Assessment of Energy and Cost Savings for Homes Treated under Wisconsin's Home Energy Plus Weatherization Program 2018

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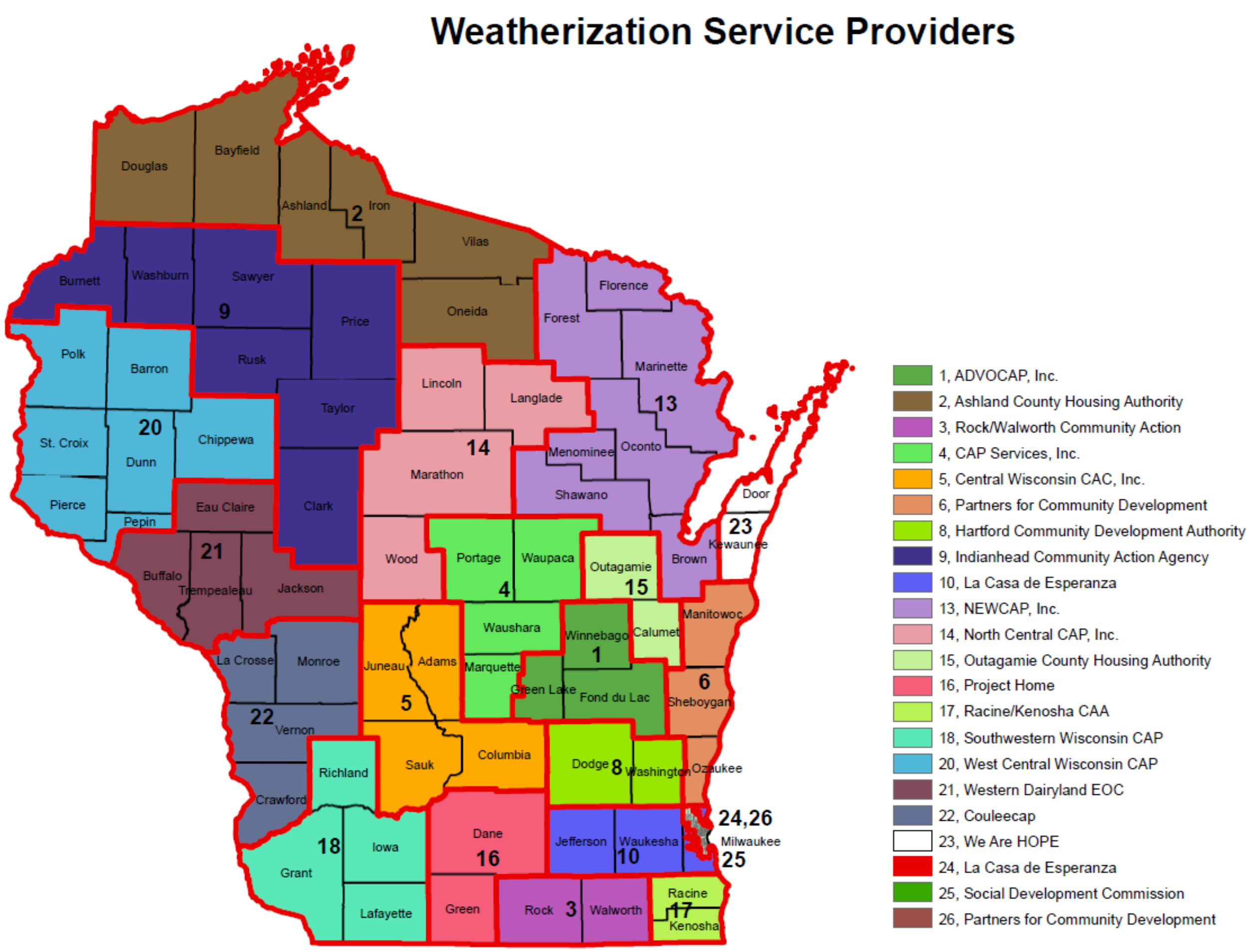
1.0 INTRODUCTION

Since 2009, an annual evaluation has been conducted of delivered energy savings for homes that have been treated by Wisconsin's low-income Weatherization Assistance Program (WAP), Home Energy Plus. Weatherization services are provided by 21 agencies throughout the state and are available to households meeting program eligibility requirements, which include a household income of 60 percent or less than the state's median income for a similar-size household. The program targets homes with a high energy burden as well as those with elderly, very young, or disabled occupants.

The main objectives of the Weatherization Assistance Program are:

1) Reduce home energy bills
2) Save energy
3) Make homes warmer in the winter and cooler in the summer

The map below illustrates the geographical coverage of Wisconsin's weatherization service providers.



While this report highlights findings from the last five program years,[1] external influences and internal policy changes affect program delivery and impacts. Shifting fuel prices and varying costs for weatherization materials and services are the primary external influences. The long-term trend toward lower natural gas prices is reflected in measure selection changes. This report represents ongoing efforts for improved program delivery and efficiency by assessing outcomes of program policy, procedures, and measures.

Policy adjustments over the period of this analysis include better coordination with the Wisconsin Home Energy Assistance Program (WHEAP), enabling the program to target households with higher energy burdens. Additionally, the Wisconsin program has increased efforts to recruit high-using homes and simplify electric-to-natural gas water heater conversions. This report includes site-built, single-family, and small multifamily homes (1-4 units). A separate report covers the manufactured homes analysis.

Section 2.0 of this report presents trends in observed gas and electricity savings for housing units weatherized between program year (PY) 13 and PY17. These savings are directly calculated from natural gas and electric utility billing data for PY13 through PY16. All billing data are weather-normalized to account for the effect of year-to-year temperature variation on household energy use. Weather normalization models are fit to individual households to capture the unique energy-temperature relationship of each home, allowing for a more nuanced adjustment of observed energy use to long-term average weather conditions. We also employ a matched group of later program participants as a comparison group to control for non-program influences unrelated to weather.

Many participants of the most recent program year (PY17) had not experienced a heating season before the start of this evaluation, meaning those homes have insufficient post-weatherization utility data for a typical billing analysis. Energy savings estimates for PY17 homes are projected using a modeling approach that applies average measure-level savings estimates from prior years to known measure installation data for these homes. This technique also extrapolates savings estimates for homes heated with natural gas—where utility data are available—to homes with other heating fuels (primarily propane and fuel oil) for which obtaining actual consumption data is more difficult.

Section 3.0 details cost savings, measure savings, incidence rates and contributions to aggregate savings. Section 4.0 shows program costs and savings-to-investment ratios. Section 5.0 (appendices) provides pre-weatherization consumption trends for program participants and state-wide, detailed data tables and methodologies for processing utility billing data, modeling energy savings, assessing heating fuel conversions, estimating one of the key non-energy benefits (water conservation), and fuel prices used in this analysis.

The remainder of this section illustrates trends in program participation.
Figure 1 shows the number of housing units weatherized in each program year, broken out by housing type. While this report focuses only on housing units in 1-4 unit site-built structures, large multifamily buildings (5+ units) and manufactured homes are included in
Figure 1 to provide a more complete picture of the changing composition of the program over time. During the most recent program years, single-family, site-built homes have made up the majority (about 60 to 70 percent) of weatherized homes.

[1] A program year is a 12-month period ending on June 30 of that program year.

Figure 1-Weatherized housing units, by housing type and program year

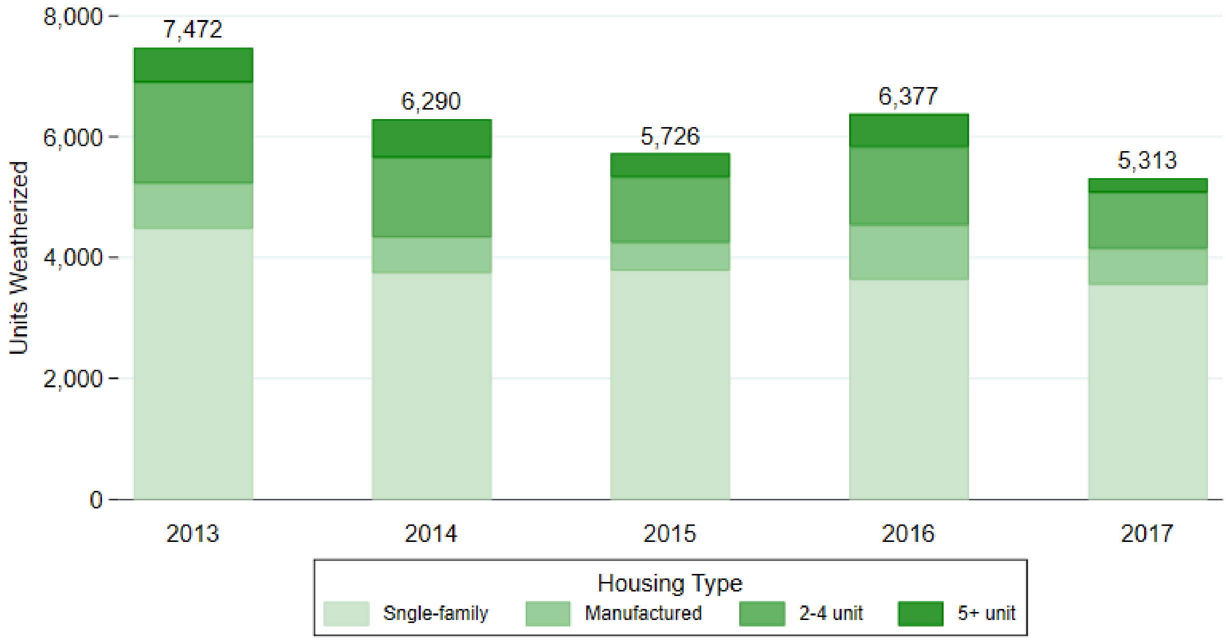
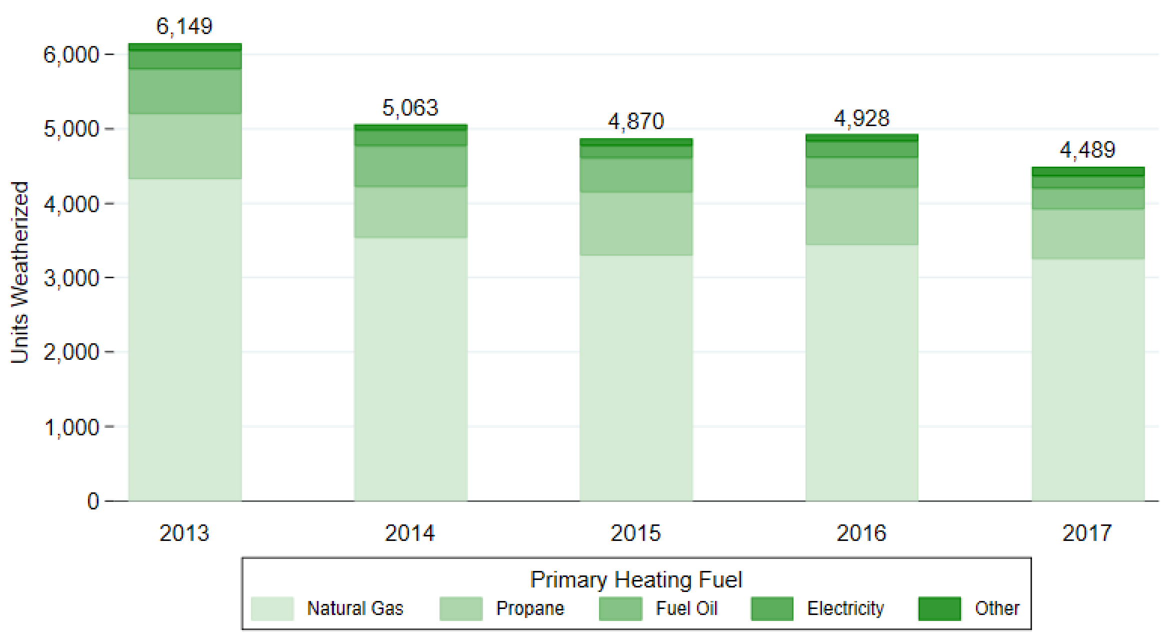


Figure 2 shows the distribution of treated homes in 1-4 unit site-built buildings across primary heating fuels. Natural gas-heated homes have traditionally comprised the majority of this pool. Their relative proportion has remained around 70 percent since 2013.

Figure 2-Weatherized housing units in 1-4 unit site-built buildings, by primary heating fuel and program year



2.0 OBSERVED ENERGY SAVINGS

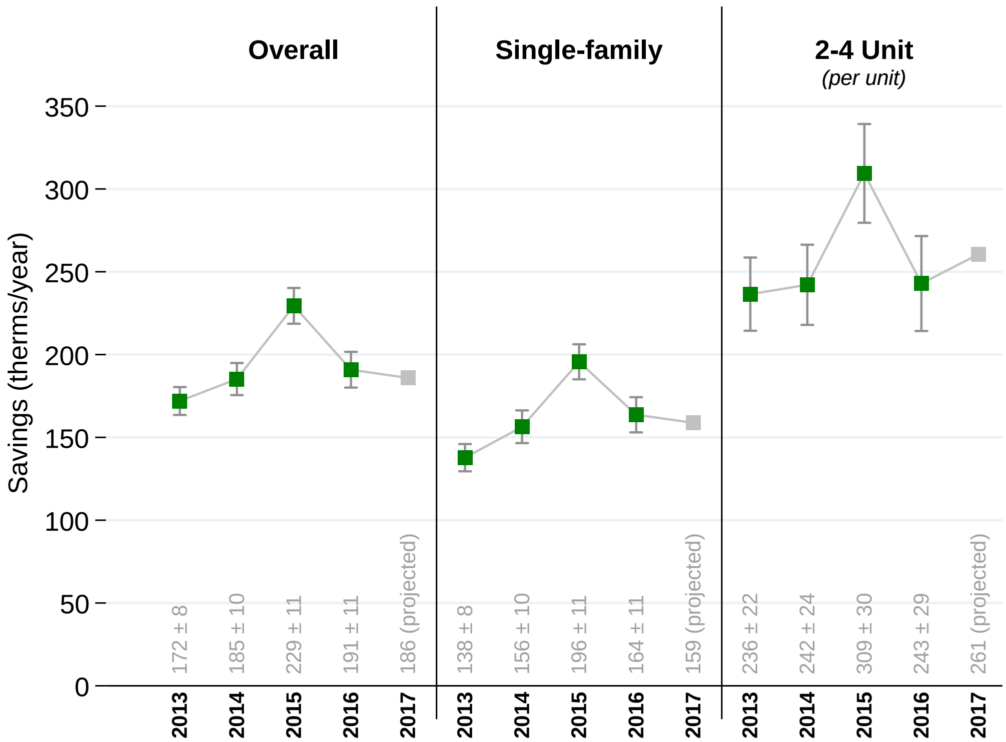
For all but the most recent program year, natural gas and electricity savings for weatherized homes use monthly utility billing data collected from Wisconsin's five major investor-owned utilities. The six utilities that supplied customer billing data are Alliant Energy, Madison Gas & Electric, We Energies, Wisconsin Public Service, Xcel Energy, and electricity-only billing data from WPPI Energy. WPPI Energy supplied only electric data while the others supplied both electric and natural gas. Billing data from pre- and post-weatherization periods are weather-normalized, and the difference between the two periods reflects the gas and electric savings for each treated home. Additionally, pre-weatherization billing data for future program participants is used to correct for non-program factors in any given year. Savings estimates are then coupled with data taken from the program's tracking database to evaluate savings by housing type and other characteristics. Program year 17 savings estimates are preliminary projections based on measures installed and statistical modeling of energy savings. Descriptions of the weather normalization methodology and energy savings models are included in Appendix 5.3.

Note that fuel savings for homes that switch heating fuels (from fuel oil, propane, or electricity to natural gas or, in some cases, to propane) during weatherization are not reflected in observed energy savings because these homes typically have insufficient usage data for a billing analysis. Usage data for bulk heating fuels are not incorporated into this evaluation since collection and usage allocation are difficult, and the data is inherently unreliable. Cost savings for fuel switches are discussed in Section 4.0.

2.1 NATURAL GAS SAVINGS

Except for PY15, natural gas savings have remained stable in recent years (right panel of Figure 3). Overall, observed natural gas savings in site-built, 1-4 unit homes increased in PY15, from 185 therms per unit in earlier years to 229 therms in PY15. Subsequently, savings decreased significantly to previous levels in PY16 with a non-statistically significant decrease in PY17. Based on the measures installed, savings for PY17 homes are projected to be like those observed in the PY16 results. As a result of the relatively small number of units treated each year, the results in 2-4 unit buildings have greater statistical uncertainty than the single-family savings.

Figure 3-Annual gas savings for gas-heated homes, by housing type and program year

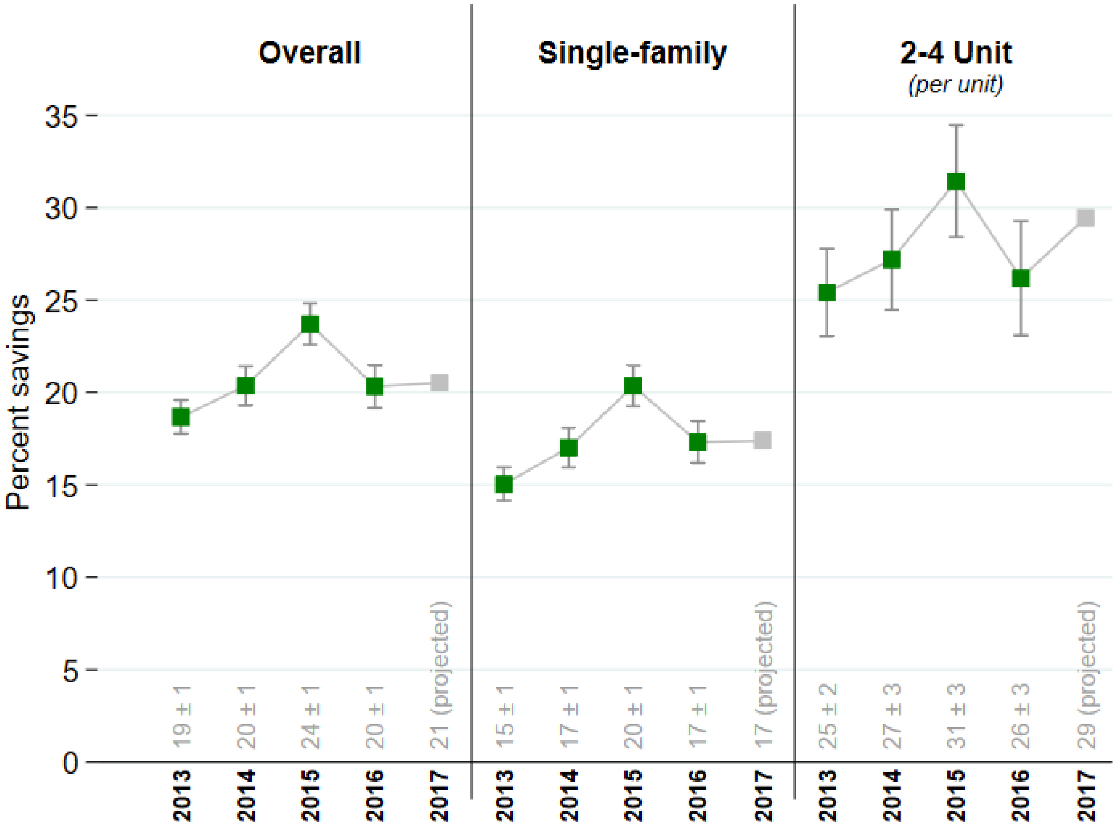


Similar trends are evident when savings are expressed as a percentage of pre-weatherization consumption (Figure 4). More details related to trends in pre-weatherization consumption can be found in Appendix 5.1.

Natural gas savings for the Wisconsin program compare similarly but slightly favorably to the U.S. average, as reported in the national evaluation of the WAP. [2] That evaluation found an average of about 15 percent natural gas savings (147 ± 9 therms/year) for single-family homes treated in PY11, in climates similar to Wisconsin.

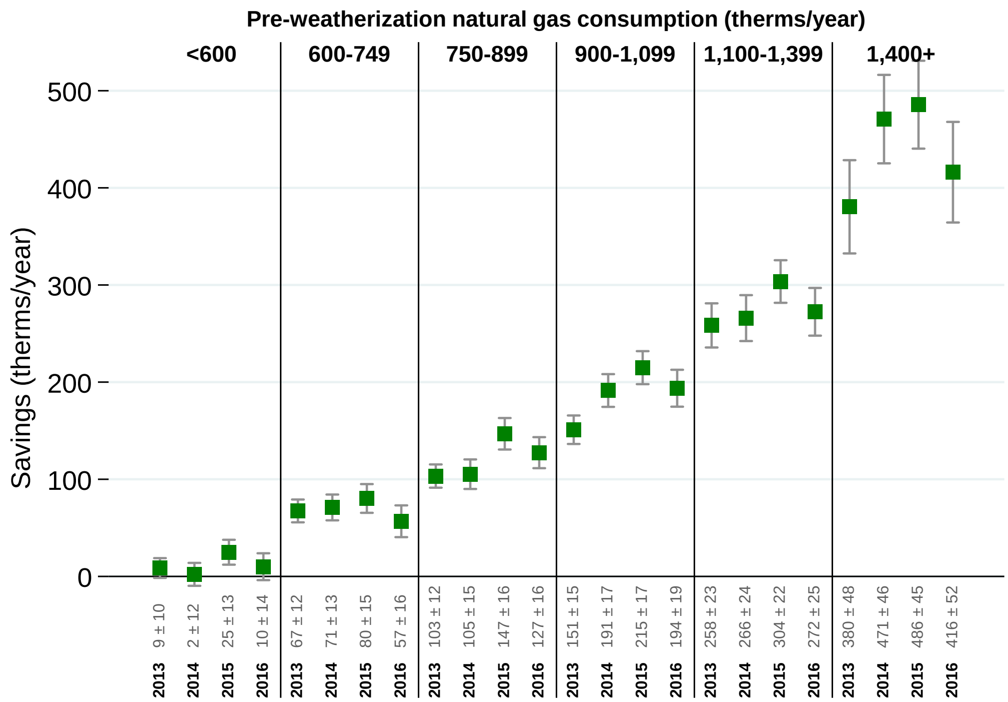
[2] Blasnik, Michael Greg Dalhoff, David Carroll, Ferit Ucar and Dan Bausch. 2015. “Evaluation of the Weatherization Assistance Program during Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single-family Homes,” ORNL/TM-2014/582. (2015), http://weatherization.ornl.gov/RecoveryActpdfs/ORNL_TM-2014_582.pdf

Figure 4-Annual gas savings, as a percentage of pre-weatherization usage, for gas-heated homes, by housing type and program year



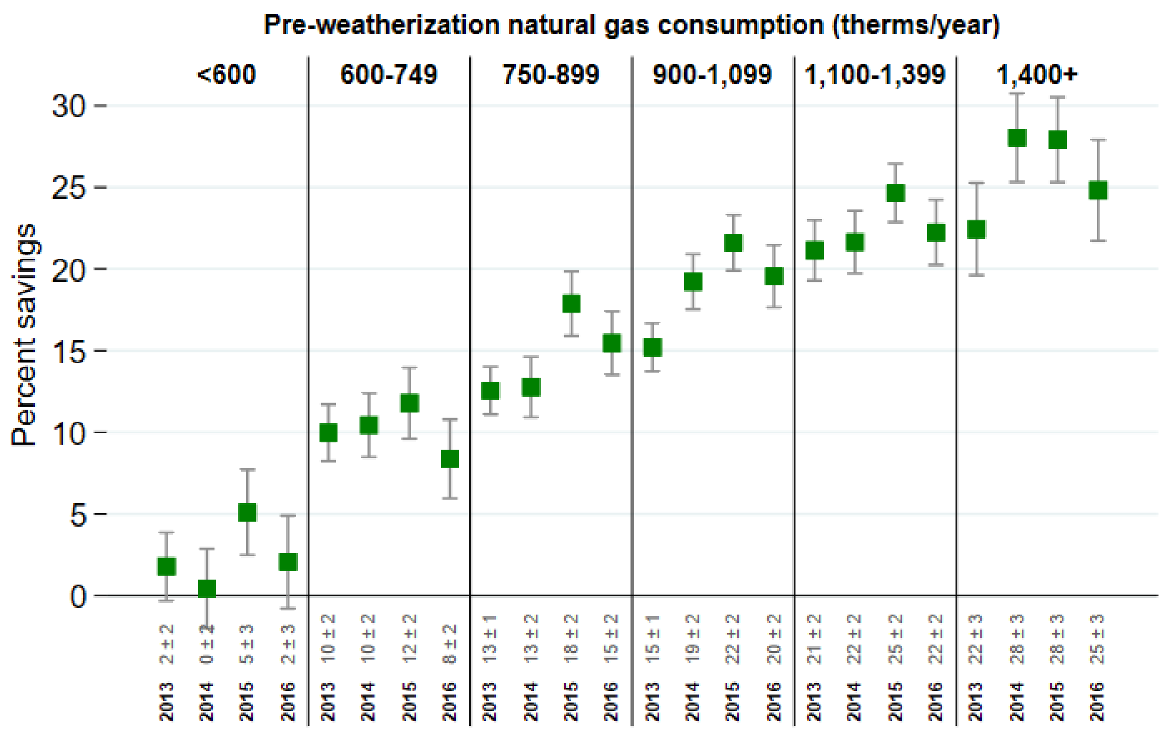
The data are quite clear that homes using more natural gas prior to weatherization save more energy following weatherization (Figure 5). The highest users (1,400+ therms per year, representing about 10 percent of treated homes) yield the greatest savings, typically more than 400 therms per year depending on the treatment year in question. Given the small number of units involved, the savings estimates for the highest users have relatively high uncertainty. High users typically have lower levels of existing insulation, less efficient heating systems, and more uncontrolled air leakage—all opportunities addressed by the program.

Figure 5-Annual gas savings for gas-heated single-family homes, by pre-weatherization usage bin and program year



High users also tend to save a larger percentage of their pre-weatherization consumption (Figure 6). Homes in the highest-use group save about 25 percent of their pre-weatherization gas consumption, compared to only about five percent among homes in the lowest-use group. Gas savings increases by about five percentage points for every 150 to 200 therms of increased annual pre-weatherization usage.

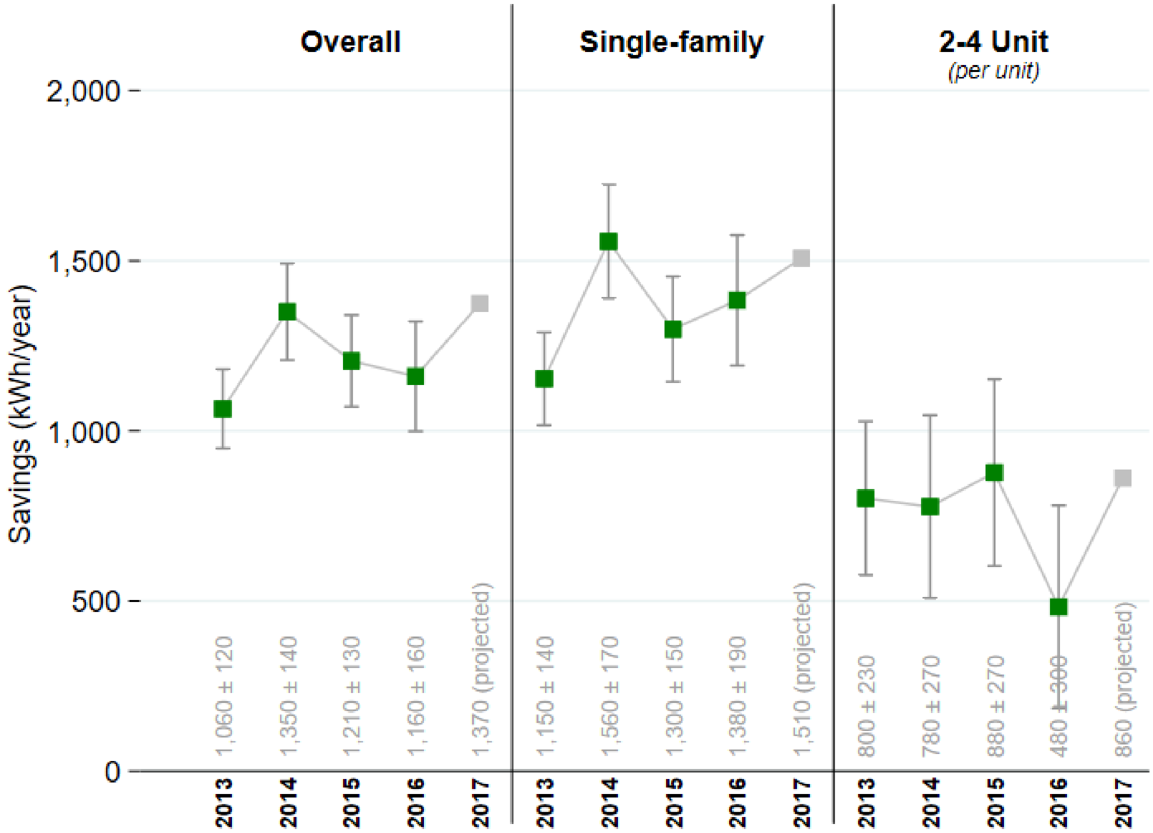
Figure 6-Annual gas savings, as a percentage of pre-weatherization usage, for gas-heated single-family homes, by pre-weatherization usage bin and program year



2.2 ELECTRICITY SAVINGS

Evidenced by the confidence intervals in Figure 7—compared to previous natural gas figures—electricity consumption is inherently more variable than natural gas use, making savings estimates less precise. Overall, savings estimates range from about 500 to 1,500 kWh per year per housing unit—less for multifamily properties and more for single-family homes. With the exception of PY13 to PY14, average electricity savings from the program appear to be trending upward among single-family homes. Year-to-year changes are not statistically significant. Savings trends are similar for savings expressed as a percentage of pre-weatherization consumption (Figure 8).

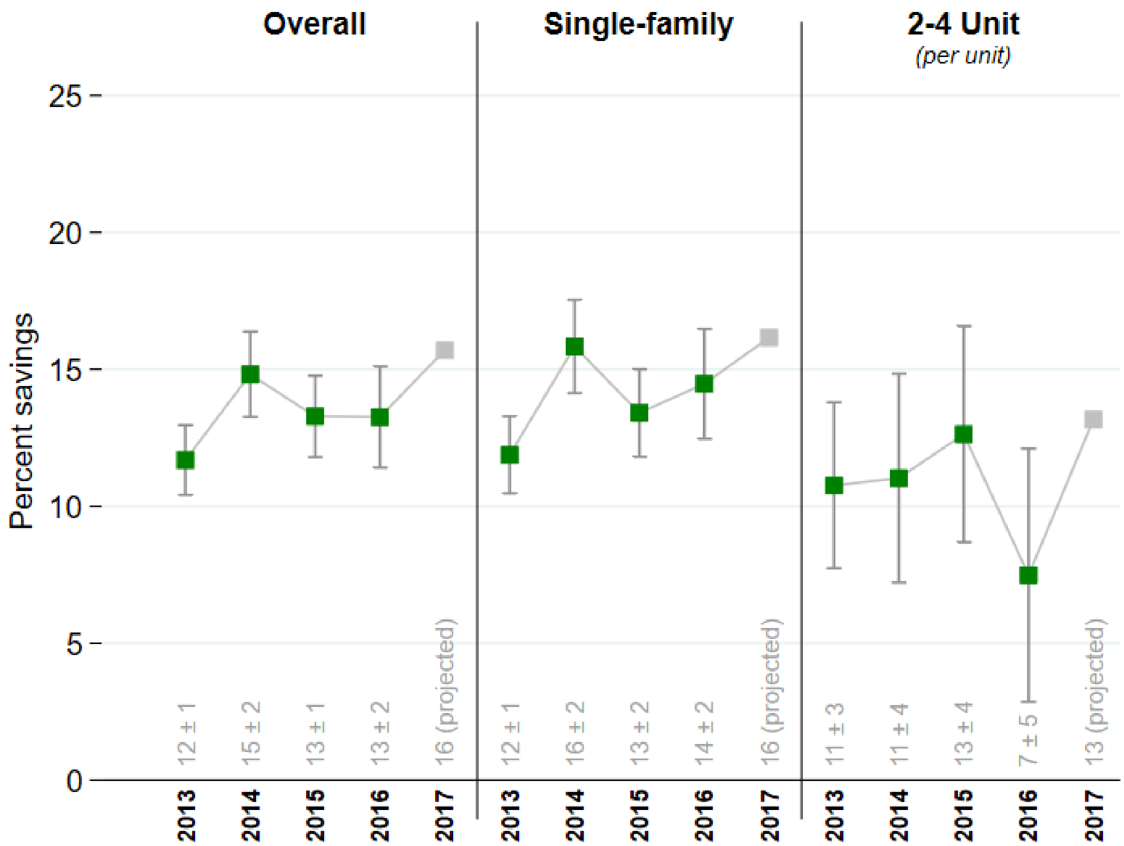
Figure 7-Annual electricity savings for homes without electric heat, by housing type and program year



As with natural gas, electricity savings for the Wisconsin program exceed those found for the recent national evaluation of the WAP, which found about eight percent electric savings (for homes with natural gas heat) in climates like Wisconsin's.[3]

[3] Blasnik et al. "Evaluation of the Weatherization Assistance Program during Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single-family Homes," (2015).

Figure 8-Annual electricity savings, as a percentage of pre-weatherization usage, for homes without electric heat, by housing type and program year



Like natural gas, higher users of electricity tend to save more following weatherization (Figure 9), though the trend is not nearly as dramatic. The major difference is that a clear correlation is not apparent between electricity savings as a percent of pre-weatherization usage levels (Figure 10). Compared to natural gas, electric end uses are much more numerous and diverse, and many of them cannot addressed by the program. Since there are many more ways that a household can be a high user, weatherization treatment has somewhat less impact because it treats a smaller fraction of measures that create high use. Still, treated homes typically see savings of between 10 and 15 percent, regardless of their pre-weatherization usage level.

Figure 9-Annual electricity savings for single-family homes without electric heat, by pre-weatherization usage bin and program year

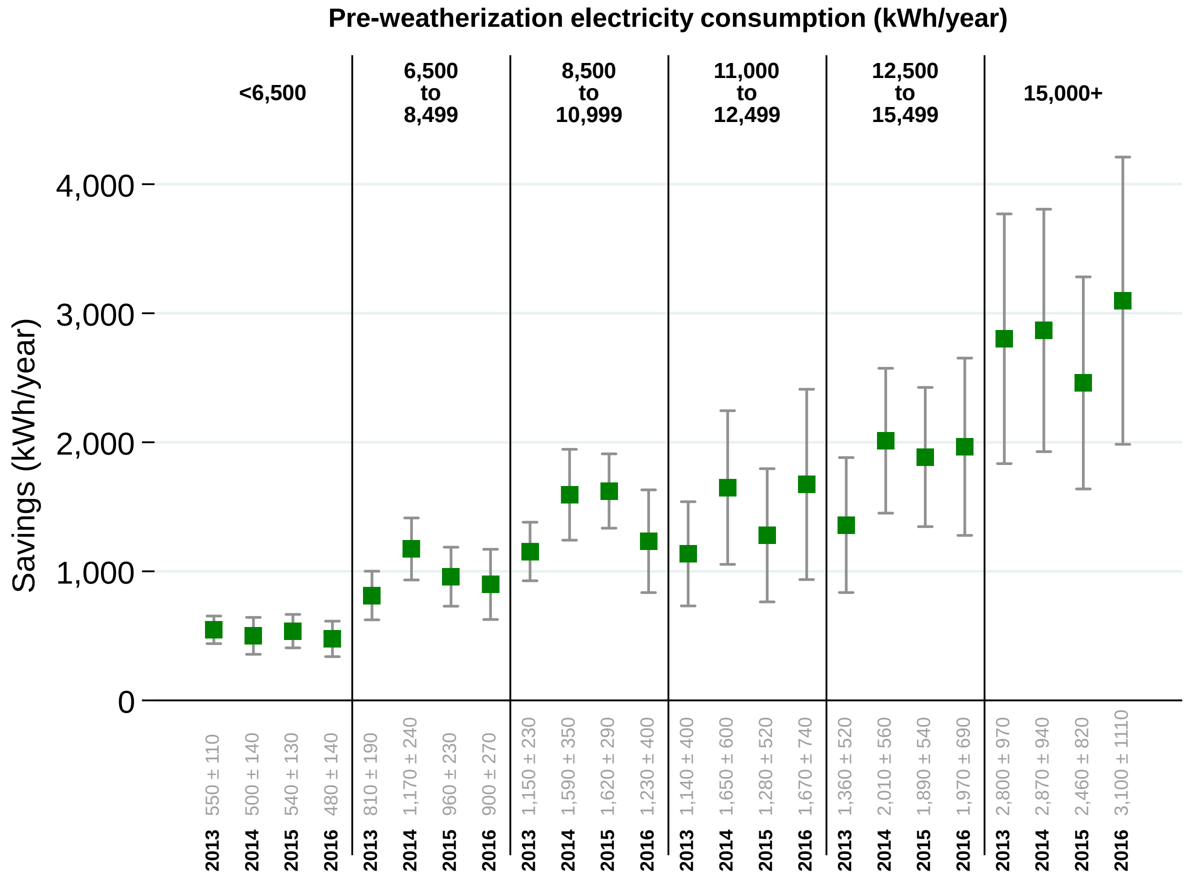
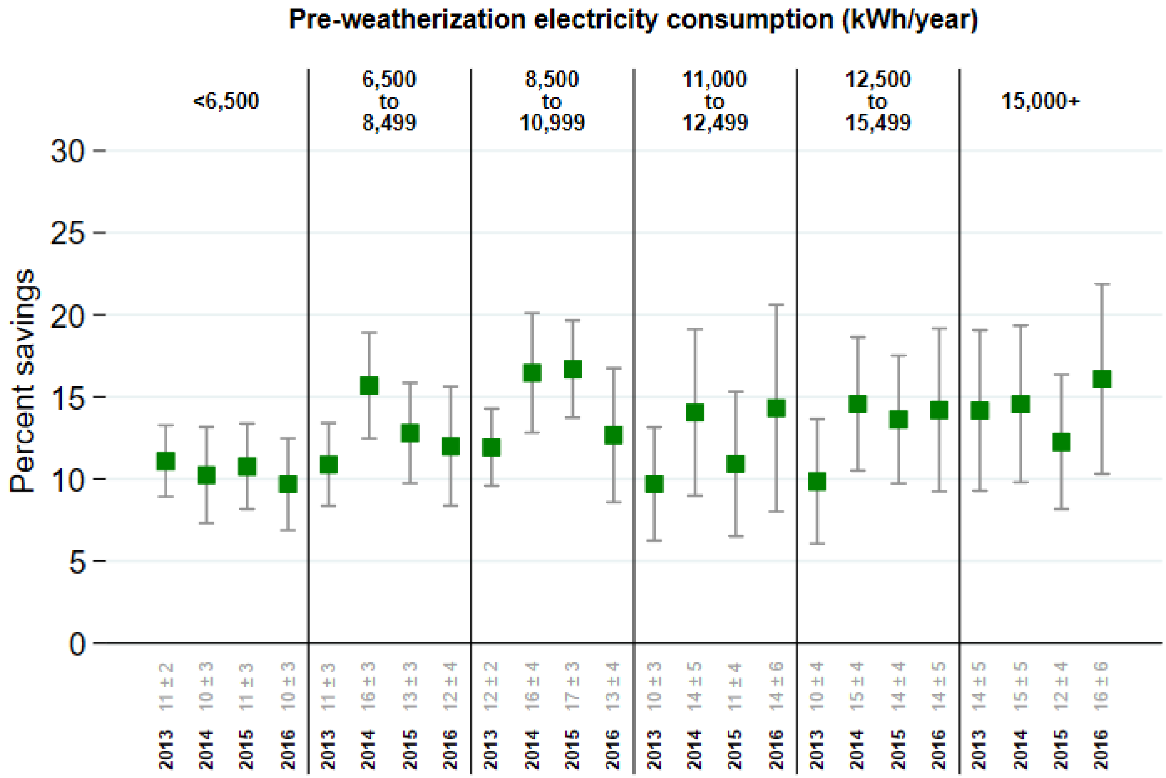


Figure 10-Annual electricity savings for single-family homes without electric heat, by pre-weatherization usage bin and program year



3.0 MODELED ENERGY AND COST SAVINGS

This study used a statistical model of energy savings for two purposes: (1) to disaggregate overall observed natural gas and electricity savings by conservation measure; and (2) to extrapolate observed savings for homes with adequate pre-and post-weatherization billing data to more recently treated homes and to treated homes heating with bulk fuels. Modeled energy savings for all participating homes are then combined with average fuel prices and projected fuel-price increases to estimate cost savings directly following weatherization and throughout the life of installed measures.

Estimating cost savings attributable to Wisconsin's program is a key element of this evaluation and is used to determine the program's cost-effectiveness. This section measures cost-savings at three levels: through the savings attributable simply to consuming less energy following weatherization (conservation only), an additional level that includes savings from space heating fuel conversions (conservation and fuel switching), and water conservation from installed low-flow showerhead and faucet aerators (total cost savings).

More detail on the energy savings model and conceptual approaches to estimating cost savings associated with heating fuel conversions and water conservation can be found in Appendix 5.4.

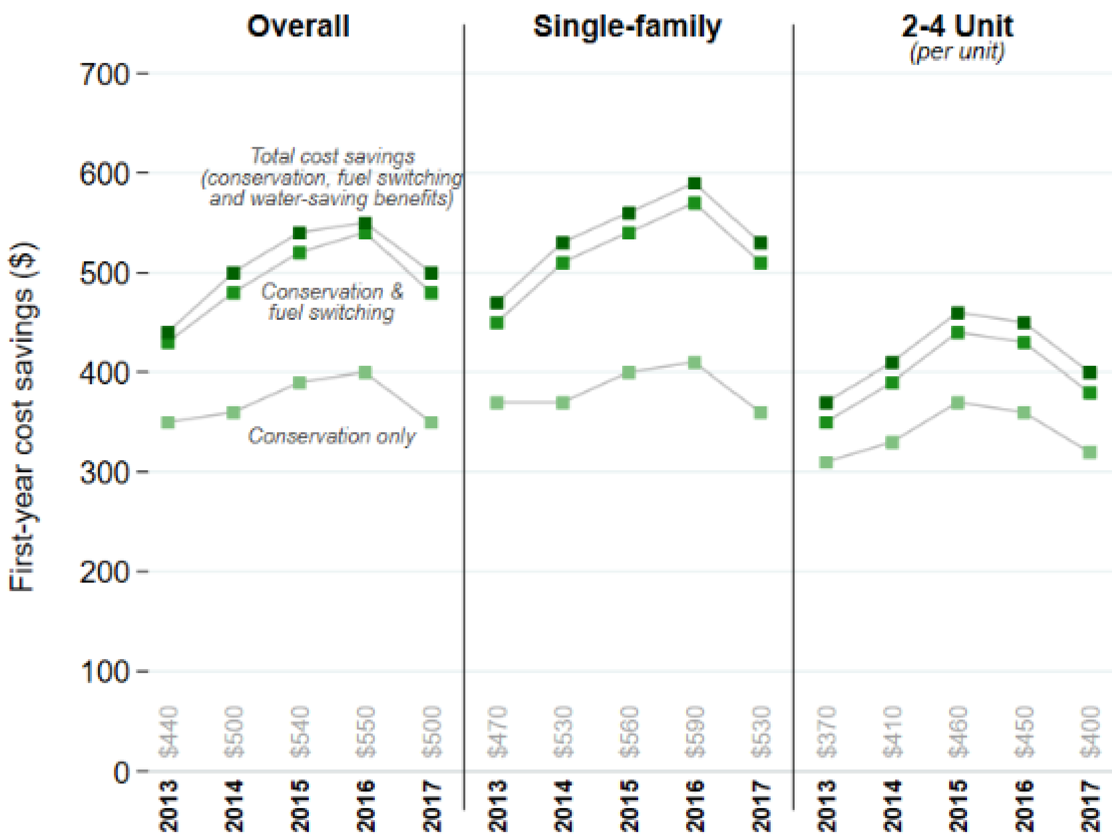
3.1 PER-HOME COST SAVINGS

Overall, participating households from the most recent program year (PY17) are projected to save an average of $500 on their energy bills in the first year of post-weatherization from the program (Figure 11). This average, however, obscures the wide variation in expected savings, dependent on housing type, heating fuel, and if the home received a space heating and/or water heating fuel switch. In Figure 11, average annual cost savings per home are presented by source(s) of savings (conservation measures, fuel switching, and reduced water use) and housing type.

Savings from energy reduction measures account for close to three-quarters of total cost savings and, despite small year-to-year changes, have been relatively stable over the past five program years with slight variation across housing types. Two-thirds of participating single-family homes heat with natural gas, as do more than 90 percent of units in small multifamily properties. That is why energy-based cost savings generally follows the natural gas savings trends presented in Section 2.1. Natural gas savings increase slightly in PY15, then decline from PY16 and PY17. The decrease from PY16 to PY17 results from a combination of a decrease in the price of natural gas (Appendix 5.7), lower incidence of key measures, including attic and wall insulation and furnace replacements—and a slightly lower incidence of heating-system fuel switches, which have a disproportionate impact on overall average energy-cost savings.

Water conservation from faucet aerators and flow-reducing showerheads accounted for a small but constant source of cost savings, from $17-19 per year. Cost savings estimates are based on a typical Wisconsin water and sewer rate of about $7.50 per 1,000 gallons, applied to a calculated reduction volume per installed unit per year. Assumptions used in estimating the amount of water saved per unit are provided in Appendix 5.6.

Figure 11-Average first-year cost savings per home, by housing type and program year



The impact of fuel conversions is more evident in Figure 12 which shows average cost savings (total and conservation-based savings only) broken out by primary heating fuel. Homes heating with fuel oil or electricity experience large cost savings but represent a small but impactful subset of the program. Fuel oil-heated homes make up 6 to 11 percent of annual program participation and electric-heated homes account for about 4 percent.

Fuel switching from expensive heating fuels like electricity and fuel oil to natural gas produces significant energy-cost savings—in addition to the savings gleaned from efficiency improvements. Switching from a higher-cost to a lower-cost heating (or water heating) fuel makes it less expensive to operate a furnace or water heater in general, even if there was no efficiency improvement. Figure 12 highlights this as the large difference between total cost savings and savings from conservation only for fuel oil and electricity.

Figure 12-Average first-year cost savings per home, by heating fuel type and program year

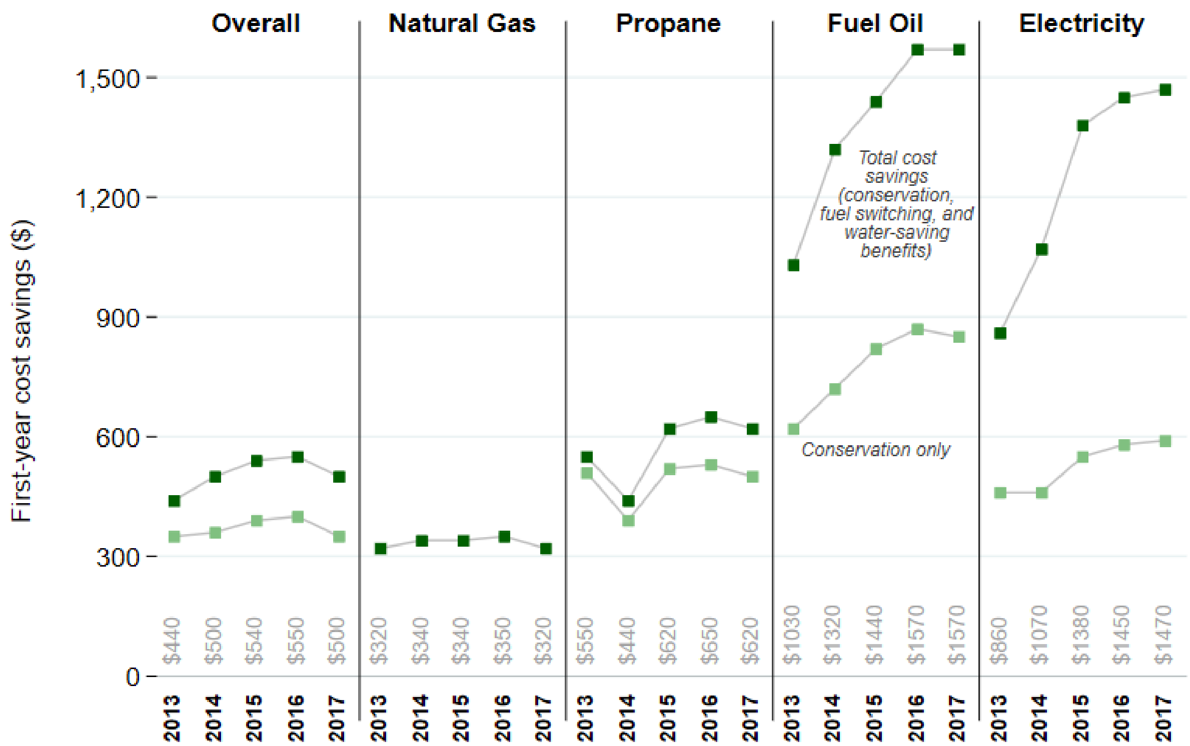


Figure 13 plots the predicted first-year cost savings for each home weatherized by the program in PY17 (including natural gas-heated homes) by the presence and type of fuel switch. The box-and-whisker plots show the distribution of first-year cost savings across homes: boxes indicate the range for the middle 50 percent of homes in each group, and the whiskers show the range between the fifth and ninety-fifth percentiles.

The largest difference shows results from homes that received a space heating fuel switch. Homes not receiving a heating fuel switch measure, regardless of housing type or primary heating fuel are, on average, expected to save less ($290 to $490 during the first year following weatherization). In contrast, homes receiving a heating fuel switch measure are, on average, expected to save between $1,630 and $1,920. Although homes that received space heating fuel switches have wider variation in first-year cost savings than those without, the difference from non-space heating fuel switches is statistically significant and adds upwards of $1,000 to first year cost savings.

The incidence of space heating fuel switching is an important contributor to cost savings because it is the highest-saving measure. In PY16, 12 percent of single-family homes received a fuel switch from electricity or bulk fuel to natural gas. This figure declined to 10 percent in PY17, contributing to lower first year cost savings in PY17. The price gap between electricity and bulk fuels to natural gas continues to be a significant source of cost savings for both water heating and space heating.

Figure 13-First year cost savings for individual homes treated in PY17 as a result of fuel switching

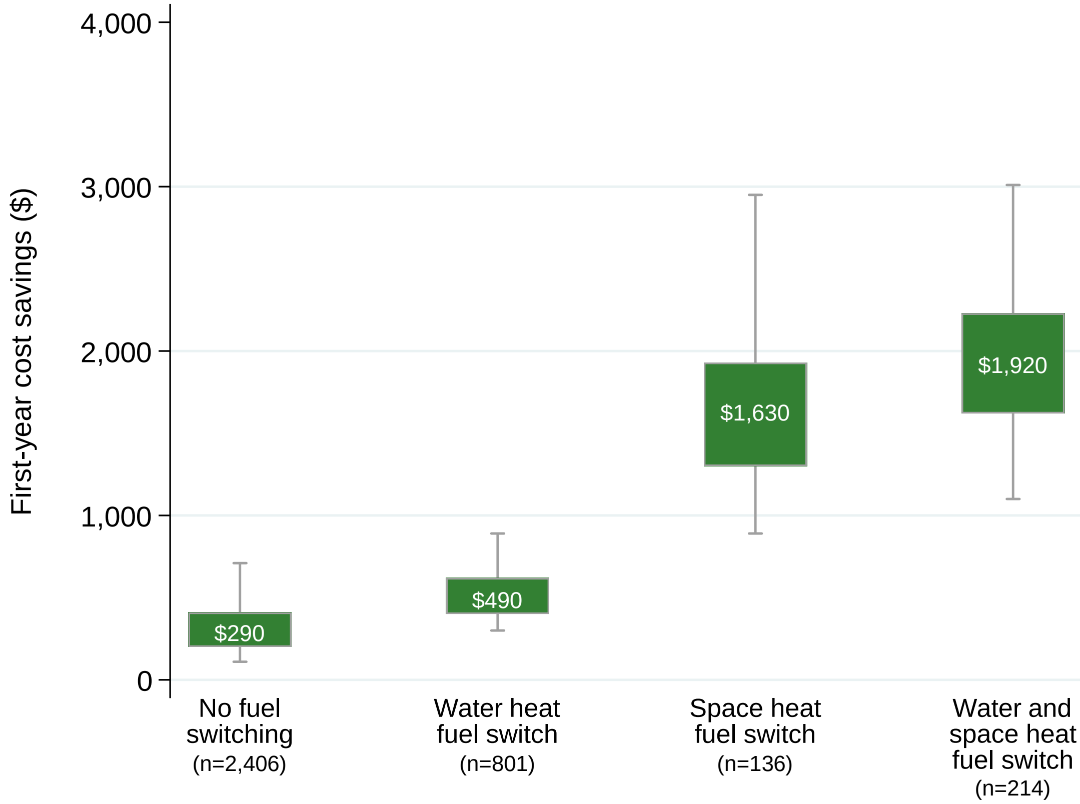


Table 1 expands on the data portrayed above by presenting average, per-home cost savings expected during the initial year after weatherization for more specific subgroups: by housing type, heating fuel, and if a heating fuel conversion measure was installed. A similar table showing projected cumulative savings over the useful life of installed measures is included in the appendices (Appendix 5.2). Notably, two-thirds of single-family homes and more than 90 percent of small multifamily homes are heated with natural gas. Even though savings from fuel switching is a potent contributor to savings, the majority of both home types did not experience a fuel switch measure.

Overall, average energy cost savings are higher among single-family homes than among small multifamily homes. Significant minorities of the former were heated with more expensive fuels before weatherization, while nearly all multifamily properties had natural gas heat. Generally, cost savings among all single-family homes is driven by homes with natural gas heat.

Table 1-Average first year cost savings for homes treated in PY17, by housing type and fuel type

Housing type & primary heating fuel	Units with no fuel switching			Units with a <u>water</u> heating fuel switch		Units with a <u>space</u> heating fuel switch*	
	Treated units	% of units	First-year savings	% of units	First year savings	% of units	First-year savings
Single-family	3,557	68%	$330	23%	$530	10%	$1,840
Natural Gas	2,383	76%	$270	24%	$470		
Propane	662	68%	$520	27%	$690	5%	$1,560
Fuel Oil	267	16%	$500	5%	$720	79%	$1,840
Electricity	125	32%	$480	11%	$650	57%	$2,340
Other	120	61%	$550	12%	$670	28%	$1,140
2-4 Unit	930	89%	$320	8%	$640	2%	$2,380
Natural Gas	863	93%	$310	7%	$580		
Propane	10	20%	$570	80%	$830		
Fuel Oil	16	19%	$400	6%	$1,150	75%	$2,080
Electricity	41	66%	$580	7%	$1280	27%	$2,700

*Approximately two-thirds of jobs in which space heating fuel was converted; water heating fuel was also converted.

3.2 INDIVIDUAL MEASURE ENERGY SAVINGS AND INSTALLATION RATES

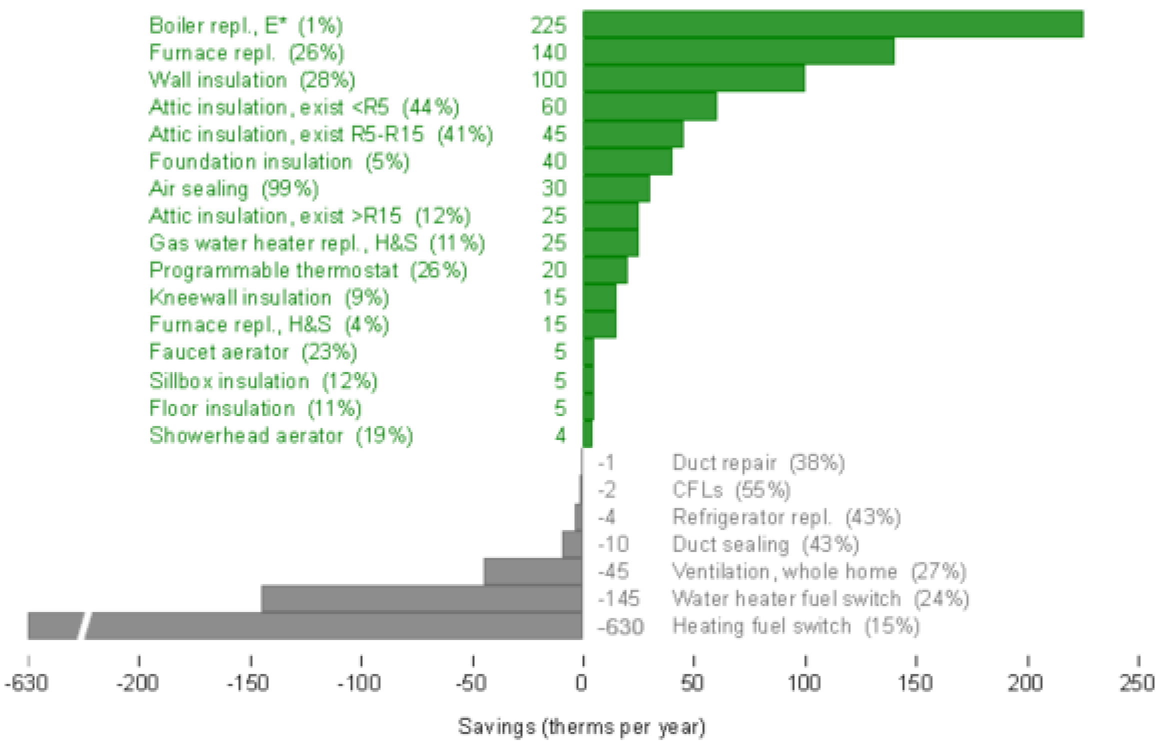
As mentioned previously, a statistical model is used to estimate average natural gas and electricity savings for individual measures. Figure 14 and Figure 15 present savings and measure installation rates for single-family homes, since they make up the largest portion of treated site-built homes.

Individual measures yielding the greatest gas savings include heating system replacements and insulation, especially for walls and attics. At 225 therms per year, boiler replacements produce the highest savings, but only occur in one percent of single-family weatherization cases. Air sealing, while not a large energy saver (30 therms per year), is notable because it is completed in nearly all homes.

Other measures increase natural gas consumption. The most notable of these is fuel switching. Converting a central heating system to natural gas is shown in Figure 14 as a truncated bar on the bottom of the graph because it *adds* an average of 630 therms to a home's annual natural gas load. Mechanical exhaust ventilation also carries a natural gas penalty simply by influencing heating loads via increased airflow exchange.

Of the other measures listed in Figure 14, duct repairs, duct sealing, refrigerator replacements, and compact fluorescent lights (CFLs) all have negative savings. Savings estimates for duct sealing and repairs are not statistically distinguishable from zero, nor do either of these measures have a large effect on savings. Negative savings for refrigerator replacements and CFLs follows a theoretical basis for a natural gas penalty in which the electricity saved by these measures reduces the amount of heat generated indoors by refrigerators and lighting, demanding slightly more of the heating system.

Figure 14-PY17 annual gas savings per measure, when measures installed in single-family, site-built homes (measure incidence rate in parentheses)



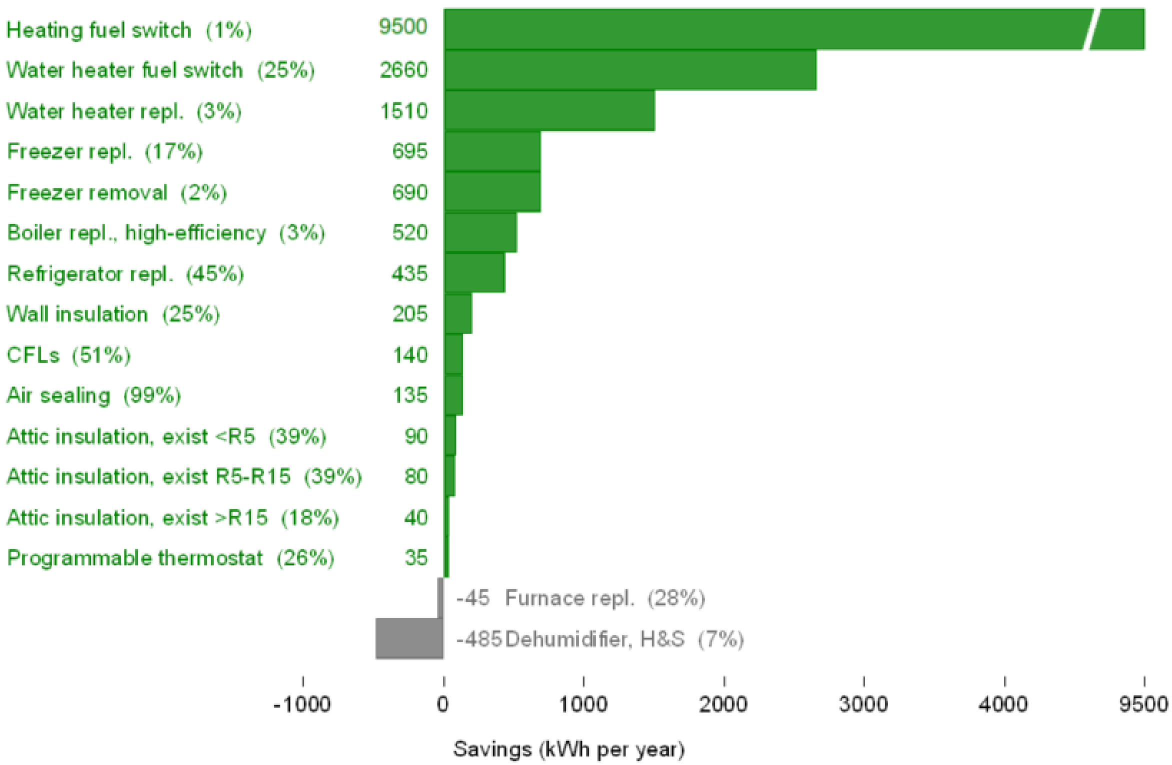
Most electrical savings derive from electric-to-natural gas primary space heating systems. In PY17, approximately one percent of homes converted an electric heating system to gas. Shown in Figure 15 as a truncated bar on the top of the graph, the savings associated with this measure was about 9,500 kWh, which is more than a threefold savings over the next highest-saving measure.[4] The third measure listed—water heater replacements[5]—has high savings with low incidence. Refrigerator, freezer replacements, and wall insulation also provide significant electricity savings.

This analysis indicates that the installation of a dehumidifier (for homes where moisture management is necessary) increases electricity consumption. However, as indicated by the low incidence rate, these measures are not commonly installed. Furnace replacements are associated with a small amount of negative savings and have historically varied between slightly positive and negative savings. These are unlikely to have a significant effect on electricity savings.

[4] This is the total electricity reduced from the fuel switch to natural gas and is almost certainly less than shown here because over 95 percent of the electric heating systems replaced with natural gas were baseboard and portable electric resistance heating instead of electric furnaces with fans. Not accounted for here is the electricity used to power fans that circulate heat from a gas furnace. Depending if the fan is an electrically commutated motor or not, this value is expected to be 800 to 400 kWh/year lower than above. This estimate is derived from: Pigg, Scott. 2003 "Electricity Use by New Furnaces." Energy Center of Wisconsin. Report: 230-1, 230-2. Available from: http://seventhwave.org/publications/electricity-use-new-furnaces-wisconsin-field-study.

[5] The high savings is a result of this being measure representing a likely mixture of water-heater fuel switches that were not identifiable as such with electric-to-gas water heater replacements.

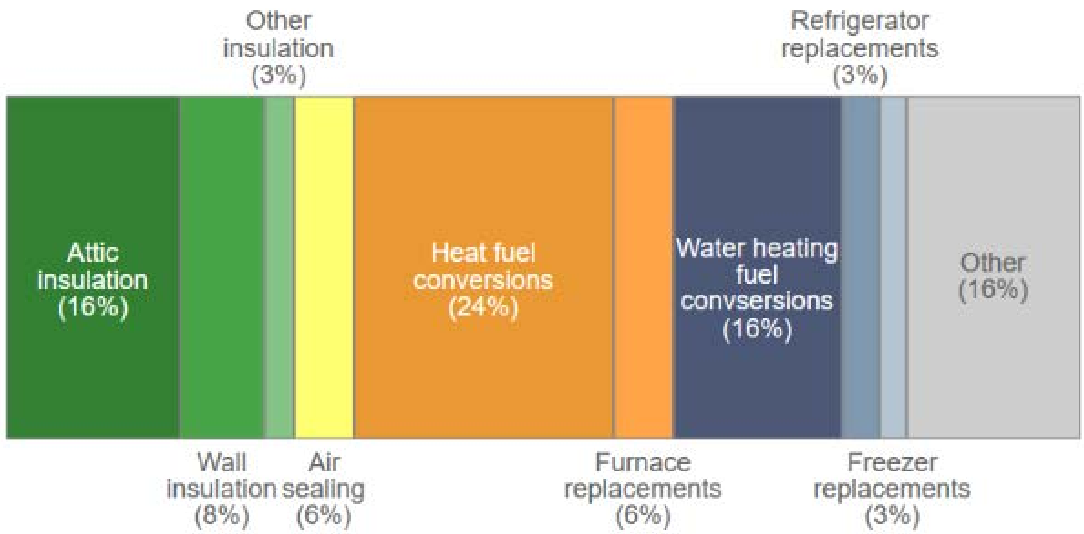
Figure 15-PY17 annual electric savings per measure, when installed in single-family, site-built homes (measure incidence rate in parentheses)



3.3 MEASURE CONTRIBUTIONS TO AGGREGATE SAVINGS

The model-estimated contributions of individual measures to total aggregate life-cycle energy cost savings for single-family homes are shown in Figure 16. The figure shows the combined effect of per-installation savings and installation rates on overall program cost savings. Over three-quarters of energy cost savings from the program are from fuel switching (40 percent), attic and wall insulation measures (24 percent), air sealing (six percent), and heating system replacements (six percent). Measures with smaller contributions to overall cost savings are bundled together in “Other” and cumulatively account for about 16 percent of savings. The “Other” category includes the effects of health and safety and repair measures, some of which may result in negative savings. Relative to PY16, the combined effect on per-installation savings and installation rate has declined for both attic insulation and heating fuel conversions.

Figure 16-PY17 measure contributions to life-cycle cost savings when installed in single-family, site-built homes



3.4 PROGRAM-WIDE ENERGY AND COST SAVINGS IMPACTS

For single-family and small multifamily units treated in PY17, the statewide program saved participating households around $2.25 million during the first year after weatherization. Over the life of the installed measures, the program is projected to yield $51 million in energy cost savings for those homes.

Aggregate cost and energy savings are down across all categories. This is because fewer units were weatherized and the proportion of high pre-weatherization users (high-savings) to low pre-weatherization users (low-savings) stayed constant during the last two program years.

Table 2-Program-wide energy savings for single-family and multifamily homes, by heating fuel type and program year

PY	Treated units	Aggregate energy savings				Aggregate cost savings				
		NG (therms)	**LPG** (gals)	**FO** (gals)	**ELEC** (kWh)	**Energy cons.**	**Fuel switch**	**Non-energy benefits**	**Total, first-year**	**Total, life of measures** (undiscounted)
PY13	6,149	866,000	176,000	103,000	7,700,000	$2,164,000	$461,000	$105,000	$2,730,000	$56,762,000
PY14	5,063	759,000	136,000	106,000	7,016,000	$1,806,000	$617,000	$90,000	$2,512,000	$57,257,000
PY15	4,870	778,000	184,000	99,000	6,627,000	$1,915,000	$607,000	$86,000	$2,608,000	$59,927,000
PY16	4,928	842,000	172,000	89,000	7,311,000	$1,956,000	$683,000	$93,000	$2,732,000	$59,780,000
PY17	4,487	699,000	152,000	67,000	6,551,000	$1,590,000	$584,000	$73,000	$2,247,000	$51,547,000

4.0 PROGRAM COST EFFECTIVENESS

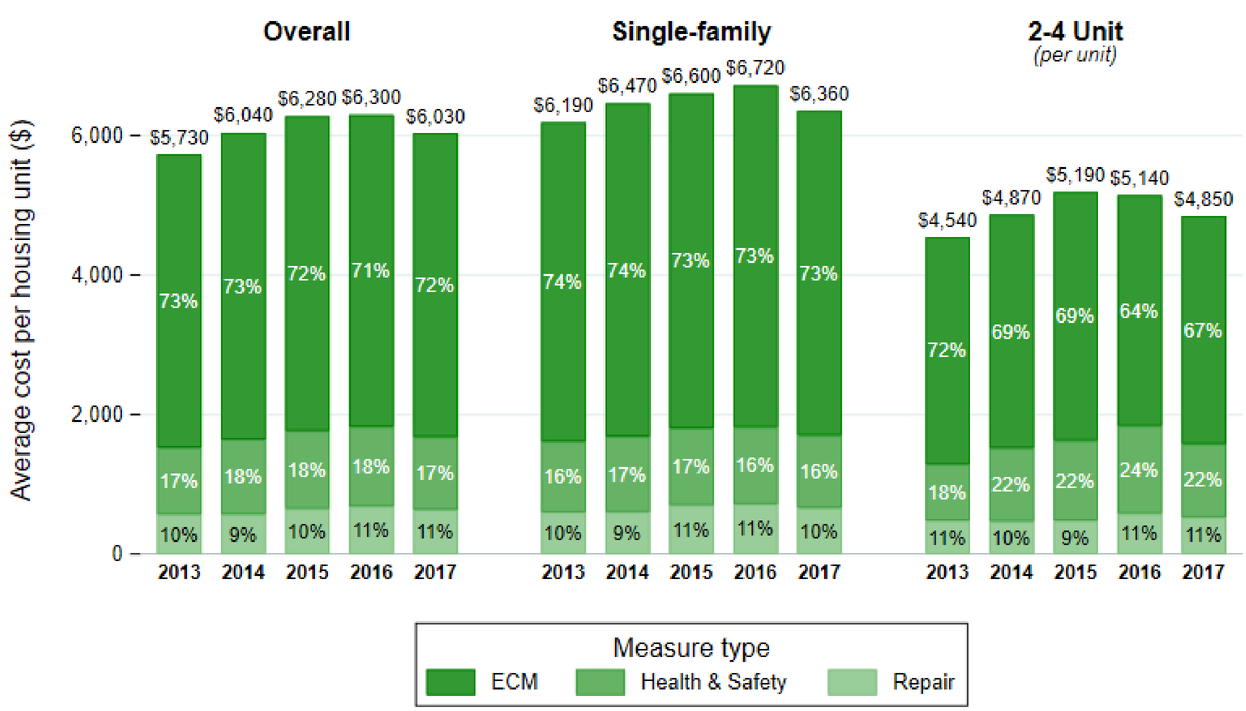
This section brings together information about program costs and projected savings. Job-level costs, broken out by measure type (energy conservation, health and safety, or repair), are presented first, followed by an analysis of program-wide cost effectiveness.

4.1 JOB-LEVEL COSTS

Overall, the average cost of weatherizing a housing unit steadily increased from PY13 to PY16, before declining in PY17. Disaggregating average cost per housing unit (Figure 17) shows similar reductions. Although the proportion of energy conservation measures, health and safety, and repair measures have remained close to historical levels, both the number of treated units and the aggregate cost of those treatments is down from PY16. The overall decrease in average cost per housing unit is tied to pre-weatherization consumption levels. Since the average home consumed less in PY17 than in PY16 (especially in therms; see Appendix 5.1), fewer measures are installed and jobs have slightly lower costs.

In PY17, the cost for single-family homes averaged above $6,000. The cost for homes in 2-4 unit buildings averaged just below $5,000 per housing unit. Throughout the program, spending is dominated by energy conservation measures (ECMs) with about $4,300 per home, but costs to address health and safety issues, as well as home repairs needed to enable installation of ECMs and other costs, amount to about $1,700 per home.

Figure 17-Job costs per housing unit, by housing type, measure type, and program year



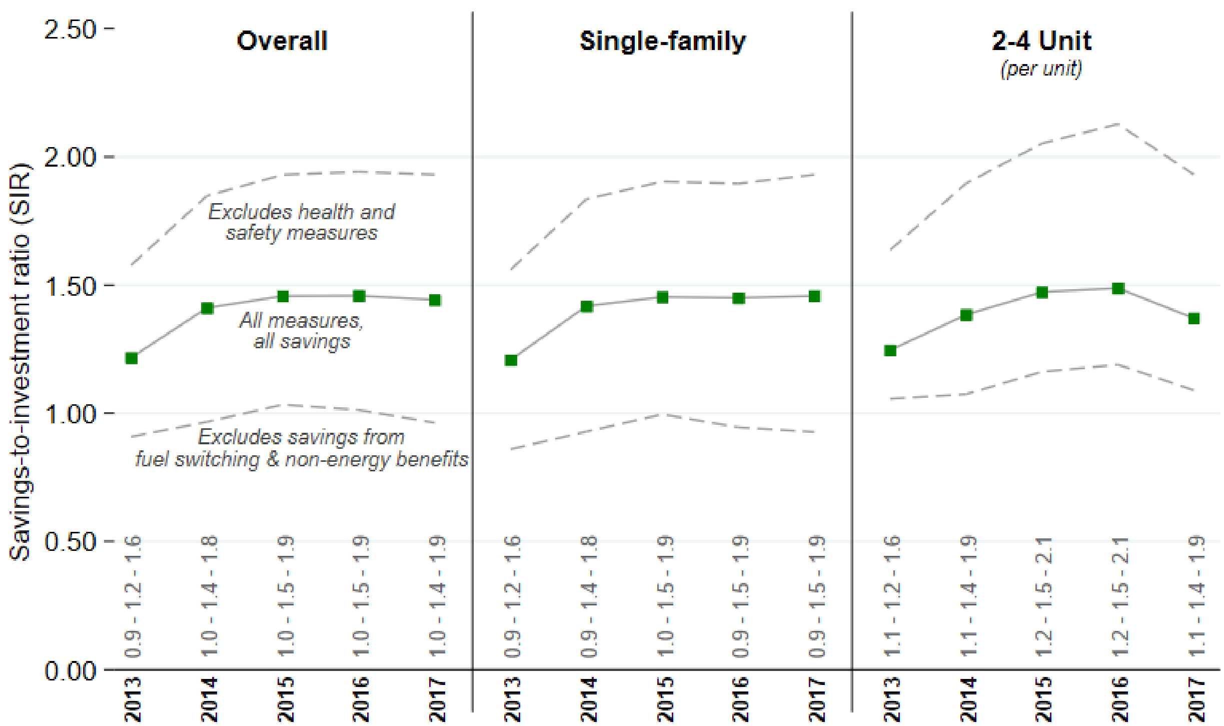
4.2 OVERALL PROGRAM COST EFFECTIVENESS

Average cost savings and information on per-unit spending is used to estimate discounted life-cycle program savings-to-investment ratios (SIRs) for each housing type and primary heating fuel. Three sets of SIRs are provided for each subgroup:

- The primary series (with green squares) includes all sources of cost savings and all measure categories.
- One alternative series (bottom) is calculated using only energy conservation-related cost savings (i.e., savings associated with fuel switching or water conservation are not included).
- Another alternative series (top) is calculated using savings and costs associated with energy conservation and repair measures only (health and safety measures are excluded).

Figure 18 shows program-wide SIRs, broken out by housing type and program year. Overall, average SIRs are well above the key threshold of 1.0 and reflect the impact of cost savings associated with space and water heating fuel switching. Without savings from fuel switching, average SIRs for single-family homes hover around 1.0, but are higher for units in small multifamily buildings. Excluding health and safety measures increases average SIRs by about 0.5. On the whole, levels of savings are lower in PY17 compared to PY16, but the efficiency of weatherization investment is equal.

Figure 18- Program-wide SIRs, by housing type and program year



Even without savings from fuel switching measures, SIRs for propane, fuel oil, and electric homes are higher than those for natural gas (Figure 19). The dominant feature of this plot is the large disparity between the cost-effectiveness of fuel switching to natural gas heating systems from fuel oil and electric space heating. The source of these differences owes to the higher value per unit of delivered energy for fuel oil and electricity.

Figure 19-Program-wide SIRs, by heating fuel type and program year

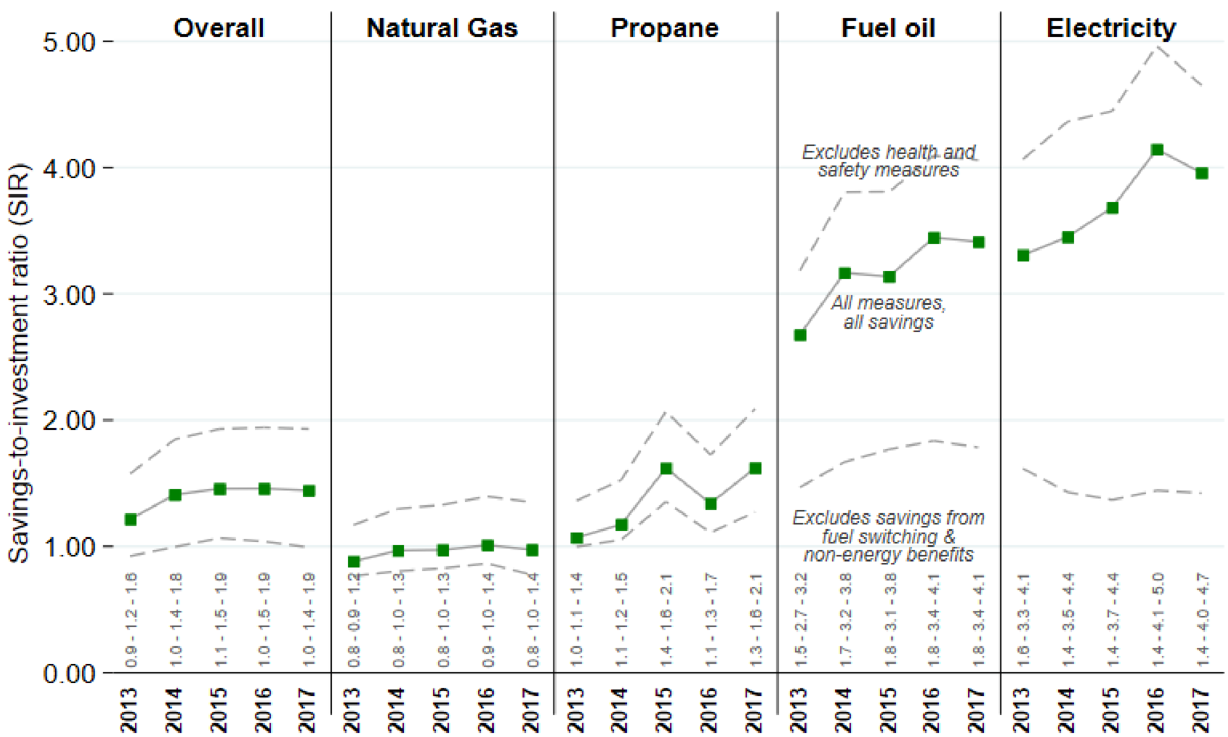


Table 3 further breaks out estimated PY17 SIRs and job costs by housing type and heating fuel. Again, across housing types, SIRs are highest for homes heated with fuel oil or electricity, and average job cost is higher for single-family homes.

Table 3-Average SIRs and job costs for homes treated during PY17, by housing type and heating fuel

Housing Type & Primary Heat Fuel	Includes health and safety measures			Excludes health and safety measures	
	SIR (using energy cons. cost savings only)	**SIR** (using total cost savings)	**Average* job cost**	**SIR** (using total cost savings)	**Average job cost**
Single-family	0.97	1.46	$6,231	1.82	$4,885
Fuel oil	1.77	3.38	$8,568	3.67	$6,634
Natural gas	0.70	0.92	$5,910	1.21	$4,580
Propane	1.27	1.61	$6,208	1.74	$4,848
Electricity	1.31	3.94	$7,266	4.23	$5,239
Other	1.54	1.75	$6,469	2.16	$4,732
2-4 unit	1.11	1.37	$4,911	1.91	$3,602
Fuel oil	2.13	3.96	$7,758	4.89	$5,152
Natural gas	1.03	1.14	$4,845	1.57	$3,550
Propane	1.87	2.84	$4,526	2.42	$3,741
Electricity	1.89	4.02	$5,287	5.41	$3,601

*Note the small discrepancy between average job cost in Figure 17. Those averages are calculated by measure types, while these are not.

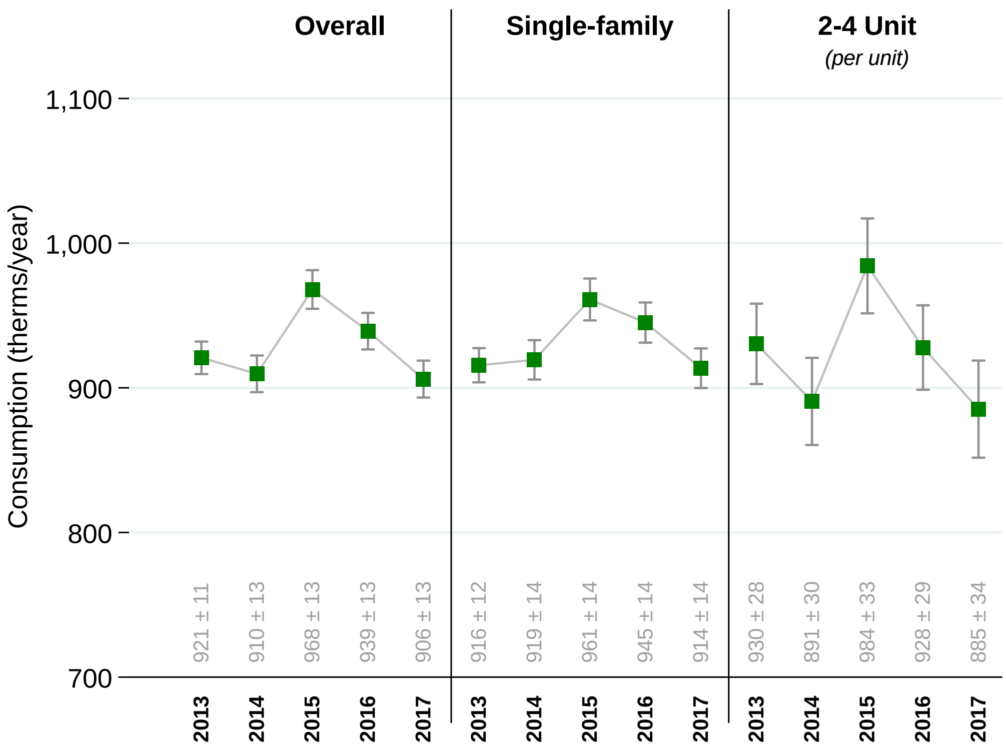
5.0 APPENDICES

5.1 PRE-WEATHERIZATION CONSUMPTION TRENDS

Given the correlation between consumption and savings (i.e., higher users tend to save more energy after weatherization), the following graphs present trends in natural gas and electricity consumption in context to the savings estimates presented in the report.

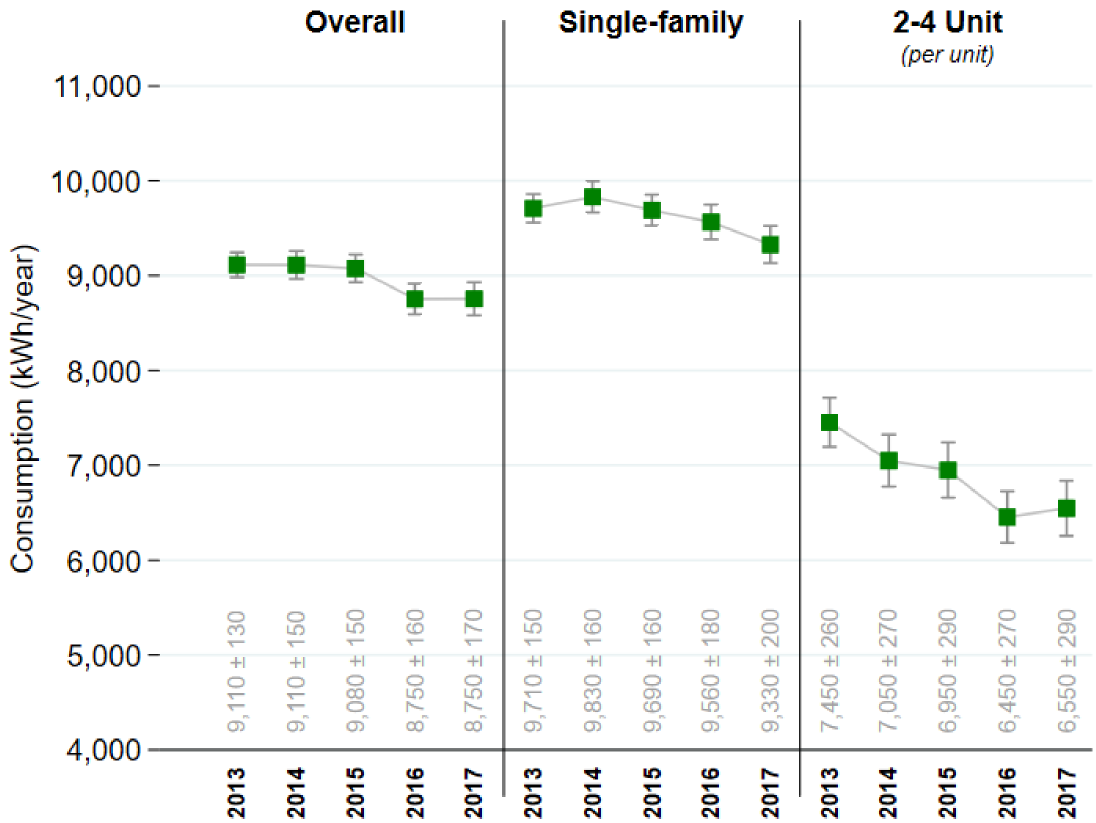
Aside from large increases in both single-family and small multifamily homes from PY14 to PY15, weather-normalized natural gas use has declined in recent years to PY13 and PY14 levels. Average natural gas use among small multifamily homes has been more variable, as might be expected given the small number of homes treated.

Figure 20-Per-home pre-weatherization natural gas consumption for program participants, 2013-2017



Conversely, single-family electricity consumption has decreased by roughly five percent over the past 5 years for homes in the program (Figure 21). At about a 12 percent rate of decline, small multifamily pre-weatherization consumption is even greater. These trends align with evolving home appliances and lighting technologies.

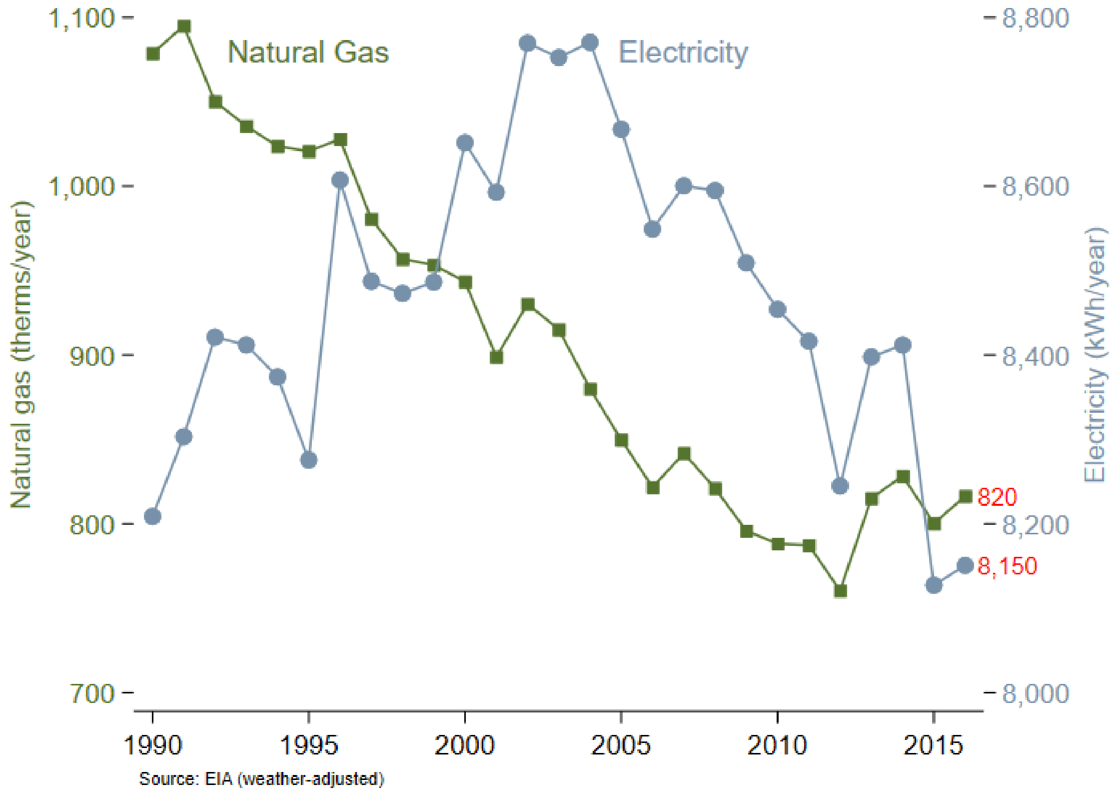
Figure 21-Per-home pre-weatherization electricity consumption for program participants, 2013-2017



As a point of comparison, Figure 22 shows long-term trends in average residential consumption of natural gas and electricity in Wisconsin, derived from aggregate sales data reported by Wisconsin utilities. The latest data available are for 2016 and are noted in red. These data cover all residential customers, not just low-income households. Also, because the aggregate data include a significant proportion of apartment dwellers, average consumption per customer tends to be lower than that of participants in the program, which is more heavily weighted toward single-family homes.

Nonetheless, statewide trends in consumption are not dissimilar from those observed for the program in recent years. After declining one to two percent per year, natural gas consumption per customer has shown a recent uptick. Electricity consumption per customer has been on a general downward decline of about 0.5 percent per year since about 2004—though the most recent years have been more volatile.

Figure 22-Statewide average natural gas and electricity consumption per residential customer



5.2 DETAILED ENERGY SAVINGS TABLES

The tables below provide more detailed statistics (and 90 percent confidence intervals) for measured savings from the program.

Table 4-Per-home natural gas savings for gas-heated homes in 1-4 unit buildings, by program year

Natural gas	2013	2014	2015	2016	2017
All					
Pre-weatherization annual usage (therms)	920 ± 10	910 ± 10	970 ± 10	940 ± 10	910 ± 10
Estimated annual savings (therms)	170 ± 10	190 ± 10	230 ± 10	190 ± 10	190
Estimated annual % savings	19 ± 1	20 ± 1	24 ± 1	20 ± 1	21
Units weatherized	4,329	3,534	3,298	3,441	3,246
Single-family					
Pre-weatherization annual usage (therms)	920 ± 10	920 ± 10	960 ± 10	950 ± 10	910 ± 10
Estimated annual savings (therms)	140 ± 10	160 ± 10	200 ± 10	160 ± 10	160
Estimated annual % savings	15 ± 1	17 ± 1	20 ± 1	17 ± 1	17
Units weatherized	2,829	2,348	2,318	2,260	2,383
2-4 unit					
Pre-weatherization annual usage (therms)	930 ± 30	890 ± 30	980 ± 30	930 ± 30	890 ± 30
Estimated annual savings (therms)	240 ± 20	240 ± 20	310 ± 30	240 ± 30	260
Estimated annual % savings	25 ± 2	27 ± 3	31 ± 3	26 ± 3	29
Units weatherized	1,500	1,186	980	1,181	863

Table 5-Per-home electricity savings for non-electrically heated homes in 1-4 unit buildings, by program year

Electricity	2013	2014	2015	2016	2017
All					
Pre-weatherization annual usage (kWh)	9,110 ± 130	9,110 ± 150	9,080 ± 150	8,750 ± 160	8,750 ± 170
Estimated annual savings (kWh)	1,060 ± 120	1,350 ± 140	1,210 ± 130	1,160 ± 160	1,370
Estimated annual % savings	12 ± 1	15 ± 2	13 ± 1	13 ± 2	16
Units weatherized	5,906	4,848	4,703	4,711	4321
Single-family					
Pre-weatherization annual usage (kWh)	9,710 ± 150	9,830 ± 160	9,690 ± 160	9,560 ± 180	9,330 ± 200
Estimated annual savings (kWh)	1,150 ± 140	1,560 ± 170	1,300 ± 150	1,380 ± 190	1,510
Estimated annual % savings	12 ± 1	16 ± 2	13 ± 2	14 ± 2	16
Units weatherized	4,342	3,599	3,661	3,490	3,432
2-4 unit					
Pre-weatherization annual usage (kWh)	7,450 ± 260	7,050 ± 270	6,950 ± 290	6,450 ± 270	6,550 ± 290
Estimated annual savings (kWh)	800 ± 230	780 ± 270	880 ± 270	480 ± 300	860
Estimated annual % savings	11 ± 3	11 ± 4	13 ± 4	7 ± 5	13
Units weatherized	1,564	1,249	1,042	1,221	889

5.3 WEATHER NORMALIZATION OF UTILITY BILLING DATA

To account for influence of year-to-year weather variation on household energy use, we fit electricity and natural gas consumption models for each household. The models disaggregate pre- and post-weatherization energy use into space heating, cooling (on the electric side) and non-space-conditioning components. Fitting the models to individual households versus the entire group of treated homes captures the unique energy-temperature relationship of each home, and allows for a more accurate adjustment of observed energy use to long-term average weather conditions.

This process is somewhat affected by seasonal variation in non-space-conditioning end uses, such as lighting and domestic hot water consumption that also vary with—but are not driven by—changes in outdoor temperature. The weather-normalization models cannot distinguish such variation from space heating, and consequently tend to somewhat overestimate heating consumption. However, since this occurs among both participants and the comparison group of untreated homes, it does not affect estimates of the savings from the program.

5.4 MEASURE-LEVEL ANALYSIS AND PROJECTED SAVINGS

Hierarchical fixed and random effects models were used to estimate the average gas and electric savings associated with individual measures. In each model, gas and electric weather-normalized annual savings for individual households were regressed against installation indicators for various measures. The model also includes interaction terms to account for variation of measure-level effects among housing types and weatherization agencies for a few key measures.

Furthermore, the hierarchical nature of the models allows for estimation of random measure effects at the agency level when sufficient data (measure installations) are available. In effect, estimated savings for large agencies with many homes in the analysis sample are more highly customized to that agency, while estimates for small agencies with few homes in the analysis tend to hew more closely to the statewide average for lack of better information. This enables greater specificity of measure-level savings when feasible, while still retaining estimates for agencies that have fewer data points. Finally, the model is run on a trailing three-year set of data, with allowances for year-to-year variation in savings.

While many measures are installed by the program, some are not amenable to this type of analysis because of the small impact on gas or electricity consumption, or because they are installed too infrequently to be statistically discerned from the available data. In the case of heating fuel conversions from bulk fuels, no pre-weatherization usage data is available to enable modeling (the analytical approach to estimate impacts for these measures is described the in the next section). Moreover, a wide variety of model specifications are possible, and different specifications can lead to a very different savings estimate for the same measure. Finally, measures are typically installed together or are associated with particular household characteristics that can make it difficult for this type of analysis to discern individual savings effects. Thus, measure-level savings estimates should not be taken as definitive, especially for measures with smaller estimated savings.

To help guard against misleading results, the analysis was implemented only for households with reasonably reliable consumption data (based on weather-normalization-fit statistics), and was restricted to cases where annual savings were estimated to lie within the range of -75 to +75 percent of pre-weatherization consumption.

Measure-specific savings coefficients from this model were then applied to the weatherization program tracking database to project per-home gas and electricity savings estimates. Gas savings were converted to gallons for homes heated with propane or fuel oil.

5.5 COST SAVINGS FROM HEATING FUEL CONVERSIONS

The gas and electricity savings models described above require a comparison of pre- versus post-weatherization consumption. For homes that switch their primary heating fuel from a higher cost fuel to natural gas, or in some instances to propane, pre-weatherization usage information is unavailable. To estimate the cost savings associated with heating system fuel conversions, the modeled energy cost savings associated with a natural gas furnace replacement (to account for the energy efficiency gains of a newer furnace) is combined with the calculated cost savings of using a cheaper fuel to heat the home. The latter is calculated by multiplying the price difference between the pre- and post-conversion fuels and the average annualized heating load after weatherization.

Another challenge in estimating the impacts of heating fuel switching is identifying homes that actually received a conversion. Unlike water heater fuel switches, WisWAP does not have unique energy conservation measure code for recording space heating fuel conversions. (Note: a heating fuel switch repair measure exists, but it is not associated with all jobs that received a heating fuel switch and appears to be used to indicate water heater fuel switches as well.) Instead, post-weatherization heating fuel types were extracted from computerized audits and linked, where possible, to job information in WisWAP. For the portion of jobs without a matched audit, post-weatherization fuel type was imputed to match the relative proportions within the pool of matched audits. Space heating fuel switches were then identified based on installation of a heating system replacement ***and*** non-matching pre- and post-weatherization fuel types.

5.6 NON-ENERGY BENEFITS: COST SAVINGS FROM WATER CONSERVATION

Cost savings from water conservation is estimated by applying a representative water and sewer rate to typical water savings based on assumptions about a typical household in the program. The water and sewer rates used in this analysis is the median for about 400 Wisconsin municipalities, contained in the “Residential Water Use: Cost and Savings Calculator for WI,” downloaded from http://psc.wi.gov/conservation/water/wc-consumers.htm on February 9, 2016. The volume of the reduction in water consumption per installed showerhead or faucet aerator is estimated using the following assumptions:

Showerheads	**Faucet aerators**
2.5 household members per participating home	2.5 household members per participating home
0.75 showers per person per day	14 gallons per person per day
7.5 minutes per shower	50% of fixture flow affected by the restrictor replacement
0.5 gallon per day reduction in shower flow rate	50% reduction in flow

5.7 LIFE-CYCLE COST SAVINGS

Key assumptions related to the calculation of program SIRs are discussed below.

Fuel Prices. Reference fuel prices are calculated at the start of each program year using a 5-year historical average for propane, fuel oil, and electricity. The reference fuel price for natural gas is a seven-year average of the previous historical five years plus two future years. The reference fuel prices used for each of the program years covered in this analysis are listed in the table below.

Table 6-Reference fuel prices

Program year	Natural Gas ($/therm)	Propane ($/gallon)	Fuel oil ($/gallon)	Electricity ($/kWh)	Other ($/MMBtu)
2012	$0.99	$1.89	$2.69	$0.117	$18
2013	$0.93	$2.00	$2.89	$0.122	$21
2014	$0.88	$1.44	$3.01	$0.128	$21
2015	$0.85	$1.92	$3.25	$0.130	$22
2016	$0.79	$1.90	$3.32	$0.135	$22
2017	$0.77	$1.76	$3.11	$0.135	$22

Fuel price escalators and discount rate. Fuel prices are adjusted using a set of fuel price escalators derived from the price indices being used in audits completed during PY17. Future savings are discounted at a rate of 3 percent per year.

Measure life. Measure lives range from 5 to 25 years, with an average life of 16 years.