation	2	82	Sqft or Lf
Thermostat	Programmable Thermostat	238	240	Thermostat

[a] Note that the number of households in Table 5 is greater than the number of unique households (N=260) since any given household could install more than one measure.

4.2 IMPACT FINDINGS

The evaluation team conducted an engineering analysis to derive PY5 WNCF impacts. The results of are provided below.

Table 6. PY5 WNCF Program Net Impacts

Number of Participants	Ex Ante Net[a]			Ex Post Net		
	kWh	kW	Therms	kWh	kW	Therms
260	568,260	441	134,700	534,471	473	123,521
			Net Realization Rate[b]	94%	107%	92%

[a] Source of ex ante savings: PY5 program-tracking database.
[b] The realization rate is calculated as the PY5 net ex post savings divided by the PY5 ex ante net savings.

The evaluation team applied a net-to-gross ratio of 1.0 to the evaluated gross savings. In PY3, the evaluation team discussed and reached agreement with the ICC and AIC staff given our

understanding of program design and targeted customers. This is due to the fact that the program is targeted to participants who fall within 200% and 300% of the federal poverty level guidelines for household size. As such, the program participants are unlikely to have installed many of the measures offered through the program without assistance. As a result, ex post gross impacts and ex post net impacts are identical.

Detailed Results

Below we provide net impact results by measure. We calculated ex post net 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 7 below). The net realization rate was 94% for electric savings, 107% for demand savings, and 92% for gas savings.

Table 7. WNCF Impacts by Measure

Measure	Ex Ante Net Impacts			Ex Post Net Impacts [a]			Net Realization Rate [b]		
	kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
CFL - Low 13 to 15 Watt	38,292	4.06	-	38,331	4.07	-	100%	100%	NA
CFL - Medium 18 to 20 Watt	18,559	1.96	-	18,579	1.97	-	100%	100%	NA
CFL - High 23 to 25 Watt	14,021	1.49	-	14,036	1.49	-	100%	100%	NA
Faucet Aerators	253	0.03	240.03	253	0.03	239.88	100%	100%	100%
Showerheads	2,943	0.19	2,158	2,943	0.19	2,158	100%	100%	100%
Air Heat Pump Replacement	7,200	0.90	-	6,511	2.15	-	90%	239%	NA
Central AC Replacement	57,641	60.21	-	73,745	75.38	-	128%	125%	NA
Furnace >95	-	-	40,079	-	-	31,809	NA	NA	79%
Gas Boiler >90	-	-	1,755	-	-	2,196	NA	NA	125%
Air Sealing	318,879	312.63	43,637	296,218	315.89	44,921	93%	101%	103%
Attic Insulation	36,542	17.78	12,260	35,783	29.89	17,706	98%	168%	144%
Wall Insulation	50,460	35.92	22,058	41,545	41.62	18,986	82%	116%	86%
Rim Joist Insulation[c]	6,404	2.15	2,060	-	-	-	0%	0%	0%
Crawl Space Insulation[c]	9,712	4.09	4,731	-	-	-	0%	0%	0%
Basement Wall Insulation[c]	66	0.03	43.46	-	-	-	0%	0%	0%
Programmable Thermostat	7,286	-	5,679	6,527	-	5,505	90%	NA	97%

Measure	Ex Ante Net Impacts			Ex Post Net Impacts [a]			Net Realization Rate [b]		
	kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
Total	568,260	441.44	134,700	534,471	473.67	123,521	94%	107%	92%

Note: Numbers may not total due to rounding.
[a] Ex post net impacts are based on the application of deemed fixed savings values to verified participation numbers.
[b] Net Realization Rate = ex post net value / *ex ante* net value.
[c] The absence of ex post savings for rim joist insulation, crawl space insulation and basement wall insulation is explained below as are other differences between ex ante and ex post savings estimates.

Table 8 below shows measures where per-unit ex ante savings were different from ex post per unit savings. The ex post per-unit values were calculated using the algorithms presented in the 2012 TRM.

Table 8. WNCF Program PY5 Ex Ante and Ex Post Per-Unit Savings Values

Component	Measure	Ex Ante Per-Unit Savings			Ex Post Per-Unit Savings		
		kWh	kW	Therms	kWh	kW	Therms
Heating/Cooling	Programmable Thermostats - Electric	1,320.85	NA	NA	1,018.91	NA	NA
Heating/Cooling	Programmable Thermostats - Gas	41.47	NA	45.07	40.09	NA	43.69

Based on our understanding of the agreement between the ICC and AIC to not count heating penalties in impacts toward goals, interactive effects were not included in ex post savings calculations of lighting measures, decreasing CFL per-unit values slightly. 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 A for use in cost-effectiveness calculations.

Ex post gross savings differ from *ex ante* gross savings largely due to lower base load or baseline heating or cooling efficiencies than specified in the TRM, inability to find data in the program-tracking database, and in one case an application of NTGR other than 1.0. We outline why ex post and ex ante gross savings differ by measure category below:

- Air sealing, attic insulation and wall insulation all have differences in realization rates due to the following:
  - Variable assumptions in the savings algorithm calculations.
  - *Ex ante* calculations used lower gas efficiencies (AFUE 0.65) than what is specified in the TRM (AFUE 0.7)
- Rim joist, crawl space and basement wall insulation ex post savings are significantly different from *ex ante* for the following reasons:
  - The evaluation team had difficulty determining the needed details for these measures. We did discuss how to look for information within the program database with CSG, but found little evidence of specifics. These measures are recorded as an "Other" type of insulation in the database, with specifications provided in the notes section. However, the database showed no participants who received *ex ante* savings for these measures. As such, the evaluation team was unable to calculate ex post savings for these measures.

- Programmable thermostat has a slightly lower realization rate for unknown reasons
- Gas boilers have a higher realization rate as ex ante calculations used a lower gas boiler base load than what is specified in the TRM. We did discuss this with CSG; this was done for participants who received shell measures as heating loads are reduced as a result of installed shell measures.
- Gas furnace has a lower realization rate due to the following:
    - Ex ante calculations used lower baseline gas efficiencies (AFUE 0.65) than what is specified in the TRM. Ex post calculations use actual efficiencies, when available, or use the default efficiency specified in the TRM (AFUE 0.8).
    - Ex ante calculations account for early retirement savings for 70 participants. It was found that 44 of the 70 participants did not have an actual efficiency associated with them in the database, and therefore an efficiency of 0.80 AFUE (default TRM value) was applied to these 44 participants when calculating the ex post savings. The ex ante efficiency assumptions for these participants is unknown, however it is likely the baseline efficiency is less than the TRM value of 0.8 resulting in a greater ex ante savings when compared to the ex post.
- Heat pump realization rate is lower for electric savings and higher for demand savings due to the following:
    - Ex ante calculations used lower efficiency values (HSPF 6.0) than what is specified in the TRM (HSPF 7.7)
    - Ex ante calculations applied a reduced capacity for the newly installed system for reduced heating/cooling loads as a result of installing envelope measures. The impact in which the implementation of envelope measures has in relation to the reduction in HVAC equipment sizing is unknown. The ex post savings were calculated using the actual capacity of the existing equipment as seen in the database. Reducing the capacity for the installed equipment resulted in greater ex ante savings when compared to ex post savings for heat pumps.
    - Ex ante calculations account for a combination of early retirement and replace on burnout savings. Ex post calculations applied the actual efficiencies for both the existing and installed equipment as seen in the database.
    - The ex ante net savings uses a 0.76 NTGR whereas the ex post savings uses a NTGR of 1.0.
- Central Air Conditioner has a higher realization rate due to the following:
    - Both ex ante and ex post energy calculations applied early retirement and replace on burnout algorithms. Ex post energy savings calculations used the actual existing efficiency for all early retirement installations and the minimum standard baseline efficiency of 13 SEER for all replace on burnout installations. The actual efficiency of the installed equipment was used for all participants regardless of early replacement or replace on burnout for ex post calculations. It is unknown how efficiencies were applied when calculating ex ante savings.

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. In this section, we provide our results of this year's billing analysis, but ultimately recommend that another year of billing data accumulate before consideration of application of Illinois specific billing analysis values within any TRM adjustment. Table 9 provides the engineering and billing analysis results.

Table 9. PY5 WNCF Program Net Impacts, by Approach

Analytical Approach	Ex Ante Net[a]			Ex Post Net		
	kWh	kW	Therms	kWh	kW	Therms
Engineering Analysis	568,260	441	134,700	534,471	473	123,521
	Net Realization Rate[b]			94%	107%	92%
Billing Analysis	568,260	441	134,700	211,203	164	51,120
	Net Realization Rate[c]			37%	37%	38%

[a] Source of ex ante savings: PY5 program-tracking database.
[b] The engineering analysis realization rate is calculated as the PY5 net ex post savings divided by the PY5 ex ante net savings.
[c] The billing analysis realization rate is calculated as the PY4 net ex post savings (observed in billing analysis) divided by the PY4 ex ante net savings (using PY5 per-unit savings assumptions).

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 affect 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 WNCF program achieved approximately one-third of anticipated ex ante electric and gas net savings, we explored the ex ante and billing analysis data in an effort to understand why. The following items may be affecting our estimates of ex post savings:

- Gas savings are driven relatively largely by air sealing (32% of ex ante savings), furnaces (30% of ex ante savings), and insulation (31% of ex ante savings). Water measures accrue savings year-round, but with only 2% of gas savings coming from DHW measures, and 4% of thermostats, 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 56% of ex ante savings, while central air conditioning replacement represents 10% of ex ante savings.

- The billing analysis shows that electric savings from envelope measures (which include air sealing) and HVAC measures represent 94% of savings with a 37% realization rate. Envelope and boiler and furnaces measures for gas show a similar realization rate (at 38%). 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 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 analysis indicates that increasing the baseline efficiency of heating units reduces the engineering estimates, and may be one reason for why we see the billing analysis results.

- **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 WNCF 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.

- **Regression Model 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 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. APPENDIX A: ENGINEERING ANALYSIS ALGORITHMS

In PY5, the impact evaluation efforts estimated gross impact savings for the Warm Neighbors Cool Friends (WNCF) participants by applying savings algorithms from the 2012 Illinois Statewide Technical Reference Manual (2012 TRM)[8] to the information in the program-tracking database. The algorithms used to calculate all evaluated program savings are presented below, along with all input variables. A NTGR of 1.0 was applied to MI gross savings to obtain PY5 net savings.

A.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%[9]
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 = 0.095

A.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. Heating penalties were not included in the ex post energy savings.

[8] State of Illinois: Energy Efficiency Technical Reference Manual. Final as of September 14, 2012. Effective June 1, 2012.
[9] ISR calculated for the WNCF 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%[10]

HOURS = Annual operating hours = 938 hours

HF = Heating Factor = 0.49

ηHeat = Efficiency of Heating equipment (Assumed COP 2.0 for heat pumps, 1.0 COP for electric resistance heating, and AFUE 0.8 for gas heating)

Table 10. 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

A.3 WATER HEATING MEASURE ALGORITHMS

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

[10] ISR calculated for the WNCF program 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 11. 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 12. 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 13. 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[11]

Table 14. ISR for Water Heating Measures

Measure	ISR
Faucet Aerator	95%
Showerhead	98%

Hours = Annual electric DHW recovery hours

Table 15. Hours for Water Heating Measures

Measure	Hours
Faucet Aerator	197
Showerhead	431

CF = Coincidence Factor for electric load reduction

Table 16. CF for Water Heating Measures

Measure	CF
Faucet Aerator	0.0220
Showerhead	0.0278

A.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: $\Delta kWh = \Delta kWh_cooling + \Delta kWh_heating$

$$\Delta kWh_cooling = [(((CFM50_existing - CFM50_new)/N_cool) * 60 * 24 * CDD * DUA * 0.018) / (1000 * \eta Cool)] * LM$$

$$\Delta kWh_heating\ (electric\ heat) = (((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018) / (\eta Heat * 3{,}412)$$

Demand Savings: $\Delta kW = (\Delta kWh_cooling / FLH_cooling) * CF$

[11] ISR calculated for the WNCF program 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[12]

CDD = Cooling Degree Days

Table 17. 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 18. 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 19. 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

[12] Assumed Zone 2 Normal Exposure.

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions = 15.75[13]

HDD = Heating Degree Days

Table 20. 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 21. 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 22. 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%

A.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.

[13] 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 = R-value of new attic or wall assembly

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

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

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

Framing_factor = Adjustment to account for area of framing = 0.15

CDD = Cooling Degree Days

Table 23. Cooling Degree Days by Climate Zone

Climate Zone	CDD
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108

Climate Zone	CDD
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 24. 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 25. 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 26. 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%

A.6 Rim Joist Insulation and Basement Wall Insulation Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post basement wall insulation and 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 8. Rim Joist Insulation Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

*ΔkWh_cooling = (((1/R_old_AG – (1/(R_new + R_old_AG))) * L_rimjoist * H_rimjoist * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool)*

*ΔkWh_heating (electric heat) = (((1/R_old_AG – (1/(R_new + R_old_AG))) * L_rimjoist * H_rimjoist * (1-Framing_factor)) * 24 * HDD) / (3412 * ηHeat)*

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

Gas Savings (gas heat): *ΔTherms = (((1/R_old_AG – (1/(R_new + R_old_AG))) * L_rimjoist * H_rimjoist * (1-Framing_factor)) * 24 * HDD) / (100,067 * ηHeat)*

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

Equation 9. Basement Sidewall Insulation Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

*ΔkWh_cooling = (((1/R_old_AG – (1/(R_new + R_old_AG))) * L_basement_wall total * H_basement_wall_AG * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool)*

*ΔkWh_heating (electric heat) = (((1/R_old_AG – (1/(R_new + R_old_AG))) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/R_old_BG – (1/(Rnew + R_old_BG)) * L_basement_wall_total * (H_basement_wall_total – H_basement_wall_AG) * (1-Framing_Factor))) * 24 * HDD) / (3412 * ηHeat)*

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

Gas Savings (gas heat): *ΔTherms = (((1/R_old_AG – (1/(R_new + R_old_AG))) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/R_old_BG – (1/(Rnew + R_old_BG)) * L_basement_wall_total * (H_basement_wall_total – H_basement_wall_AG) * (1-Framing_Factor))) * 24 * HDD) / (100,067 * ηHeat)*

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

Where:

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

R_old_BG = R-value of existing foundation wall assembly below grade (including thermal resistance of Earth) = 10.71 (for 6' below grade basement wall)

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

L_rimjoist = Total linear feet of installed insulation (ft)

L_basement_wall_total = Length of basement wall for the insulated perimeter (ft)

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

H_basement_wall_AG = Height of above grade insulated basement wall (ft) = 1.0 ft

H_basement_wall_total = Total height of basement wall = 7.0 ft

Framing_factor = Adjustment to account for area of framing = 0.0 for spray foam and 0.15 for studs and cavity insulation)

CDD = Cooling Degree Days (assumed unconditioned basement)

Table 27. 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 (SEER) of cooling system = 10 SEER

HDD = Heating Degree Days (assumed unconditioned basement)

Table 28. 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 29. 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 30. FLH_cooling by Climate Zone

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

Climate Zone	FLH_cooling
5 (Marion)	903

CF = Coincidence Factor = 0.915

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

A.7 CRAWLSPACE INSULATION ALGORITHMS

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post crawlspace insulation savings.

Equation 10. Crawlspace Insulation Algorithms

Energy Savings: $\Delta kWh = \Delta kWh_cooling + \Delta kWh_heating$

$$\Delta kWh_cooling = (((1/R_old - (1/(R_new + R_old))) * Area * (1\text{-}Framing_factor)) * 24 * CDD * DUA) / (1000 * \eta Cool)$$

$$\Delta kWh_heating\ (electric\ heat) = (((1/R_old - (1/(R_new + R_old))) * Area * (1\text{-}Framing_factor)) * 24 * HDD) / (3412 * \eta Heat)$$

Demand Savings: $\Delta kW = (\Delta kWh_cooling / FLH_cooling) * CF$

Gas Savings (gas heat): $\Delta Therms = (((1/R_old - (1/(R_new + R_old))) * Area * (1\text{-}Framing_factor)) * 24 * HDD) / (100{,}000 * \eta Heat)$

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

Where:

R_old = R-value of existing floor prior to installed crawlspace insulation (assume ¾" plywood subfloor and carpet with pad) = 4.94

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

Area = Total floor area of installed insulation (ft^2)

Framing_factor = Adjustment to account for area of framing = 0.15

CDD = Cooling Degree Days (assumed unconditioned (vented) crawlspace)

Table 31. Cooling Degree Days by Climate Zone for Unconditioned (Vented) Crawlspace

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

DUA = Discretionary Use Adjustment = 0.75

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

HDD = Heating Degree Days (assumed unconditioned (vented) crawlspace)

Table 32. Heating Degree Days by Climate Zone for Unconditioned (Vented) Crawlspace

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 33. 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 34. 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%

A.8 PROGRAMMABLE THERMOSTAT ALGORITHMS

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post programmable thermostat savings.

Equation 11. Programmable Thermostat Algorithms

$$\Delta kWh_heating\ (electric\ heat) = \%ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR$$

Gas Savings (gas heat): $\Delta Therms = \%FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR$

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

Where:

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

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

Elec_Heating_Consumption = Estimated annual household heating consumption for electrically heated homes

Table 35. Electric Resistance Heating Consumption by Climate Zone

Climate Zone	kWh
1 (Rockford)	26,038
2 (Chicago)	24,875
3 (Springfield)	21,304
4 (Belleville)	16,434
5 (Marion)	16,726

Gas _Heating_Consumption = Estimated annual household heating consumption for gas heated homes

Table 36. Gas Heating Consumption by Climate Zone

Climate Zone	Therms
1 (Rockford)	889
2 (Chicago)	849
3 (Springfield)	727
4 (Belleville)	561
5 (Marion)	571

Heating_Reduction = Reduction in heating energy consumption due to installing programmable thermostat = 6.2%

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

Eff_ISR = Percentage of thermostats installed and effectively programmed = 100% (Direct Install)

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

A.9 GAS BOILER ALGORITHMS

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post gas boiler savings.

Equation 12. Gas Boiler Algorithms

Gas Savings (gas heat): $\Delta Therms = Gas_Boiler_Load * ((1/AFUE_{base})-(1/AFUE_{eff}))$

Where:

Gas_Boiler_Load = Estimated annual household load for gas boiler for single family homes

Table 37. Gas Boiler Load by Climate Zone

Climate Zone	Therms
1 (Rockford)	1,275
2 (Chicago)	1,218
3 (Springfield)	1,043
4 (Belleville)	805
5 (Marion)	819

$AFUE_{base}$ = Baseline boiler efficiency = actual or if unknown 80% AFUE was used

$AFUE_{eff}$ = Efficient boiler efficiency = Actual efficiency was used

A.10 Gas Furnace Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post gas furnace savings.

Equation 13. Gas Furnace Algorithms

Gas Savings (gas heat): $\Delta Therms = Gas_Furnace_Heating_Load * ((1/AFUE_{base})-(1/AFUE_{eff}))$

Where:

Gas_Boiler_Load = Estimated annual household load for gas furnace for single family homes

Table 38. Gas Furnace Load by Climate Zone

Climate Zone	Therms
1 (Rockford)	843
2 (Chicago)	**806**
3 (Springfield)	690
4 (Belleville)	532
5 (Marion)	542

$AFUE_{base}$ = Baseline furnace efficiency = actual or if unknown 80% AFUE was used

$AFUE_{eff}$ = Efficient furnace efficiency = Actual or if unknown 95% AFUE was used

A.11 Air Source Heat Pump Algorithms

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post savings for the installation of air source heat pumps.

Equation 14. Air Source Heat Pump Algorithms

Energy Savings: $\Delta kWh = \Delta kWh_cooling + \Delta kWh_heating$

$$\Delta kWh_cooling = ((FLH_cooling * Capacity_Cooling * ((1/SEER_{base})-(1/SEER_{eff})))/1000$$

$$\Delta kWh_heating\ (electric\ heat) = ((FLH_heating * Capacity_heating * ((1/HSPF_{base})-(1/HSPF_{eff})))/1000$$

Demand Savings: $\Delta kW = (Capacity_cooling * ((1/EER_{base})-(1/EER_{eff}))/1000)*CF$

Where:

FLH_cooling = Full load hours for air conditioning

Table 39. Full Load Cooling Hours by Climate Zone

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

Capacity_Cooling = Cooling capacity of air source heat pump in units of Btuh = actual value from database

$SEER_{base}$ = Seasonal Energy Efficiency Ratio (SEER) for the baseline air source heat pump = actual value from database

$SEER_{eff}$ = Seasonal Energy Efficiency Ratio (SEER) for the newly installed air source heat pump = actual value from database

FLH_heating = Full load hours for heating

Table 40. Full Load Heating Hours by Climate Zone

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

Capacity_Heating = Heating capacity of air source heat pump in units of Btuh = actual value from database

$HSPF_{base}$ = Heating System Performance Factor (HSPF) for the baseline air source heat pump = 7.7 HSPF

$HSPF_{eff}$ = Heating System Performance Factor (HSPF) for the newly installed air source heat pump = actual value from database

EER_{base} = Energy Efficiency Ratio (EER) for the baseline air source heat pump (actual value from database was used) calculated using using EER = -0.02 * $SEER^2$ + 1.12 * SEER)

EER_{eff} = Energy Efficiency Ratio (EER) for the newly installed air source heat pump (actual value from database was used) calculated using using EER = (-0.02 * $SEER^2$) + (1.12 * SEER))

CF = Coincidence Factor = 0.915

A.12 CENTRAL AIR CONDITIONER ALGORITHMS

The evaluation team used the algorithms below, from the 2012 TRM, to calculate the ex post savings for the installation of central air conditioners.

Equation 15. Central Air Conditioner Algorithms

$$(\text{Time of Sale})\ \Delta kWh_cooling = ((FLH_cooling * Capacity_Cooling * ((1/SEER_{base})-(1/SEER_{eff})))/1000$$

$$(\text{Early Replacement})\ \Delta kWh_cooling = ((FLH_cooling * Capacity_Cooling * ((1/SEER_{exist})-(1/SEER_{eff})))/1000$$

$$\text{(Time of Sale) Demand Savings: } \Delta kW = (Capacity_cooling * ((1/EER_{base})-(1/EER_{eff}))/1000)*CF$$

$$\text{(Early Replacement Demand Savings: } \Delta kW = (Capacity_cooling * ((1/EER_{exist})-(1/EER_{eff}))/1000)*CF$$

Where:

FLH_cooling = Full load hours for air conditioning

Table 41. Full Load Cooling Hours by Climate Zone

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

Capacity_Cooling = Cooling capacity of air conditoiner in units of Btuh = actual value from database

$SEER_{base}$ = Seasonal Energy Efficiency Ratio (SEER) for the baseline air conditioner for a time of sale installation = 13 SEER

$SEER_{exist}$ = Seasonal Energy Efficiency Ratio of the existing air conditioner (SEER) = actual value used or if unknown 10 SEER

$SEER_{eff}$ = Seasonal Energy Efficiency Ratio (SEER) for the newly installed air conditioner = actual value used of if unknown 14.5 SEER

EER_{base} = Energy Efficiency Ratio (SEER) for the baseline air conditioner for a time of sale installation = 11.2 EER

EER_{exist} = Energy Efficiency Ratio of the existing air conditioner (SEER) = actual value used or if unknown 9.2 EER

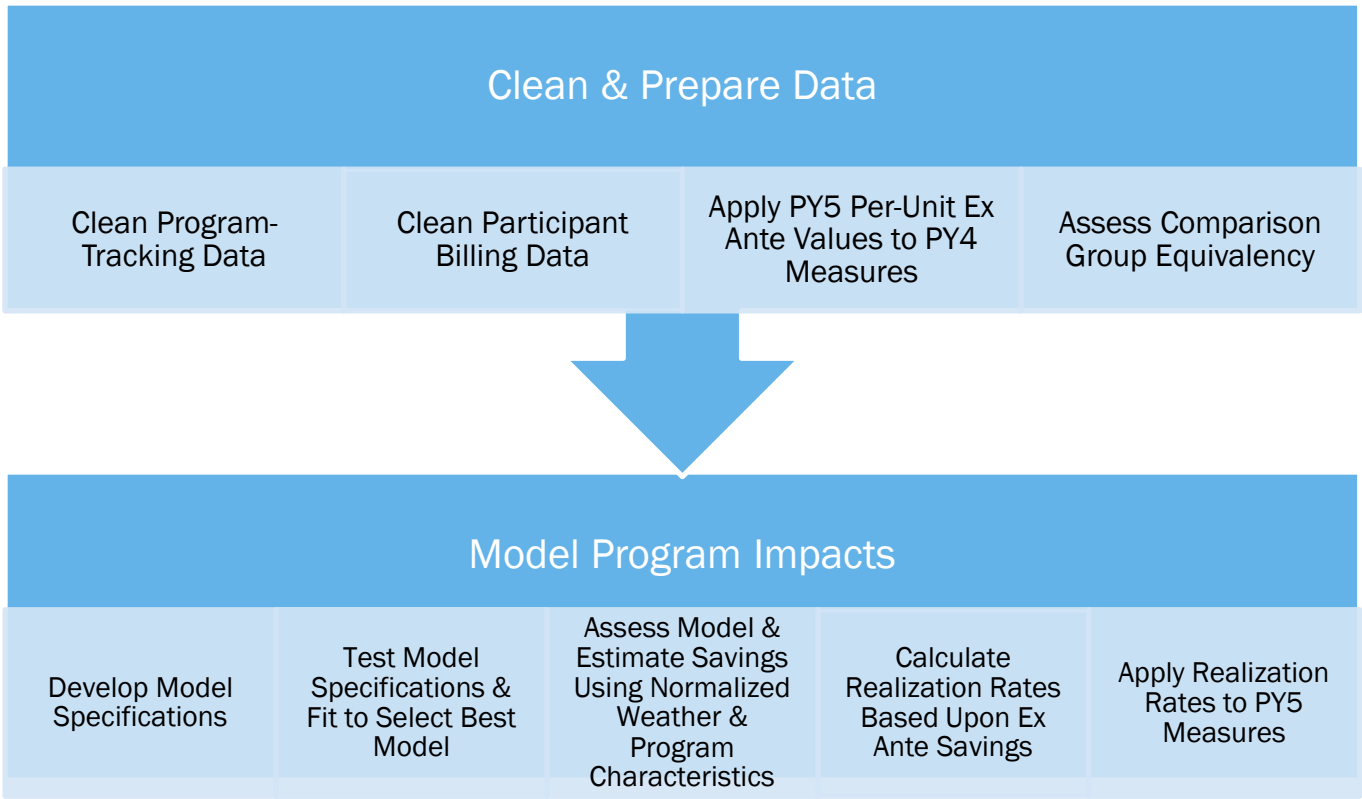
EER_{eff} = Energy Efficiency Ratio (SEER) for the newly installed air conditioner = actual value used of if unknown 12 EER

CF = Coincidence Factor = 0.915

B. Appendix B. Billing Analysis Methods & Results

We conducted a one-way[14] fixed effects linear model incorporating a comparison group of PY5 program participants to estimate net program impacts. Because a billing analysis is best conducted on a complete year of billing data before and a complete year of billing data after 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 most participants are dual-fuel customers with both electric and gas ex ante savings, 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.

[14] 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.

B.1 CLEAN & PREPARE DATA

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

B.2 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 WNCF 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 (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 project lists and the measure level datasets from the two program years (PY4 and PY5) before cleaning the file.

We encountered several minor data issues and took careful measures to address and correct each one to assure 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[15] matching and regular expression comparisons.

[15] We did not use account numbers 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. 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

- **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 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[16] to make sure that each of the negative values had a corresponding positive value for which the sum becomes zero[17].

- **Project IDs with Different Names and Addresses:** A few project IDs have completely different names and addresses in the project list and the measure 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.

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 42 shows these cleaning results.

Table 42. Participant Database Cleaning Results

	Electric Customers			Gas Customers		
	PY4 Participants (Treatment)	PY5 Participants (Comparison)	Total	PY4 Participants (Treatment)	PY5 Participants (Comparison)	Total
Initial #	273	292	525	264	276	502

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.

[16] 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.

[17] 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.

	Electric Customers			Gas Customers		
No Electric Measures Installed	16	6	10	0	0	0
# After Adjustment	257	286	515	264	276	502
No Gas Measures Installed	0	0	0	33	1	17
# After Adjustment	257	286	515	231	275	485
0 kWh Savings or 0 Therm Savings	0	0	0	0	0	0
# After Adjustment	257	286	515	231	275	485
% After Adjustment	94%	98%	98%	88%	100%	97%
No Overlap with Clean Billing Data (See Table 43)	46	52	84	41	54	93
# After Adjustment	211	234	431	190	221	392
Participant overlaps PY4 and PY5 (classified as PY4 participant for analysis; removed from PY5 accounting)	0	14	0	0	19	0
# After Adjustment	211	220	431	190	202	392
% After Adjustment	77%	75%	82%	72%	73%	78%

B.2.1 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 (>6 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 (e.g., 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 2 months of pre-period data in the summer and winter periods, respectively

    - Less than 2 months of post-period data in the summer and winter periods, respectively (PY4 customers only)

    - Less than 9 billing periods in the pre-period

    - Less than 9 billing periods in the post-period (PY4 customers only)

Table 43 provides the results of the data cleaning effort for the billing analysis.

Table 43. Data Cleaning Results: Electric and Gas Participants

	Electric Customers			Gas Customers		
	PY4 Participant (Treatment)	PY5 Participant (Comparison)	PY4 %	PY4 Participant (Treatment)	PY5 Participant (Comparison)	PY4 %

	Electric Customers			Gas Customers		
Unique Accounts[18]	**515**			**499**		
Account not in participant data	1			15		
# accounts remaining Total	262	252	100%	246	238	100%
No usage data	0	1	0.0%	0	1	0.0%
# accounts remaining	262	251	100%	246	237	100%
Negative Usage	0	0	0.0%	0	0	0.0%
# accounts remaining	262	251	100%	246	237	100%
Billing Dates Out of Range	0	0	0.0%	0	0	0.0%
# accounts remaining	262	251	100%	246	237	100%
Duplicative Billing Dates	0	0	0.0%	0	0	0.0%
# accounts remaining	262	251	100%	246	237	100%
Overlapping Billing Periods	0	0	0.0%	0	0	0.0%
# accounts remaining	262	251	100%	246	237	100%
High ADC Overall	0	0	0.0%	Not Applicable[19]		
High ADC in the Pre-Period Only	0	0	0.0%			

[18] 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.

[19] 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.

	Electric Customers			Gas Customers		
High ADC in the Post-Period Only	0	0	0.0%			
# accounts remaining	262	251	100%	246	237	100%
Low ADC Overall	0	0	0.0%	0	0	0.0%
Low ADC in the Pre-Period Only	0	0	0.0%	0	0	0.0%
Low ADC in the Post-Period Only	0	0	0.0%	0	0	0.0%
# accounts remaining	262	251	100%	246	237	100%
Extremely long duration	0	0	0.0%	0	0	0.0%
# accounts remaining	262	251	100%	246	237	100%
No pre-program billing data	3	0	1.1%	2	1	0.8%
# accounts remaining	259	251	99%	244	236	99%
Insufficient data in pre-period summer	9	22	3.4%	Not Applicable[20]		
# accounts remaining	250	229	95%			
Insufficient data in post-period summer	31	N/A[21]	11.8%	Not Applicable[22]		
# accounts remaining	219	229	84%			

[20] 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).

[21] Post-period drops are not applicable to the comparison group of PY5 customers because their post-period consumption data is not used in analysis.

[22] 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).

	Electric Customers			Gas Customers		
Insufficient data in pre-period winter	3	4	1.1%	13	12	5.3%
# accounts remaining	216	225	82%	231	224	94%
Insufficient data in post-period winter	2	N/A[23]	0.8%	9	N/A[24]	3.7%
# accounts remaining	214	225	82%	222	224	90%
Insufficient pre-program billing data (less than 9 observations in pre-period)	2	5	0.8%	19	22	7.7%
# accounts remaining	212	220	81%	203	202	83%
Insufficient post-program billing data (less than 9 observations in post-period)	1	N/A[25]	0.4%	13	N/A[26]	5.3%
# accounts remaining	**211**	**220**	**81%**	**190**	**202**	**77%**

In summary, we retained approximately 81% to 75% of PY4 participants and 75% and 73% of PY5 participants (Table 44).

Table 44: Summary of Participants Used in Billing Analysis

Sample for Analysis	Electric Customers		Gas Customers	
	PY4 (Treatment)	PY5 (Comparison)	PY4 (Treatment)	PY5 (Comparison)
Initial Customer Count (from participation database Table 42) [27]	273	292	264	276

[23] Post-period drops are not applicable to the comparison group of PY5 customers because their post-period consumption data is not used in analysis.

[24] Post-period drops are not applicable to the comparison group of PY5 customers because their post-period consumption data is not used in analysis.

[25] Post-period drops are not applicable to the comparison group of PY5 customers because their post-period consumption data is not used in analysis.

[26] Post-period drops are not applicable to the comparison group of PY5 customers because their post-period consumption data is not used in analysis.

[27] 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 43).

Sample for Analysis	Electric Customers		Gas Customers	
	PY4 (Treatment)	PY5 (Comparison)	PY4 (Treatment)	PY5 (Comparison)
Total Drops	62	72	74	74
Final N	211	220	190	202
% Remaining	81%	75%	75%	73%

Notably, there were 260 unique households that participated in PY5 only. However, there were 40 households began participating in the program in PY4 and participated in PY5 as well through installed equipment. As such, 300 households installed equipment in PY5, with 292 customers claiming electric savings, and 276 gas customers claiming gas savings.

B.2.2 Apply PY5 Per-Unit Values to PY4 Measures

The WNCF program claimed gross 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 derived through billing analysis could be applied to PY5 ex ante savings, we re-calculated 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 for equivalent measures installed in PY4 to recalculate net realization rates for PY4 participants in PY5 terms.

The evaluation team applied a net-to-gross ratio of 1.0 to these gross savings. The evaluation team discussed and reached agreement with the ICC and AIC staff given our understanding of program design and targeted customers. This is due to the fact that the program is targeted to participants who fall within 200% and 300% of the federal poverty level guidelines for household size. As such, the program participants are unlikely to have installed many of the measures offered through the program without assistance. As a result, ex post gross impacts and ex post net impacts are identical.

Specifically, we 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[28] 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.

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

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

B.2.3 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.
- **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 WNCF 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 gas versus electric resistance heating (Table 45). While a slightly higher percentage of participants with electric measures in PY5 had gas space heat than in PY4 (98% vs. 94%), we do not expect this difference to affect electric results.

Table 45. Percent of Participants in Billing Analysis with each Heating Fuel Type

	Participants with Electric Measures		Participants with Gas Measures	
Heating Fuel Type	PY4 Participant Group (n=211)	PY5 Participant Group (n=220)	PY4 Participant Group (n=190)	PY5 Participant Group (n=202)
Gas	96%	98%	99%	100%
Electric	3%	2%	1%	0%
Other	0%	0%	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 somewhat different. PY5 participants with electric savings were less likely to install CFLs, but slightly more likely to install HVAC equipment, than their PY4 counterparts. Still, a similar proportion installed envelope measures. PY5 participants with gas savings were slightly more likely to install boilers or furnaces and thermostats compared with their PY4 counterparts, and less likely to install envelope measures. We considered the impact these differences may have on the applicability of the PY4 realization rate to PY5 customers, and found it acceptable.

We conducted a few additional analyses to determine if any adjustments to realization rates based on measure mix were possible or appropriate. For example, we isolated a few groups of customers with distinct measure combinations[29] and examined differences in realization rates between these groups. In most cases the differences in realization rates between groups were only plus or minus 5-10% from the overall realization rate, which we deemed acceptable. We did not find a basis for adjusting the WNCF realization rates before applying them to PY5 WNCF customers, and as such, the realization rates generated from the billing analysis of PY4 customers represent the best-available estimates of overall realization rates (because of the reliance on actual pre- and post-installation billing data).

Table 46. Measure Mix among Participants with Electric Savings (% of Accounts and % of Ex Ante Savings)

Within-Fuel Measure Mix [a]	Proportion of Electric Accounts [a]		Proportion of Electric Ex Ante Net Savings	
	PY4 Participant Group (n=211)	PY5 Participant Group (n=220)	PY4 Participant Group (n=211)	PY5 Participant Group (n=220)
Envelope	73%	72%	63%	74%
HVAC	19%	23%	14%	10%
Boiler/Furnace	--	--	--	--
Thermostat	13%	36%	1%	1%
CFLs	91%	70%	20%	15%
DHW	8%	2%	2%	0%

[a] The measure mix distribution reflects the distribution within each of the two fuel types we analyzed – For example, while only 72% of PY5 households with any electric savings installed envelope measures that had associated electric savings, more PY5 households may have installed envelope measures with gas savings

Table 47. Measure Mix among Participants with Gas Savings (% of Accounts and % of Ex Ante Savings)

Within-Fuel Measure Mix [a]	Proportion of Electric Accounts [a]		Proportion of Gas Ex Ante Net Savings	
	PY4 Participant Group (n=190)	PY5 Participant Group (n=202)	PY4 Participant Group (n=190)	PY5 Participant Group (n=202)
Envelope	84%	76%	74%	62%
HVAC	--	--	--	--
Boiler/Furnace	61%	72%	21%	32%
Thermostat	18%	44%	2%	4%
CFLs	--	--	--	--
DHW	78%	56%	3%	2%

[a] The measure mix distribution reflects the distribution within each of the two fuel types we analyzed – For example, while 76% of PY5 households with any gas savings installed envelope measures that had associated gas savings, more PY5 households may have installed envelope measures with electric savings

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

[29] For electric: CFLs only vs. All Other; participants with vs. without HVAC; CFLs & Envelope only. For gas, participants with vs. without furnace/boiler replacement.

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

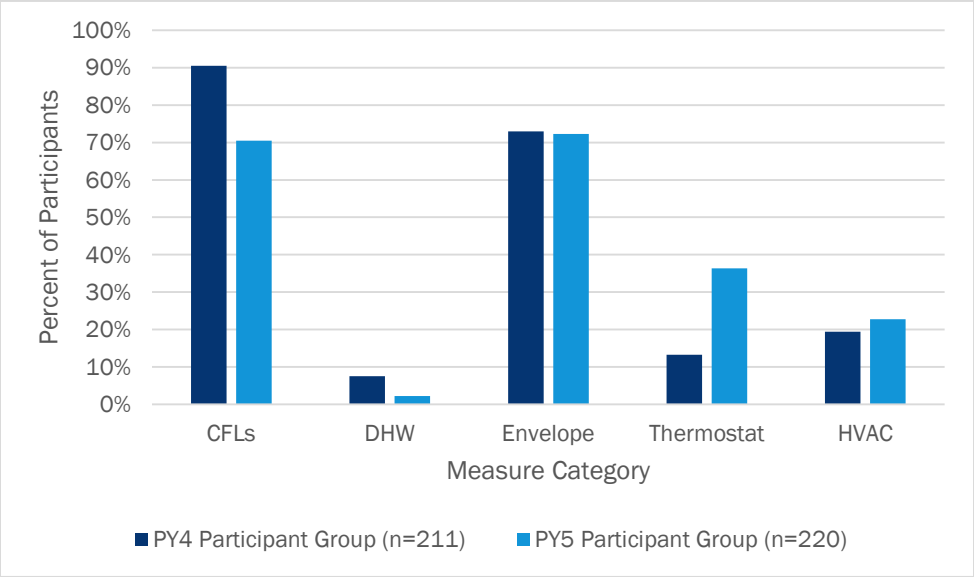
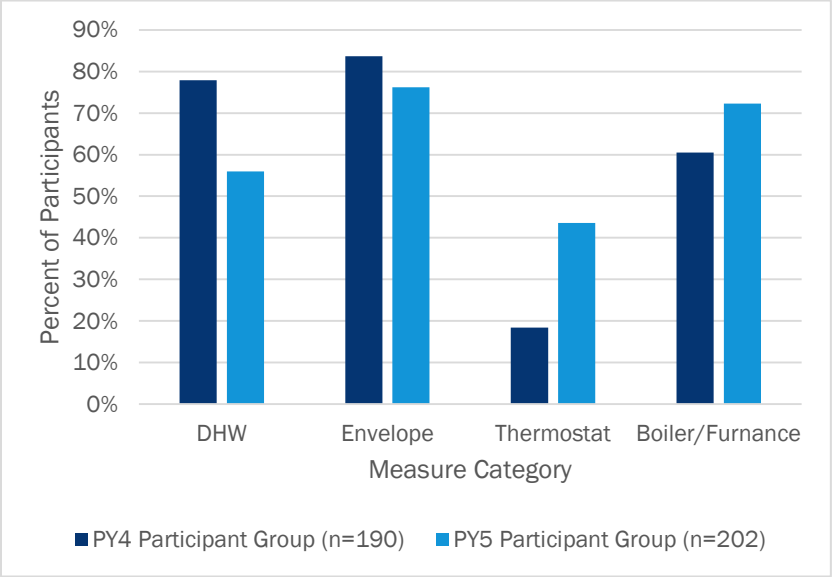


Figure 3. Percent of Accounts in Gas Billing Analysis that Installed Each Measure



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 48 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. PY4 participants with electric savings used, on average, 0.5% more electricity per day than their PY5 counterparts. PY4 participants with gas savings used, on average, 6% less gas per day than their PY5 counterparts. Looking at how gas consumption varied over the course of the PY3 baseline period, we see that this difference occurs mainly in the winter months (Figure 5). Because not all gas participants are included in (a) the annualized PY3 baseline comparison, and (b) every month of the

month-by-month analysis (see sample sizes in Table 48, showing that 12% of PY5 gas participants did not have enough PY3 data to be included in the comparison), it is unclear how much these moderate differences affect billing analysis results, though we expect the impact is small.[30]

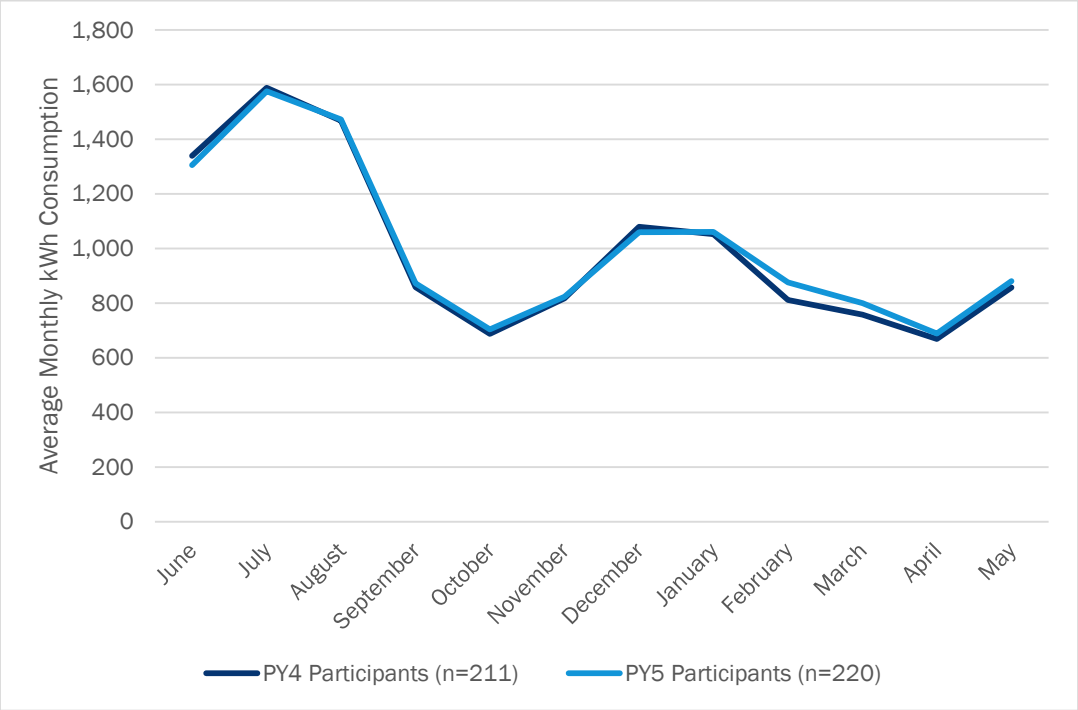
Table 48. Baseline Period (PY3) Average Daily Consumption, kWh and Therms

	Electric Accounts		Gas Accounts	
	PY4 Participant Group	PY5 Participant Group	PY4 Participant Group	PY5 Participant Group
Baseline period n [a]	205 (of 211)	197 (of 220)	184 (of 190)	177 (of 202)
Average Daily Consumption	33.0 kWh	32.9 kWh	2.48 therms	2.63 therms
Standard Deviation	17.3 kWh	16.0 kWh	0.96 therms	1.09 therms

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

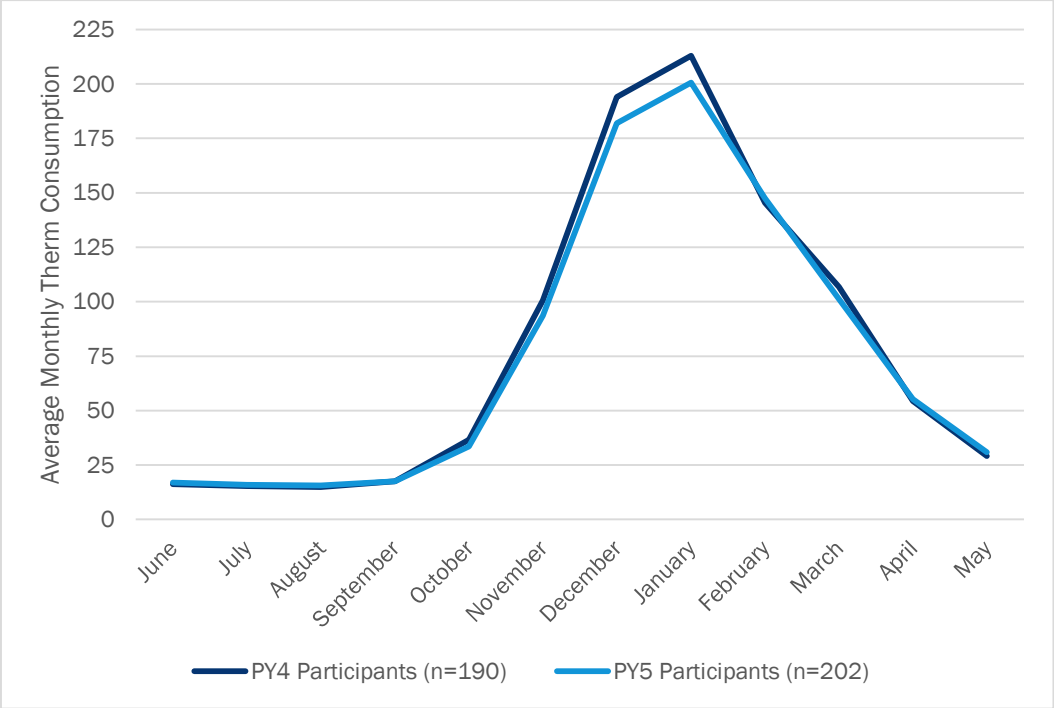
Figure 4 shows the comparison of baseline period electric consumption by month for treatment and comparison groups in electric billing analysis, and Figure 5 shows the same for gas consumption.

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



[30] We tested regression models with a baseline consumption term and found that the savings predictions and realization rate were very similar to what we report for the final models.

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



B.3 *MODEL PROGRAM IMPACTS*

B.3.1 DEVELOP & TEST MODEL SPECIFICATIONS

Our billing analysis approach used a one-way[31] fixed effects panel model. The modeling process for the WNCF program was relatively simple due to two factors: 1) it was not feasible to estimate measure-specific models, and 2) there were virtually no electric space heating households in either program year. Thus, the model selection was based on relatively few models with various specifications involving participation and weather variables, as well as their interactions. The results were quite stable across these specifications. Our final selection was a model that had good fit and that applies equally well to gas and electric impacts (though of course the same variables generate different coefficients for gas and electric models). We show the list of measure categories and how they compared between PY4 and PY5 in Table 46 and Table 47.

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

[31] 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. Thus, in practice the model was actually a one-way fixed effects model.

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 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-year combination 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 because they control for the economic, political, and historical events that may have occurred during this time that would be common to both groups during the same period.

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 49), and the possibility that the relationship between weather and consumption might change following treatment.

Table 49. Average Daily HDD (Base 65) and CDD (Bas 65) for Records in Billing Analysis

Program Year	Records in Electric Billing Analysis		Records in Gas Billing Analysis	
	HDD	CDD	HDD	CDD
PY3	15.6	3.9	15.7	3.8
PY4	13.0	3.8	13.2	3.7
PY5	18.0	2.8	18.1	2.8
Average	*15.4*	*3.6*	*15.5*	*3.5*

We estimated a number of models with different combinations of variables and their interactions. We used several criteria to decide which model specification to choose. We always consider plausibility of the results (e.g. an implausible result would be a realization rate of 500%), the stability of the models over minor differences in specification and finally, the Akaike Information Criterion[32].

Our final electric models were the fixed-effects linear models with the specifications shown below. The estimating equations were the same for both gas and electric models.

$$ADC_{it} = B_i + B_1 Post_{it} + B_2 HDD_{it} + B_3 CDD_{it} + B_4 Post_{it} \cdot HDD_{it} + B_5 Post_{it} \cdot CDD_{it} + B_t \pi_{my} + \varepsilon_{it}$$

Where:

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

[32] 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 the model fits, but which of several models fits the data more efficiently than the others.

B_i= Household-specific constant for the ith customer

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

HDD_{it} = Average daily Heating Degree Days provided by AIC (Base 65) for the ith customer at time t

CDD_{it} = Average daily Cooling Degree Days provided by AIC (Base 65) for the ith customer at time t

π_{my} = Month-Year dummies for all time periods in the model

ε_{it} = Error term

B_n = The change in ADC for a one unit change in a given independent variable

B.3.2 Assess Models, Estimate Savings, & Calculate Realization Rates

As described in Section B.3.1, we used the same model for gas and electric savings. 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 50. Regression Model Results for Electric Savings

(Dependent variable is average daily kWh consumption.
Number of customers = 431, Number of observations = 12,878, R^2 = 0.721)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	-0.892	1.102	-0.81	0.419
postXhdd	-0.030	0.055	-0.54	0.588
postXcdd	-0.264	0.132	-1.99	0.047
Hdd	0.117	0.046	2.56	0.011
Cdd	1.683	0.173	9.73	0
Month-year dummies:				
Jun-10	4.675	1.143	4.09	0
Jul-10	7.016	1.539	4.56	0
Aug-10	5.959	1.331	4.48	0
Sep-10	-0.001	0.504	0	0.999
Oct-10	-1.006	0.755	-1.33	0.184
Nov-10	3.659	0.955	3.83	0
Dec-10	9.298	1.548	6.01	0
Jan-11	8.143	1.636	4.98	0
Feb-11	4.800	1.249	3.84	0

Variable	Coefficient	Robust SE	t-statistic	p-value
Mar-11	0.609	1.006	0.61	0.545
Apr-11	-1.311	0.735	-1.78	0.075
May-11	-1.857	0.497	-3.74	0
Jun-11	2.707	0.859	3.15	0.002
Jul-11	8.396	1.794	4.68	0
Aug-11	5.001	1.173	4.27	0
Sep-11	-0.188	0.636	-0.3	0.767
Oct-11	-0.580	0.821	-0.71	0.48
Nov-11	3.353	0.927	3.62	0
Dec-11	5.963	1.172	5.09	0
Jan-12	6.061	1.303	4.65	0
Feb-12	3.877	1.157	3.35	0.001
Mar-12	-3.210	0.934	-3.44	0.001
Apr-12	-1.814	0.795	-2.28	0.023
May-12	0.113	0.678	0.17	0.867
Jun-12	4.539	1.211	3.75	0
Jul-12	8.083	2.123	3.81	0
Aug-12	4.179	1.044	4	0
Sep-12	1.160	0.838	1.38	0.167
Oct-12	0.296	0.956	0.31	0.757
Nov-12	3.140	1.066	2.95	0.003
Dec-12	7.100	1.464	4.85	0
Jan-13	7.502	1.657	4.53	0
Feb-13	6.783	1.613	4.21	0
Mar-13	3.912	1.480	2.64	0.008
Apr-13	0.124	0.974	0.13	0.899
May-13	0.038	1.199	0.03	0.974
Constant	21.141	0.994	21.27	0

Table 51. Regression Model Results for Gas Savings

(Dependent variable is average daily therm consumption.
Number of customers = 392, Number of observations = 11,702, R^2 = 0.807)

Variable	Coefficient	Robust SE	t-statistic	p-value
Post	0.135	0.084	1.61	0.109
postXhdd	-0.035	0.005	-6.79	0

Variable	Coefficient	Robust SE	t-statistic	p-value
postXcdd	-0.011	0.006	-1.73	0.084
Hdd	0.049	0.007	7.21	0
Cdd	-0.027	0.010	-2.83	0.005
Month-year dummies:				
Jun-10	0.108	0.066	1.63	0.104
Jul-10	0.147	0.091	1.62	0.105
Aug-10	0.094	0.078	1.21	0.229
Sep-10	-0.126	0.031	-4.08	0
Oct-10	0.014	0.064	0.22	0.825
Nov-10	1.461	0.145	10.05	0
Dec-10	3.516	0.257	13.65	0
Jan-11	3.944	0.279	14.16	0
Feb-11	2.894	0.218	13.29	0
Mar-11	1.340	0.175	7.64	0
Apr-11	0.439	0.092	4.77	0
May-11	0.105	0.036	2.93	0.004
Jun-11	0.053	0.058	0.92	0.359
Jul-11	0.166	0.106	1.57	0.117
Aug-11	0.046	0.073	0.63	0.531
Sep-11	-0.201	0.037	-5.45	0
Oct-11	0.089	0.071	1.25	0.212
Nov-11	1.187	0.126	9.4	0
Dec-11	2.206	0.186	11.88	0
Jan-12	2.811	0.203	13.85	0
Feb-12	2.291	0.184	12.45	0
Mar-12	0.005	0.144	0.03	0.974
Apr-12	-0.046	0.079	-0.59	0.555
May-12	-0.107	0.046	-2.3	0.022
Jun-12	-0.038	0.093	-0.4	0.687
Jul-12	0.154	0.137	1.13	0.26
Aug-12	-0.045	0.076	-0.59	0.553
Sep-12	-0.219	0.055	-4.01	0
Oct-12	0.286	0.097	2.96	0.003
Nov-12	1.194	0.146	8.19	0

Variable	Coefficient	Robust SE	t-statistic	p-value
Dec-12	2.202	0.193	11.41	0
Jan-13	2.971	0.225	13.23	0
Feb-13	2.913	0.217	13.41	0
Mar-13	2.138	0.204	10.48	0
Apr-13	0.662	0.124	5.35	0
May-13	0.141	0.093	1.52	0.129
Constant	0.723	0.074	9.72	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[33] to 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 re-calculated 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 52.

Due to the high degree of overlap between measure categories, it was not possible to generate reliable estimates of measure-specific savings that we could apply to PY5 ex ante savings.

Table 52. Realization Rates from PY4 Electric and Gas Billing Analysis

Model	Treatment and Post-Period Observations	Ex Ante Net Savings		Observed Net Savings		Realization Rate
		Average Daily Savings	Annual Average Savings	Average Daily Savings	Annual Average Savings	
Electric Model (kWh)	2,795	5.76	2,103	2.14	781	37%
Gas Model (therms)	2,482	1.13	412	0.43	157	38%

B.3.3 Apply Results to PY5 Measures

Given that some WNCF customers are dual fuel customers, the evaluation estimated both electric and gas savings. We developed overall models for gas and electric participants. It was not feasible to generate any measure-specific savings estimates due to very pronounced overlap in measures, making it impossible to separate savings due to one measure versus others that were installed at the same time. In addition, there were insufficient numbers of participants installing only one

[33] 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.

measure type to support measure-specific estimates in that way. For descriptive purposes, we collapsed several measure types into broader categories, including CFLs, domestic hot water (DHW), and envelope measures (see Table 5 for groupings). In the end we chose two models, one for overall gas savings and one for overall electric savings. The same model specification provided good results for both (Table 53 and Table 54 summarizes net ex ante and net ex post savings for the PY5 WNCF program.

Table 53. PY5 Electric Ex Ante and *Ex Post* Savings [a]

Measure Category	Number of Accounts	PY5 Ex Ante Net Savings[b]		Realization Rate [c]	PY5 Ex Post Net Savings	
		Total kWh	Total kW		Total kWh	Total kW
Overall Savings	**286[a]**	**568,260**	**441.44**	37%	**211,203**	**164.07**
Envelope	217	422,064			156,867	
HVAC	70	64,841			24,099	
Thermostat	113	7,286			2,708	
CFLs	180	70,873			26,341	
DHW	7	3,196			1,188	

[a] This represents the total number of electric accounts that claimed electric savings in PY5 as per the program-tracking database (excludes 6 participants with no claimed electric savings).
[b] Source of ex ante savings: PY5 program-tracking database.
[c] The realization rate is calculated as the PY4 net ex post savings (observed in billing analysis) divided by the PY4 ex ante net savings (using PY5 per-unit savings assumptions).
Note: Values may not total due to rounding.

Table 54 summarizes net ex ante and net ex post gas savings for the PY5 WNCF program.

Table 54. PY5 Gas Ex Ante and *Ex Post* Savings [a]

Measure Category	Number of Accounts	PY5 Ex Ante Net Savings [b]	Realization Rate [c]	PY5 Ex Post Net Savings
		Total Therms		Total Therms
Overall Savings	**275[a]**	**134,700**	38%	**51,120**
Envelope	214	84,789		32,178
Boiler/Furnace	198	41,834		15,876
Thermostat	125	5,679		2,155
DHW	135	2,398		910

[a] This represents the total number of gas accounts that claimed gas savings in PY5 as per the program-tracking database (excludes 1 participants with no claimed gas savings).
[b] Source of ex ante savings: PY5 program-tracking database.
[c] The realization rate is calculated as the PY4 net ex post savings (observed in billing analysis) divided by the PY4 ex ante net savings (using PY5 per-unit savings assumptions).
Note: Values may not total due to rounding.

C. APPENDIX C: 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 WNCF Net Impacts (Including Heating Penalties)

WNCF Program	Electric Savings (MWh)	Demand Savings (MW)	Gas Savings (Therms)
Total	550.87	0.47	123,521