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

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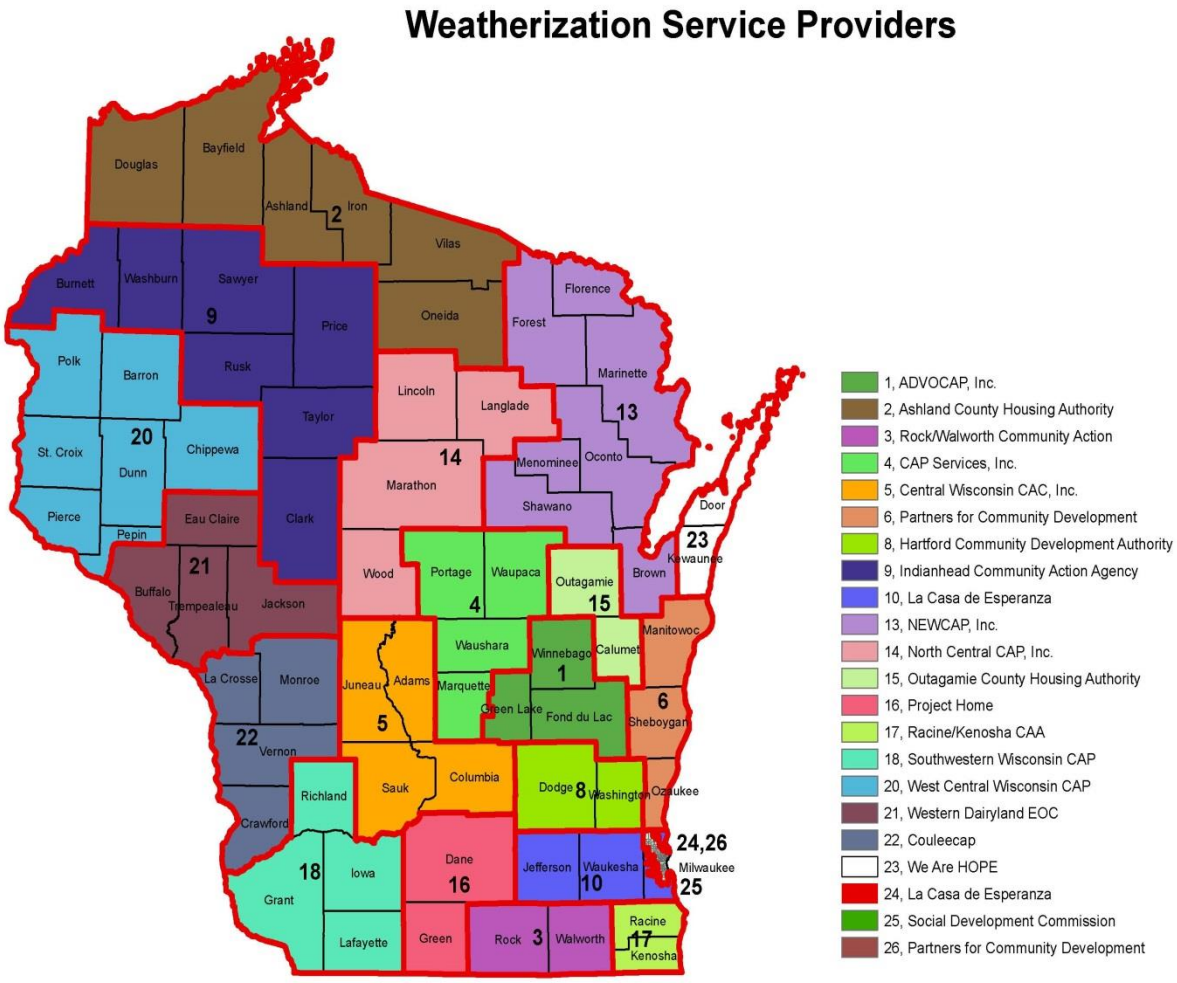
1.0 INTRODUCTION

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 20 agencies throughout the state and are available to households meeting the program eligibility requirements, including 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.



Wisconsin's program is not static. External influences and internal policy shifts 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. During Program Years (PY) 2010-2012, the American Reinvestment and Recovery Act (ARRA) increased program funding and production targets, resulting in weatherizing households that were not typically thought of as low-income.

Internally, program policy, procedures and measures are regularly assessed and adjusted to improve delivery and efficiency, and to adapt to external influences. Better coordination with the Wisconsin Home Energy Assistance Program (WHEAP) has enabled 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. It has also developed a prescriptive measures list approach to measure selection for manufactured homes in order to reduce upfront costs in homes that typically have low natural gas use.

In a departure from past reports, manufactured homes are not included with single family, site-built and 2-4 unit multifamily homes in this report. Given the significant impacts expected from the policy shift to a measures list for most natural gas-heated manufactured homes, that program component will be evaluated separately.

2.0 of this report presents trends in observed gas and electricity savings for housing units weatherized between PY12 and PY16. For PY 12 through PY15, these savings are directly calculated from natural gas and electric utility billing data. 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 (PY16) 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 PY16 homes are based on a modeling approach that applies average measure-level savings estimates from prior years to known measure installation data for these homes. This technique is also used to extrapolate 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 much more difficult.

Per-home and aggregate program energy savings are covered in 3.0, along with measure savings, incidence rates and contributions to aggregate savings. In 4.0, program costs and savings-to-investment ratios are presented. 5.0 (appendices) provides detailed data tables and methodologies for processing utility billing data, modeling energy savings, assessing heating fuel conversions, and estimating one of the key non-energy benefits: water conservation.

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) are included in Figure 1 in order to provide a more complete picture of the

changing composition of the program over time. The increased number of homes treated by the program during the ARRA period (PY11 and the early part of PY12) is clearly visible. In addition to overall growth in program production, a special ARRA-period initiative called the ARRA Multi-family Project, or AMP, resulted in a dramatic increase in the number of participating large multifamily buildings. During the most recent program years, single family, site-built homes have made up the majority (60 to 70 percent) of weatherized homes.

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

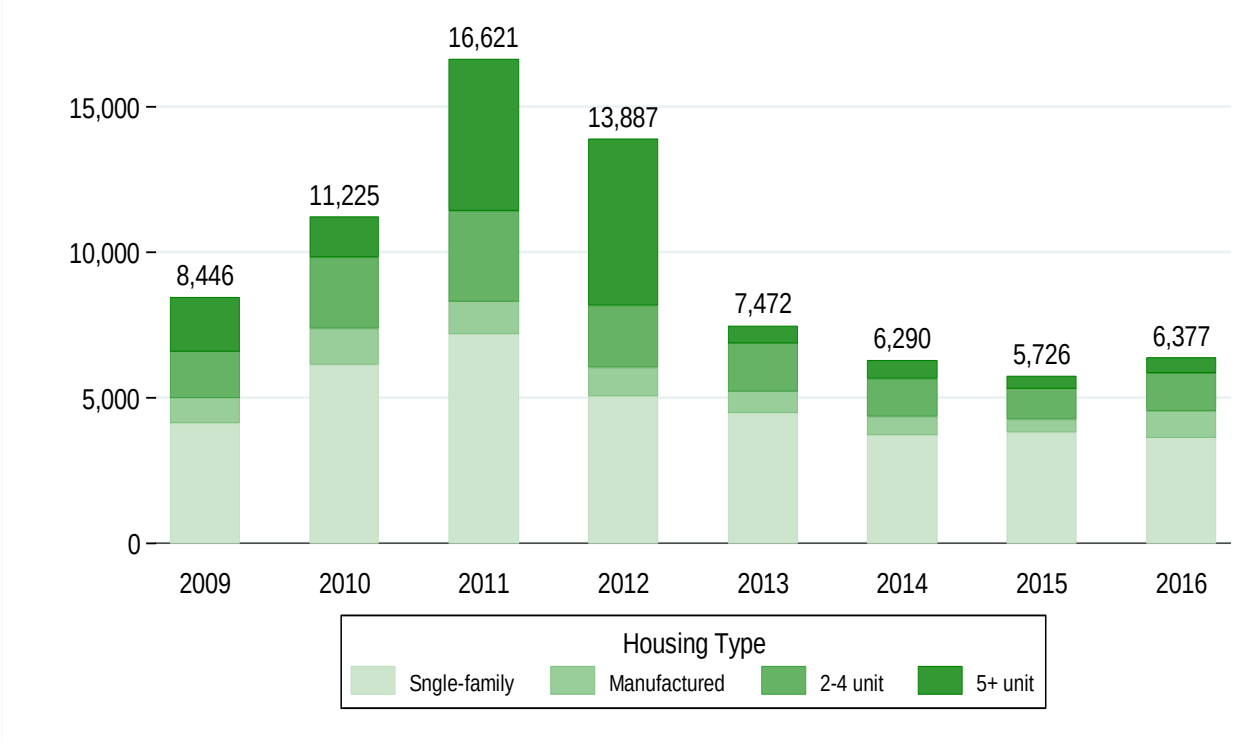
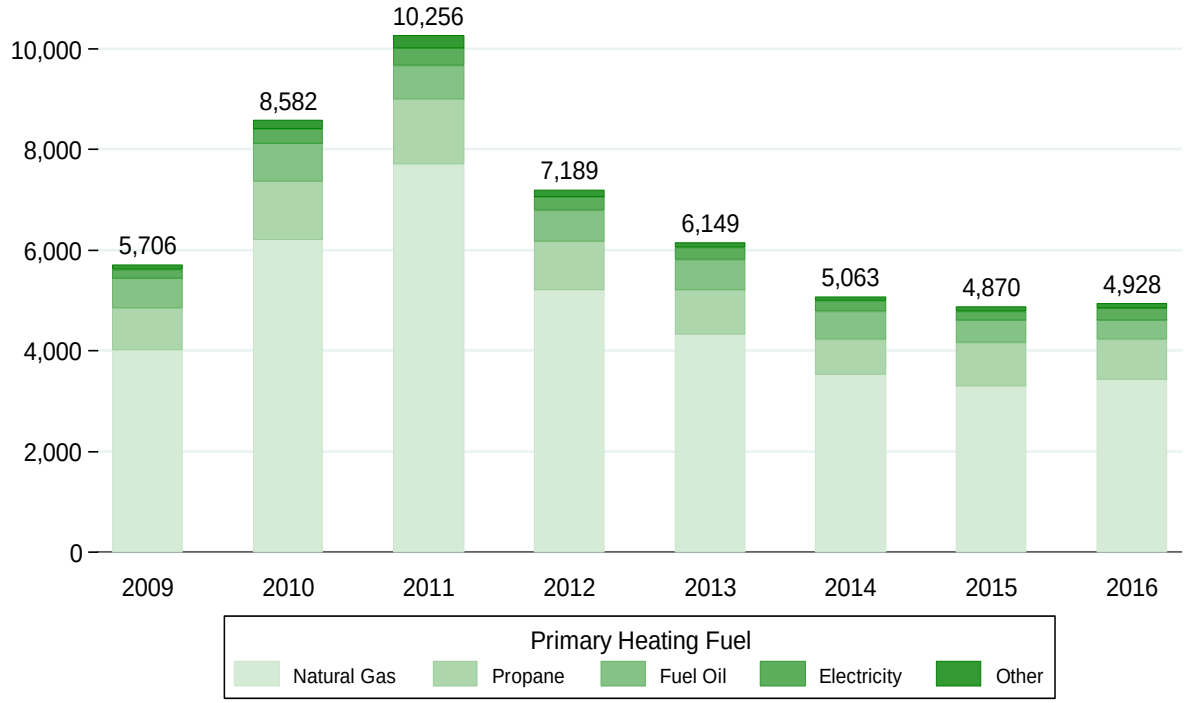


Figure 2 shows the distribution of treated homes in 1-4 unit site-built buildings across primary heating fuels. Natural gas-heated homes have traditionally comprised approximately three-quarters of this pool; however, their relative proportion has decreased in the past three program years to roughly two-thirds.

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 are measured here using monthly utility billing data collected from Wisconsin's five major investor-owned utilities. 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 are 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. PY16 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 the appendices (5.0).

It should be noted 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 extremely difficult. Cost savings for fuel switches are discussed in 4.0.

2.1 NATURAL GAS SAVINGS

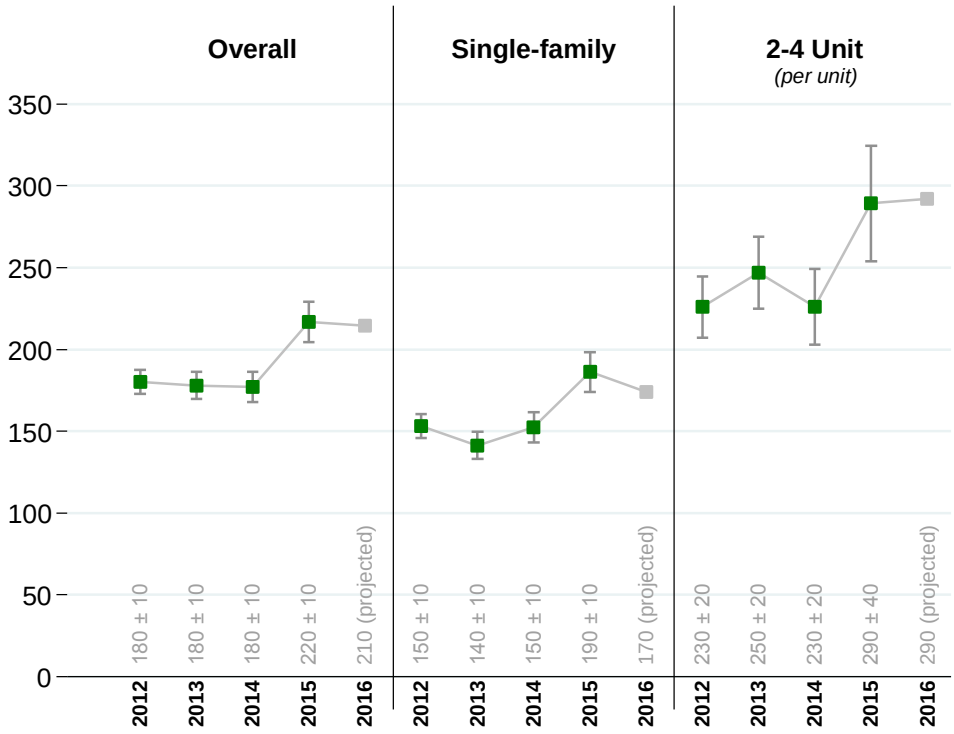
Overall, observed natural gas savings in site-built, 1-4 unit homes increased by a statistically significant amount in PY15, from 180 therms per unit in earlier years to 220 therms in PY15 (left panel of Figure 3). Based on the measures installed, savings for PY16 homes are projected to be similar to the observed PY15 results.

Single family homes also showed a statistically-significant increase in PY15 over prior years—but are projected to decline slightly for PY16 (middle panel of Figure 3). The projected PY16 decline appears to result from decreased installation rates for certain attic insulation measures and furnace replacements, as well as an increase in the incidence of electric-to-gas water heater installations. These conversions provide significant energy-cost savings, but have the side effect of increasing natural gas consumption.

Savings among 2-4 unit buildings have—with the exception of PY14—have generally increased in recent years (right panel of Figure 3). These results have greater statistical uncertainty (owing to the relatively small number of units treated each year). Given this uncertainty, it is unclear whether PY14 is a visual outlier (it is not statistically distinguishable from prior years) on an otherwise upward trend, or whether PY15 and PY16 reflect a programmatic change related to the allocation of furnace replacements between WAP and WHEAP, in addition to adjustments in the modeling protocol for heating system replacements.

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 the appendices (5.0).

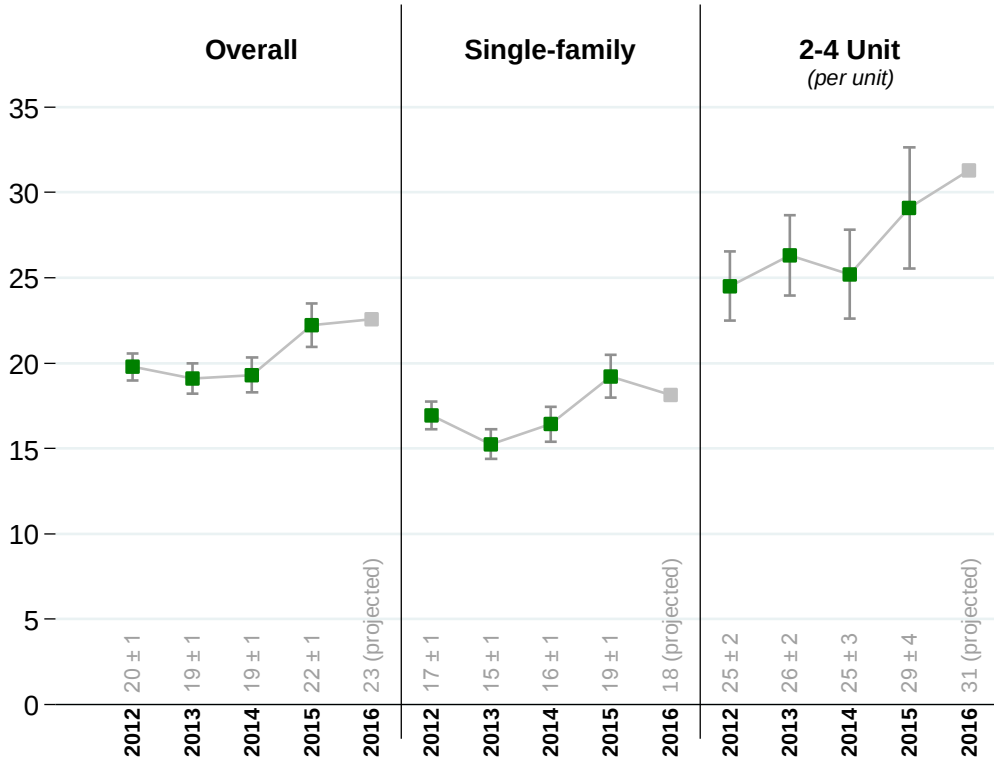
Figure 3-Annual gas savings for gas-heated homes, by housing type and program year



As a point of comparison, natural-gas savings for the Wisconsin program are greater than the U.S. average, as reported in the recent national evaluation of the Weatherization Assistance Program. That evaluation found an average of about 15 percent natural gas savings (147 ±9 therms/year) for single family homes treated in the PY11 period in climate regions similar to Wisconsin.[1]

[1] See 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. Available at 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, which represent about 10 percent of treated homes) have realized the greatest savings, typically more than 400 therms per year depending on the treatment year in question. This is no doubt due to the fact that high users typically are such because they have lower levels of existing insulation, less efficient heating systems and more uncontrolled air leakage —opportunities addressed by the program.

High users also tend to save a larger percentage of their pre-weatherization consumption (Figure 6). Homes in the highest-using group save about 25 percent of their prior gas consumption, compared to only about five percent among homes in the lowest-using group. On average, savings increase by about five percentage points for every 150 to 200 therms per year of pre-weatherization usage.

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

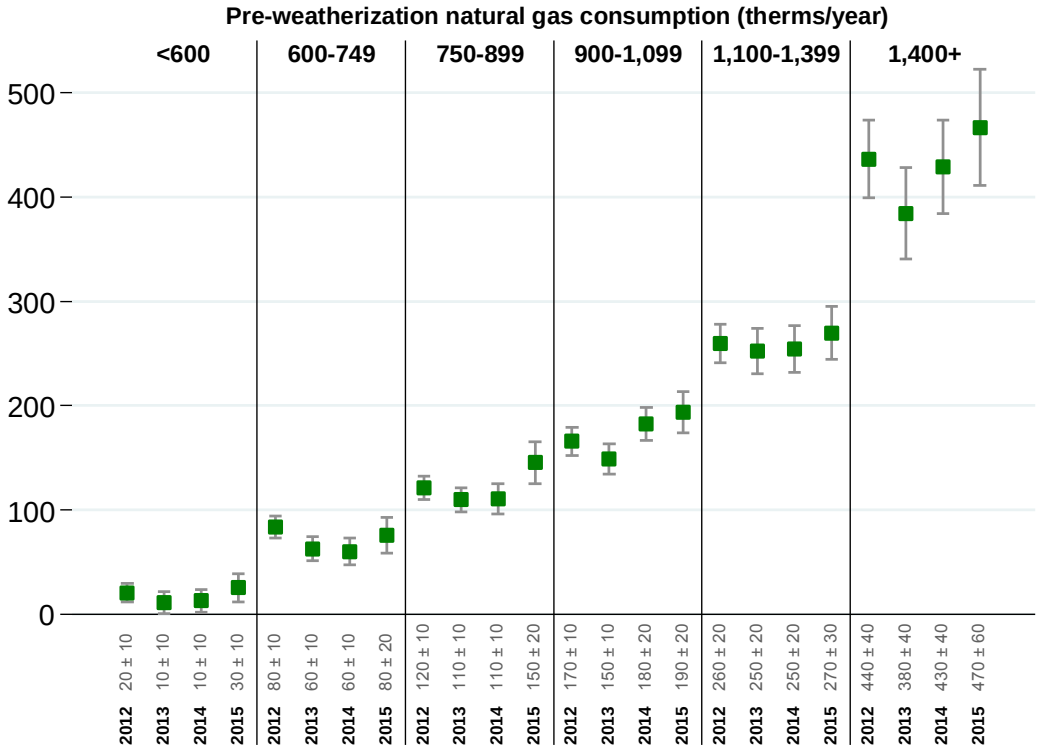
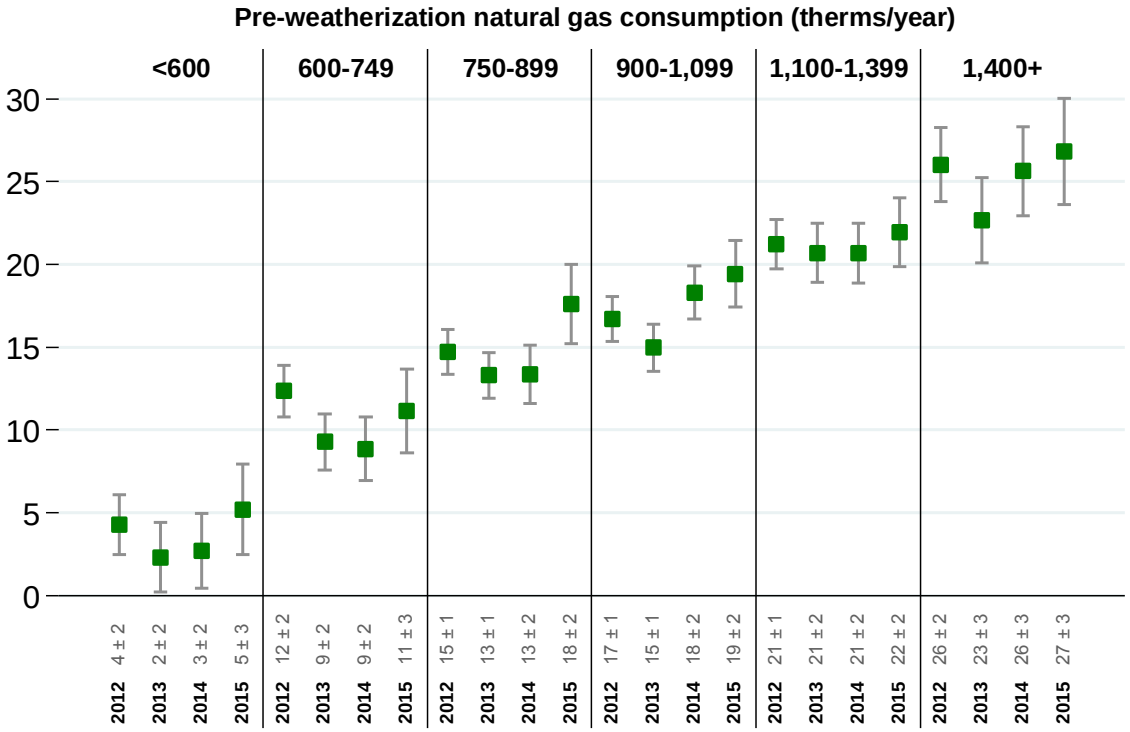


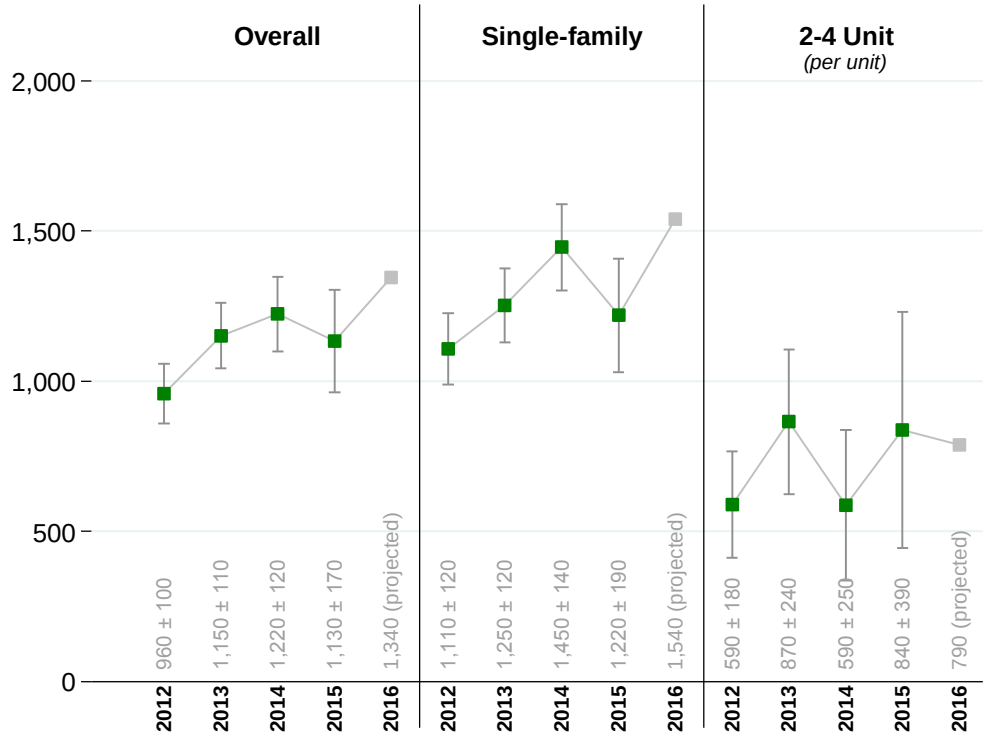
Figure 6-Annual gas savings, as a percentage of pre-weatherization usage, for gas-heated single family homes, by pre-weatherization usage bin and program year



2.2 ELECTRICITY SAVINGS

Electricity consumption is inherently more variable than natural gas use, and savings estimates are consequently somewhat less precise. Overall, savings are estimated to be in the range of about 600 to 1,500 kWh per year per housing unit: less for multifamily properties and more for single family homes (Figure 7). While average electricity savings from the program appear to be trending upward among single family homes, the year-to-year changes are not statistically significant. Trends are similar for savings expressed as a percent of pre-weatherization consumption (Figure 8).

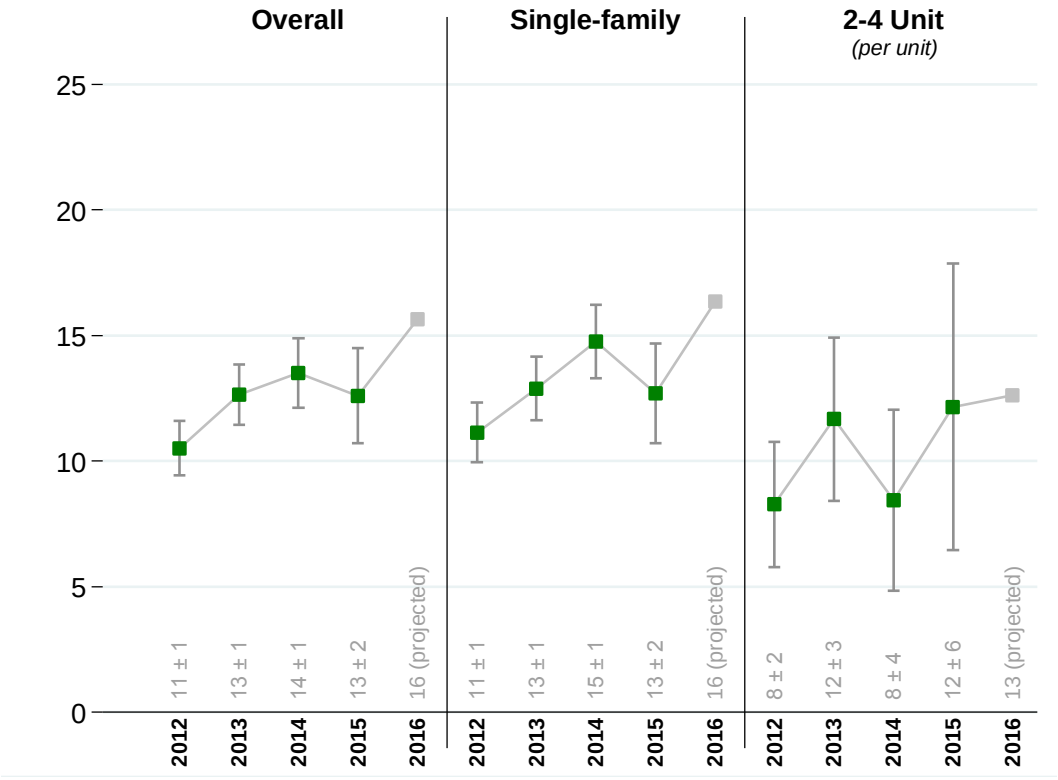
Figure 7-Annual electricity savings for homes without electric heat, by housing type and program year



As with natural gas, electricity savings for the Wisconsin program appear to exceed those found for the recent national evaluation of the Weatherization Assistance Program, which found about 8 percent electric savings (for homes with natural gas heat) in climates like Wisconsin's.[2]

[2] See 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. Available at http://weatherization.ornl.gov/RecoveryActpdfs/ORNL_TM-2014_582.pdf

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



Higher users of electricity tend to save more following weatherization (Figure 9), though the trend is not nearly as dramatic as that for natural gas. However, a clear correlation is not apparent between electricity savings as a percent of pre-weatherization usage and usage level (Figure 10). This largely has to do with the fact that many electric end-uses in homes exist—thus many more ways that a household can be a high user—most of which are not addressed by the program. Treated homes typically save between 10 and 15 percent, regardless of pre-weatherization usage level.

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

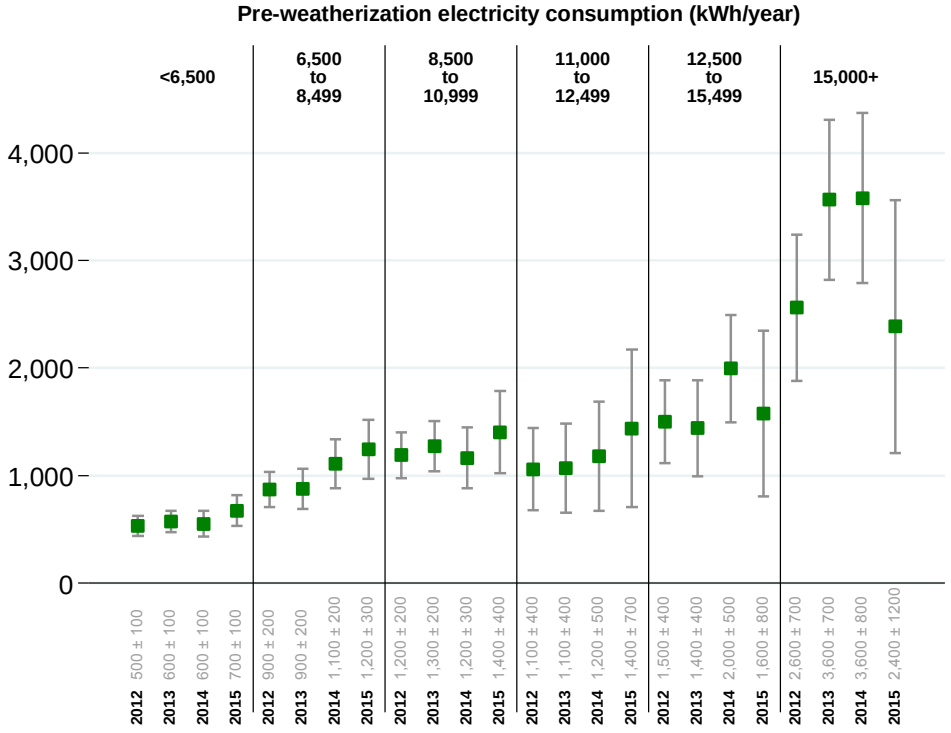
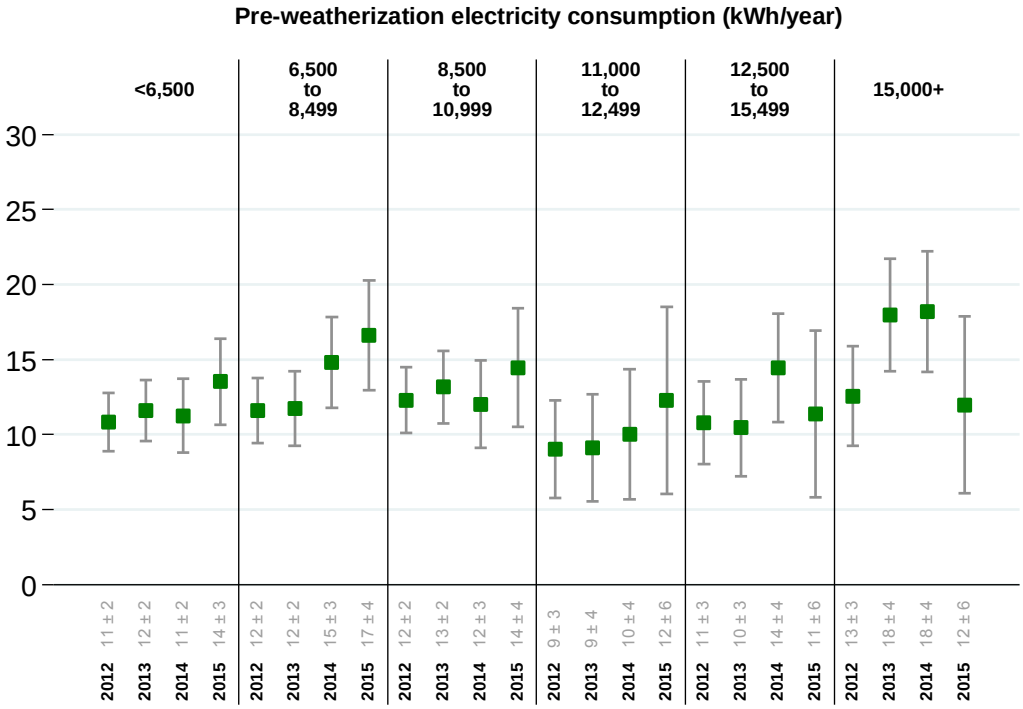


Figure 10-Annual electricity savings for single family homes without electric heat, by pre-weatherization usage bin and program year



3.0 MODELED ENERGY AND COST SAVINGS

This study uses a statistical model of energy savings to accomplish 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, as well as to 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 (first year) and throughout the life of installed measures (life cycle).

Estimating cost savings attributable to Wisconsin's program is a key element of this evaluation and is used in the determination of the program's cost effectiveness. In past years, cost savings estimates were based primarily on energy conservation (i.e. the dollar value of the energy reduction resulting from weatherizing a home). The one exception to this was water heating fuel conversions, for which the dollar savings associated with using a lower cost fuel—natural gas versus electricity—was also accounted.

This evaluation includes two additional sources of cost savings: space heating fuel conversions and water conservation from two commonly installed measures (showerhead and faucet aerators). The incidence rate of space heating fuel conversions has been on the rise in recent years, from 9 percent of single family homes weatherized in PY13 to 12 percent in PY16. This increase reflects the growing price gap between bulk fuels and natural gas and has become a significant source cost savings. Estimating the incidence rate and cost savings impact of heating fuel switches prior to PY13 is difficult due to data issues, but they are assumed to be above zero. Cost savings from water conservation is part of an effort to capture tractable, non-energy benefits associated with residential weatherization.

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 the appendices (5.0).

3.1 PER-HOME COST SAVINGS

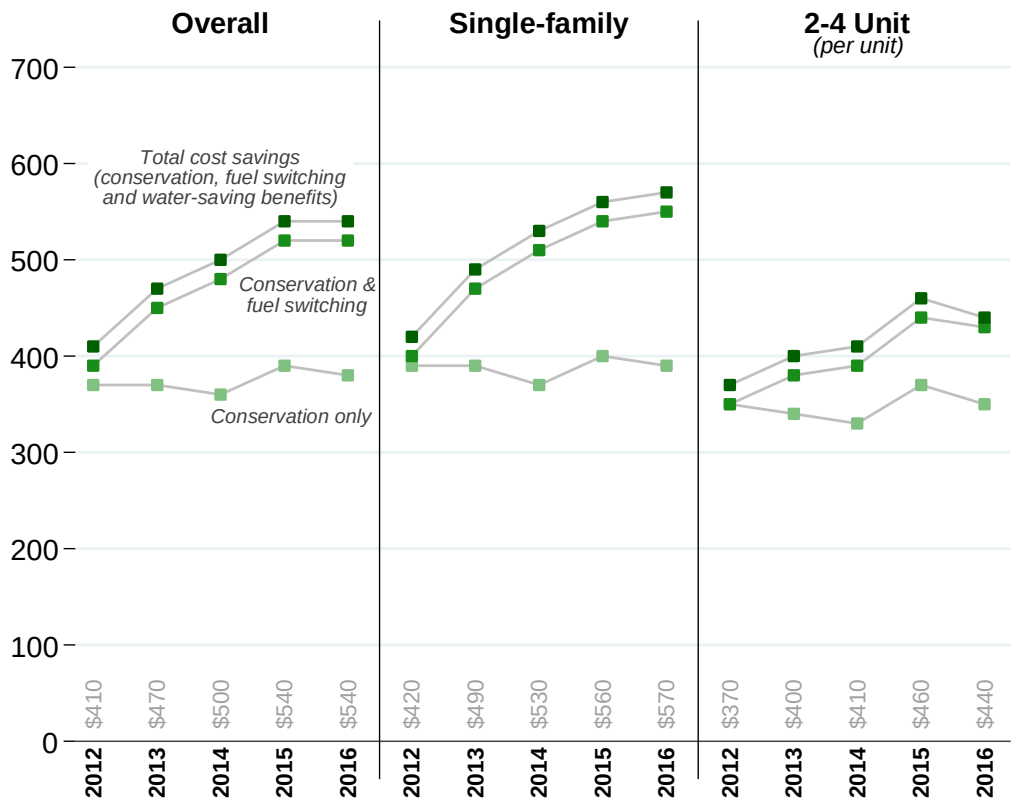
Overall, participating households from the most recent program year (PY16) are expected to save an average of $540 annually on their energy bills as a result of the program. This average, however, masks the wide variation in expected savings, dependent on housing type, heating fuel, and whether or not the home received a 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 (light green squares) account for about three-fourths of total cost savings and, despite small year-to-year changes, has remained fairly stable over the past five program years. Energy-based cost savings generally follows the natural gas savings trends presented in Natural gas savings, with an increase in PY15 and a slight decline in PY16. Roughly 60 percent of participating single family homes heat with natural gas, as does 90 percent of units in small multifamily properties. Fuel price increases for other heating fuels mitigate the effect of declining natural gas prices on single family homes, as a group.

Cost savings attributable to space and water heating fuel switches has been growing and averaged $120 to $140 per home over the past three program years. The increase in this component of cost savings reflects the widening gap between fuel prices and growing incidence rates of fuel switching measures. In PY16, more than one-quarter of homes converted their water heating fuel and 12 percent of homes switched to natural gas or propane for space heating. It should be noted that cost savings from fuel switching measures in PY12 was likely higher than estimated in this evaluation; however, insufficient data for that program year made the identification of space heating fuel switches difficult.

Water conservation as a result of program-installed faucet aerators and flow-reducing showerheads accounted for a small but constant source of cost savings, about $17 to $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 the appendices (Appendices).

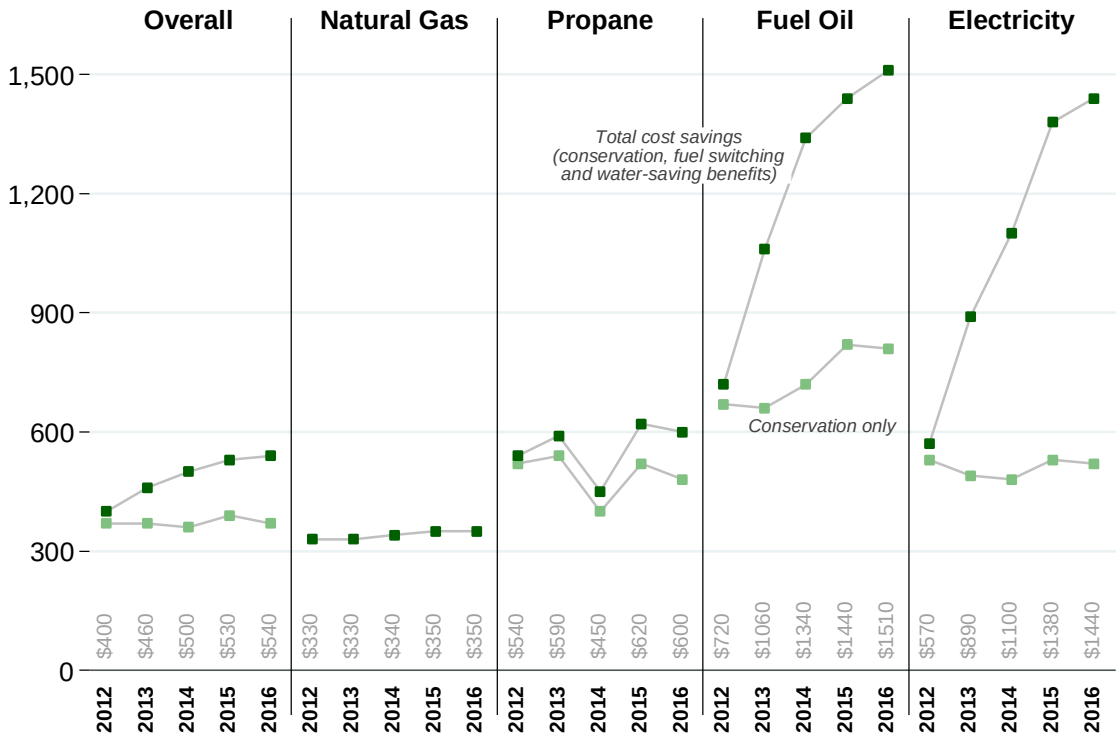
Figure 11-Average first year cost savings per home, by housing type and program year



The impact of fuel conversions is even more evident in Figure 12**Error! Reference source not found.** which shows average cost savings (total and conservation-based savings only) broken out by primary heating fuel. While homes heating with fuel oil or electricity experience large cost savings, they represent a fairly small subset of the program. Fuel oil-heated homes make up 7 to 10 percent of annual program participation and electric-heated homes account for 3 to 4 percent.

Differences in cost savings associated with energy conservation (light green squares) are largely a reflection of fuel prices. While differences in the measures installed and consequent level of energy savings play a role in these values, differences in fuel prices dominate. Fuel oil costs the most per delivered unit of energy, and natural gas costs the least.

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



The first year cost savings expected for any individual home is overwhelmingly dependent on whether or not that home had a fuel conversion measure, specifically a heating fuel conversion measure. Figure 13 plots the predicted first year cost savings for each home weatherized by the program in PY16 (including natural gas-heated homes). Homes not receiving a heating fuel conversion measure, regardless of housing type or primary heating fuel, are expected to save less than $1,000 during the first year following weatherization. Homes receiving a heating fuel conversion measure are expected to save between $1,000 and $5,000.

Figure 13-First year cost savings for individual homes treated in PY16

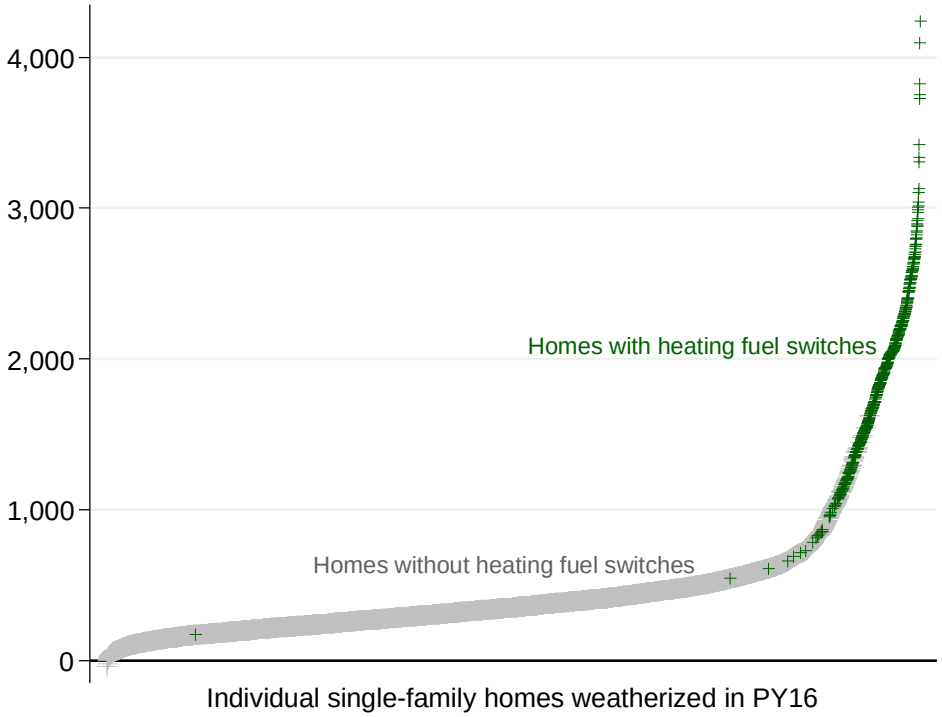


Table 1 expands on the data portrayed above by presenting average, per-home cost savings expected during the initial year after weatherization for more specific subgroups: by housing type, heating fuel, and whether or not a heating fuel conversion measure was installed. A similar table showing projected cumulative savings over the useful life of installed measures is included in the appendices (Appendices).

Overall average energy cost savings are higher among single family homes than among small multifamily homes, because significant minorities of the former are heated with more expensive fuels, while nearly all multifamily properties have natural gas heat. Among single family homes, those heated with fuel oil reap the largest cost savings, but represent a minority of treated homes. Overall cost savings among all single family homes is driven by the majority of homes with natural gas heat.

Table 1-Average first-year cost savings for homes treated in PY16, by housing type and fuel type

Housing type & primary heating fuel	Units with no fuel switching			Units with a water heating fuel switch		Units with a space heating fuel switch*	
	Treated units	% of units	First year savings	% of units	First year savings	% of units	First year savings
Single family	3,637	69%	$360	20%	$420	11%	$1,820
Natural gas	2,260	76%	$300	24%	$360		
Propane	763	76%	$500	18%	$570	6%	$1,620
Fuel oil	371	23%	$490	4%	$720	73%	$1,800
Electricity	147	41%	$480	3%	$660	55%	$2,170
Other	96	64%	$560	19%	$700	18%	$1,010
2-4 unit	1,291	90%	$350	6%	$380	4%	$2,380
Natural gas	1,181	95%	$340	5%	$350		
Propane	13	77%	$460	23%	$400		
Fuel oil	27	26%	$860			74%	$1,960
Electricity	70	44%	$490	13%	$600	43%	$2,660

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

3.2 INDIVIDUAL MEASURE ENERGY SAVINGS AND INSTALLATION RATES

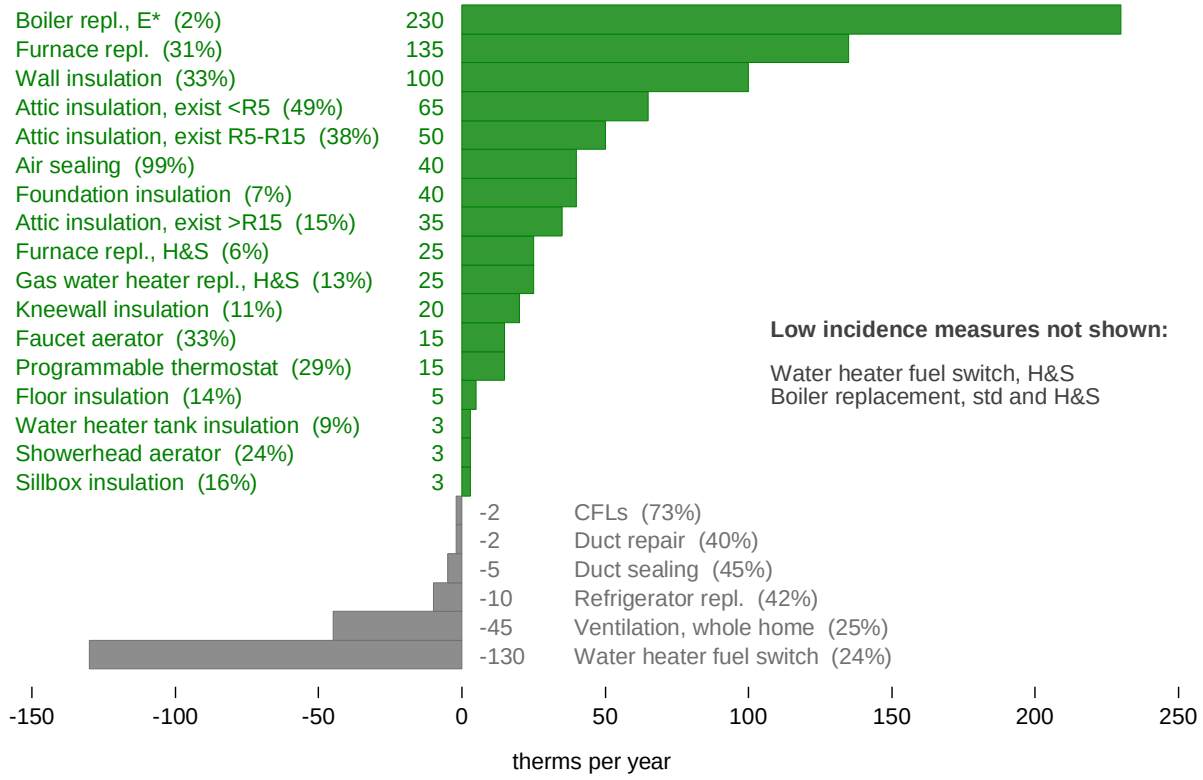
As mentioned previously, a statistical model is used to estimate average natural gas and electricity savings associated with individual measures. Figure 14 and Figure 15 present savings and measure installation rates for single family homes, since they make up the largest portion of treated site-built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

Individual measures yielding the largest gas savings include heating system replacements, wall insulation and attic insulation. Air sealing, while not a large energy saver (40 therms per year), is notable because it is completed in nearly all homes.

Some measures result in an increase in natural gas consumption. The most notable of these are fuel switches. Converting a central heating system to natural gas adds an average of 640 therms to a home's annual natural gas load. The fuel impact from this measure is not included in Figure 14 because it is nearly five times higher than the next largest gas-increasing impact, water heater fuel switching, obscuring the variation in savings impacts from other measures. Mechanical exhaust ventilation (which increases air exchange rates and thus heating loads) also carries a natural gas penalty.

The other measures in Figure 14 with apparent negative savings are not statistically distinguishable from zero. Note that there is, however, a theoretical basis for a natural gas penalty from refrigerator replacements and CFL installations. The electricity saved by these measures reduces the amount of heat generated indoors by refrigerators and lighting, thus causing the heating system to run slightly more.

Figure 14-PY16 annual gas savings per measure, when measure installed in single family, site-built homes (measure incidence rate in parentheses)

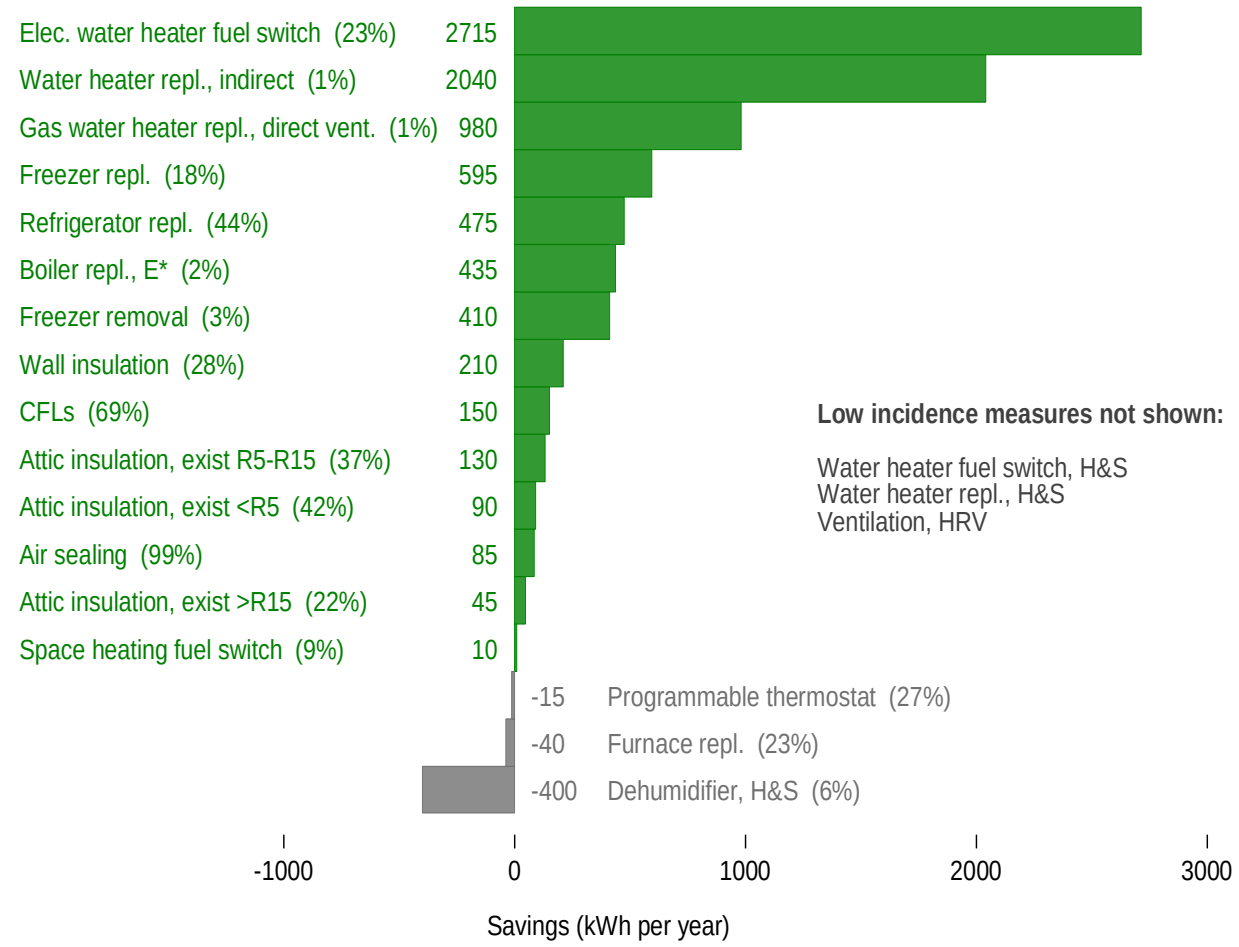


Unsurprisingly, electric-to-natural gas conversions of primary space heating systems yield the largest electricity savings. For the 2 percent of homes that converted an electric heating system in PY16, the measure-associated savings were on the order of 9,000 kWh. At more than three times the next largest electricity-saving measure—fuel conversions of electric water heaters—space heating conversions are not included in the measure-level savings presented in Figure 15.

The second measure listed—installation of an indirect water heater (which involves plumbing a space-heating boiler to also heat water in a separate storage tank)—is effectively a water heater fuel switch measure as well, because it typically involves removing an electric water heater and providing domestic hot water via a natural-gas boiler. Water heater, refrigerator and freezer replacements also provide significant electricity savings.

The analysis indicates that the installation of a dehumidifier (for homes with moisture management issues) or a heat recovery ventilator (for ventilation) increases electricity consumption. However, these measures are not commonly installed. Furnace replacements, while shown to be associated with a small amount of negative savings in this analysis, have historically varied between slight positive and negative savings and are unlikely to have a significant effect on electricity savings.

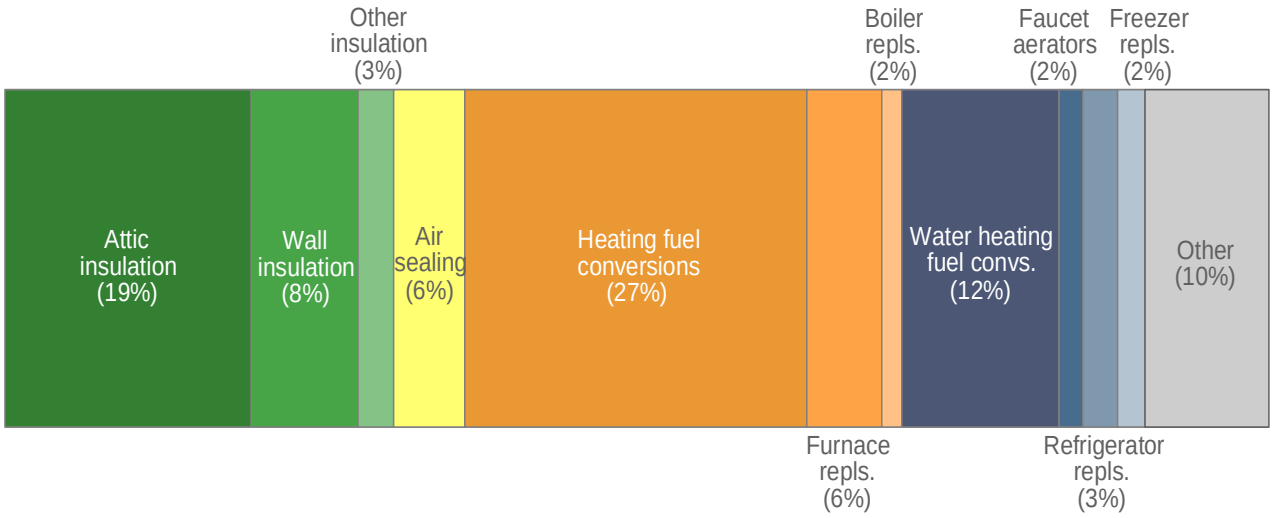
Figure 15-PY16 annual electric savings per measure, when installed in single family, site-built homes (measure incidence rate in parentheses)



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 effects of per-installation savings and installation rates on overall program cost savings. The analysis indicates that fuel switching, attic and wall insulation measures, air sealing, and heating system replacements provide the large majority of the energy-cost savings from the program. Measures with smaller contributions to overall cost savings are bundled together in “Other” and cumulatively account for about 10 percent of savings. Note that the “Other” category also includes the effects of health and safety, and repair measures that may result in negative savings.

Figure 16-PY16 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 PY16, the statewide program saved participating households upwards of $2.5 million during the first year after weatherization. Over the life of the installed measures, the program is projected to yield $56 million in energy cost savings for those homes. While program savings have fluctuated for specific fuels, the combined first year cost savings have remained fairly constant over the past three program years. Program participation among single family and small multifamily homes has hovered around 5,000 annual units during this period.

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 conservation	Fuel switching	Non-energy benefits	Total, first year	Total, life of measures (undiscounted)
PY12	7,189	1,049,000	182,000	112,000	9,125,000	$2,687,000	$73,000	$128,000	$2,887,000	$62,686,000
PY13	6,149	927,000	184,000	109,000	7,613,000	$2,298,000	$416,000	$105,000	$2,819,000	$58,494,000
PY14	5,063	781,000	138,000	106,000	6,560,000	$1,829,000	$565,000	$90,000	$2,485,000	$56,370,000
PY15	4,870	793,000	182,000	97,000	6,176,000	$1,922,000	$549,000	$86,000	$2,557,000	$58,329,000
PY16	4,928	876,000	156,000	82,000	5,841,000	$1,853,000	$583,000	$93,000	$2,530,000	$56,407,000

4.0 PROGRAM COST EFFECTIVENESS

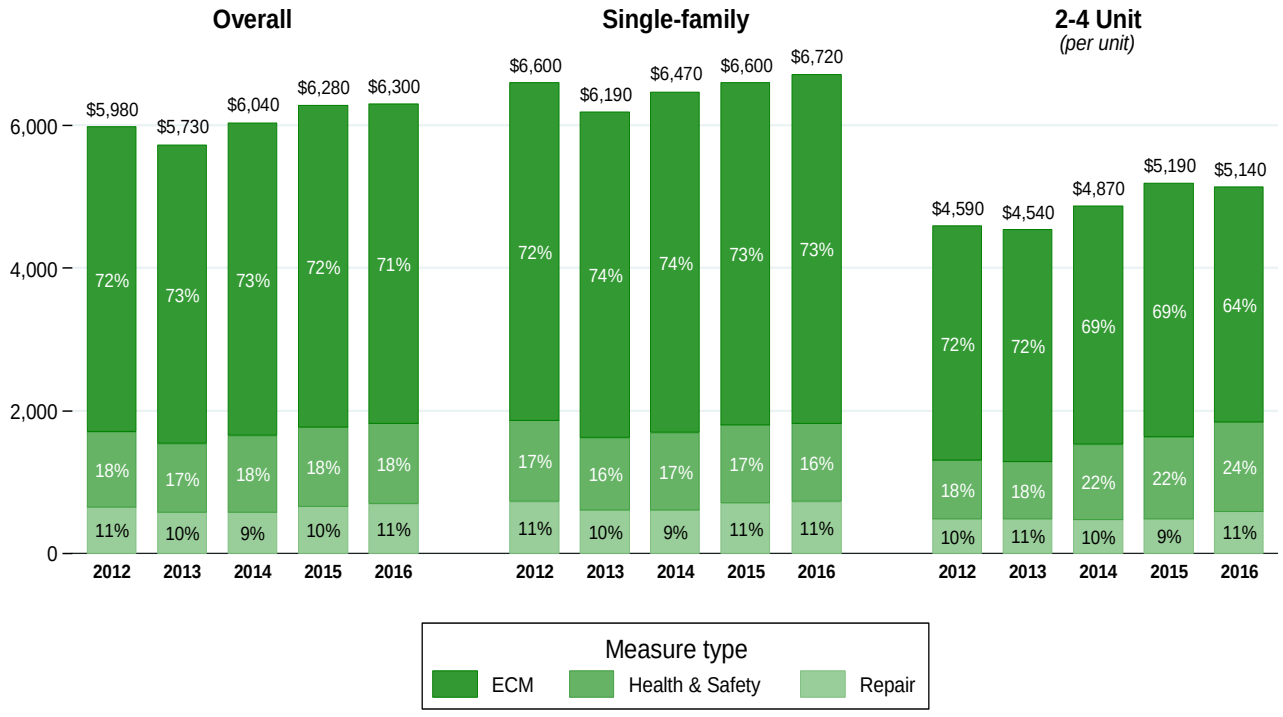
This section brings together information about program costs and projected savings. Job-level costs, broken out by measure type (energy conservation, health and safety or repair), are presented first, and this is followed by an analysis of program-wide cost effectiveness.

4.1 JOB-LEVEL COSTS

The average cost for weatherizing a housing unit dropped between PY12 and PY13, before rebounding in PY14 and PY15. The cost remained roughly the same in PY16 as in PY15. As discussed earlier in this report, homes consuming high levels of energy typically experience greater savings after weatherization because they are less efficient to begin with. The program's increased marketing to high-user homes in recent years has resulted in more measures being installed and higher job costs. During the ARRA years, the push for production, particularly with 2-4 unit buildings, meant more homes were weatherized, but these were not necessarily high-user homes, and jobs tended to have slightly lower costs.

In PY16, the cost for single family homes averaged about $6,700. The cost for homes in 2-4 unit buildings averaged just over $5,000 ($5,140) per housing unit. Spending in homes is dominated by energy conservation measures (ECMs), 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 $2,000 per home.

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



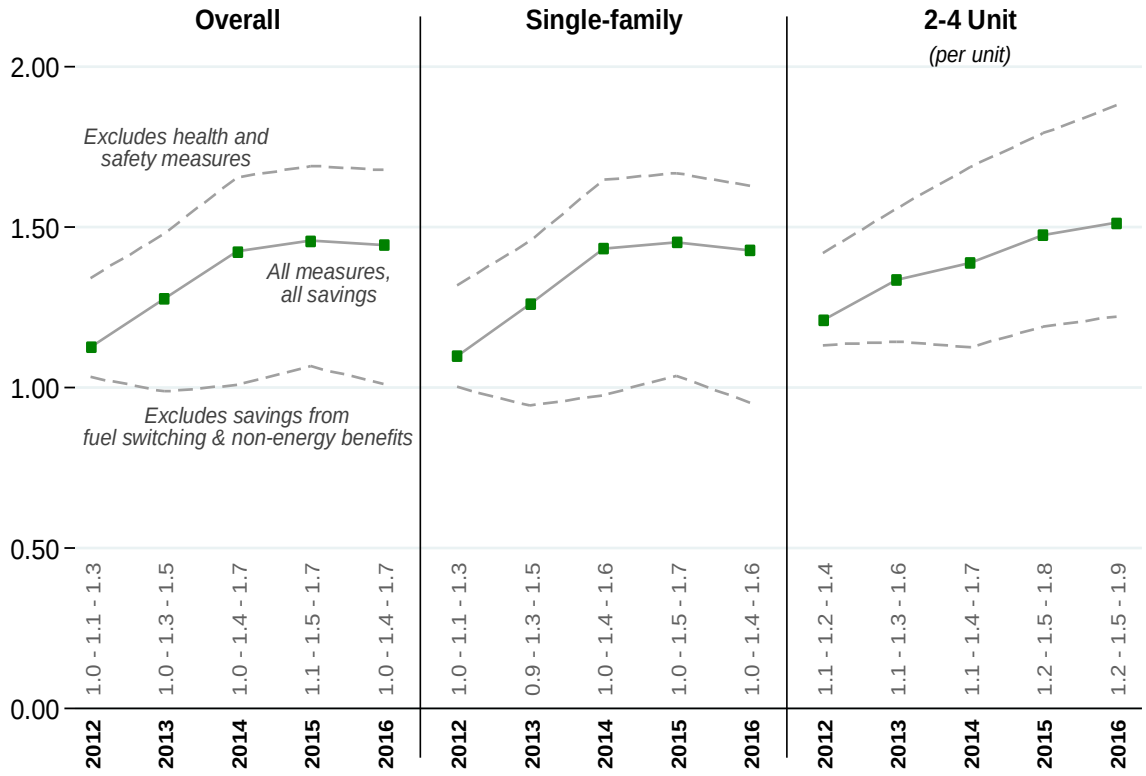
4.2 OVERALL PROGRAM COST EFFECTIVENESS

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); and
- 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 upwards trend of space and water heating fuel switching and associated cost savings. 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 0.2.

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 (see Figure 19-Program-wide SIRs, by heating fuel type and program year), owing to higher purchase costs: each unit of energy saved by the program for these fuels is simply worth more in dollar terms than a unit of natural gas savings. The jump in SIR values among propane-heated homes weatherized in PY15 is likely a reflection of the large price increase from PY14 to PY15. The price stayed fairly constant from PY15 to PY16; however, energy savings among propane-heated homes, which overwhelmingly are single family, declined by more than 10 percent in PY16.

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

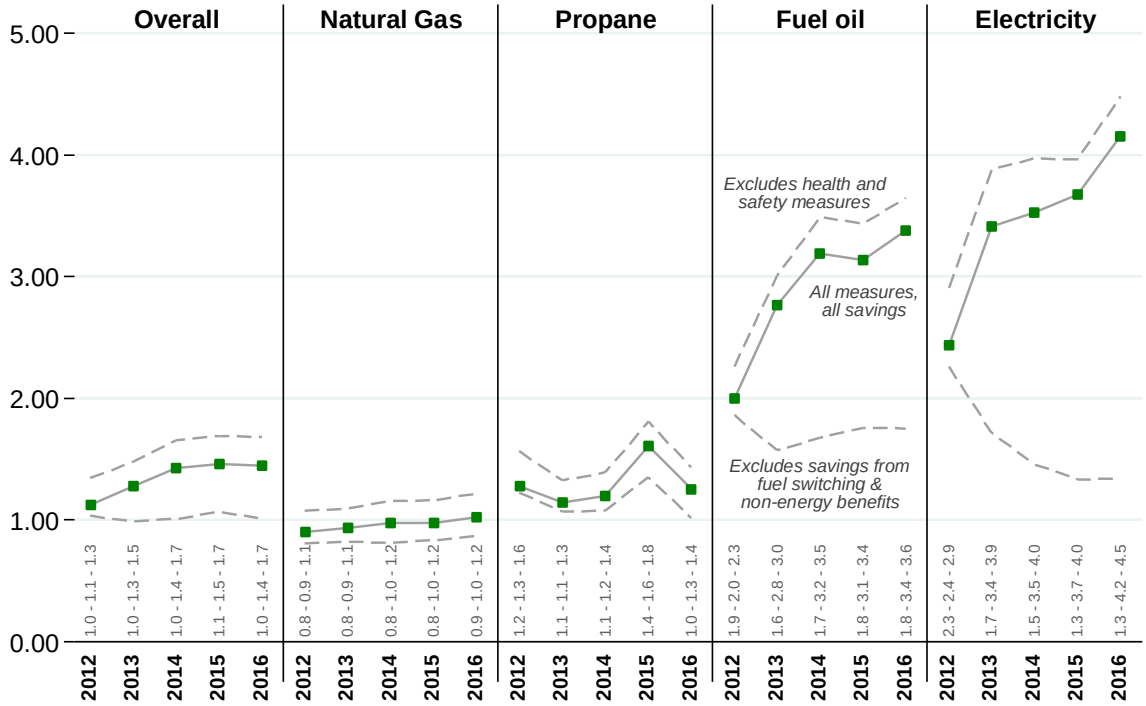


Table 3 further breaks out estimated PY16 SIRs and job costs by housing type and heating fuel (excluding the small number of homes heated with electricity or wood). Again, SIRs are highest for homes heated with fuel oil or electricity, within housing type, and highest for 2-4 unit multifamily buildings.

Table 3-Average SIRs and job costs for homes treated during PY16, by housing type and heating fuel

Housing type & primary heating 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	0.95	1.43	$6,606	1.63	$5,822
Natural gas	0.75	0.93	$6,547	1.09	$5,666
Propane	1.02	1.25	$6,156	1.43	$5,471
Fuel oil	1.71	3.33	$7,900	3.58	$7,394
Electricity	1.20	3.91	$6,716	4.22	$6,170
Other	1.37	1.56	$6,393	1.77	$5,686
2-4 unit	1.22	1.51	$5,189	1.88	$4,113
Natural gas	1.16	1.24	$5,173	1.57	$4,065
Propane	1.05	1.35	$4,375	1.78	$3,564
Fuel oil	2.48	4.29	$6,308	4.92	$5,408
Electricity	1.73	4.82	$5,182	5.23	$4,514

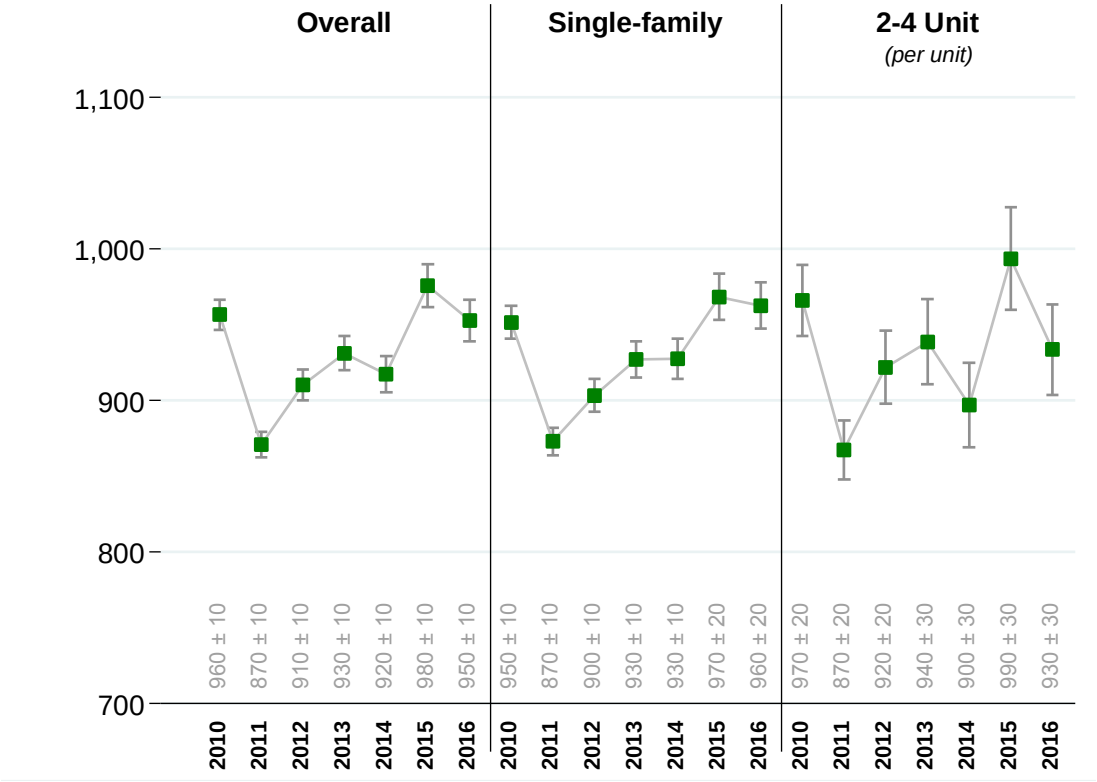
5.0 APPENDICES

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 as context to the savings estimates presented in the report.

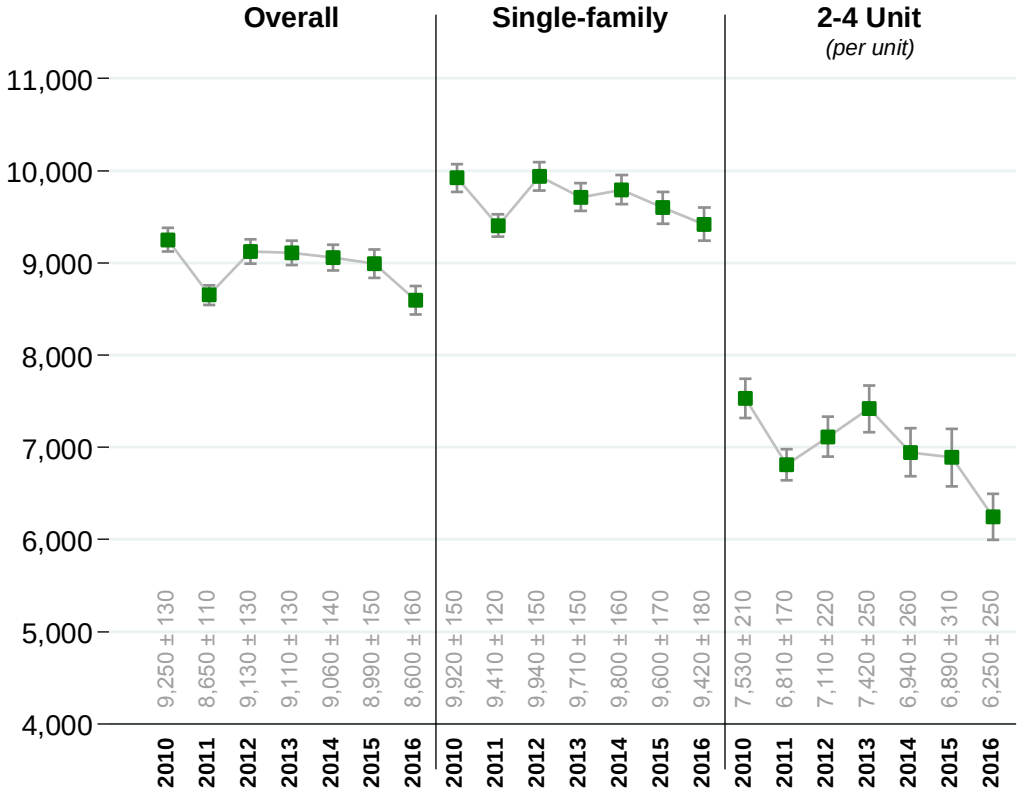
Among single family homes in the weatherization program, weather-normalized natural gas use has increased by about five percent over the past 5 years, or by approximately one percent per year. Average natural gas use among small multifamily homes has been more variable, as might be expected given the small number of homes treated.

Figure 20-Per-home pre-weatherization natural gas consumption for program participants, 2012-2016



Conversely, single family electricity consumption has decreased by roughly 5 percent over the past 5 years for homes in the program (Figure 21). The rate of decline among small multifamily units is even greater. These trends align with slowly increasing electricity prices, but may also be an indicator of broad changes in home appliances and lighting.

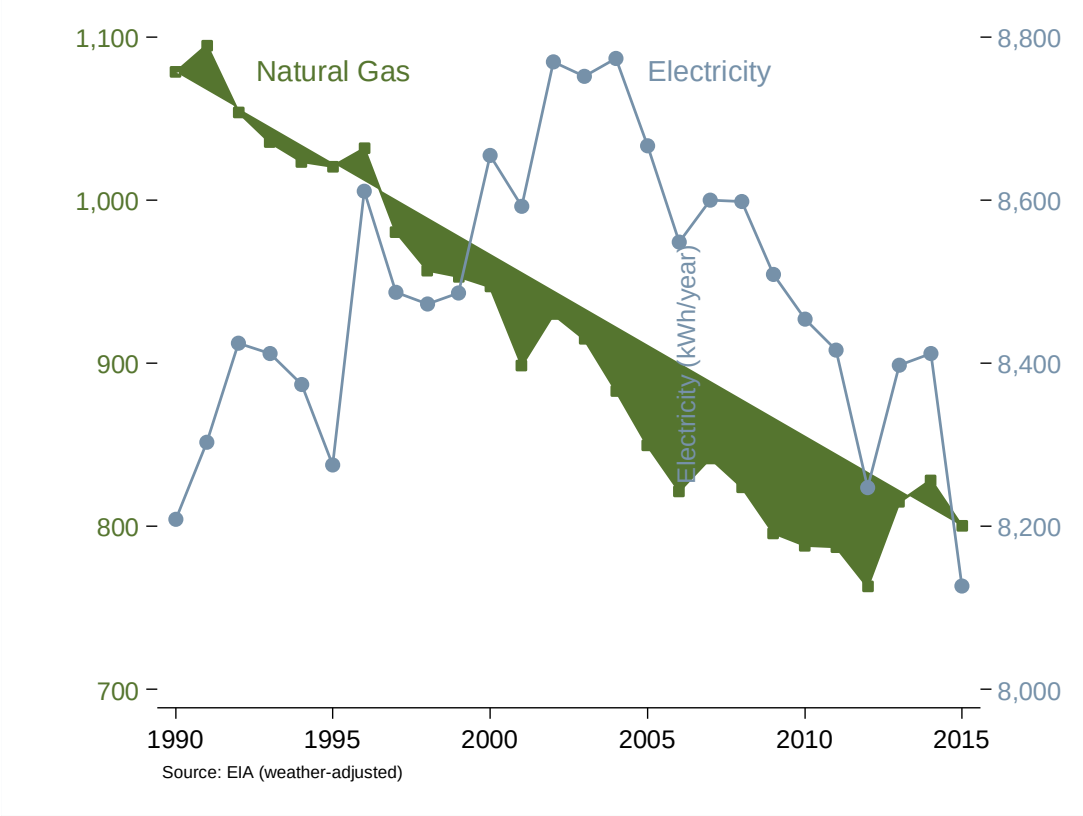
Figure 21-Per-home pre-weatherization electricity consumption for program participants, 2012-2016



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. 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 at 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	2012	2013	2014	2015	2016
All					
Pre-weatherization annual usage (therms)	910 ± 10	931 ± 11	917 ± 12	976 ± 14	953 ± 14
Estimated annual savings (therms)	180 ± 7	178 ± 8	177 ± 9	217 ± 13	214
Estimated annual % savings	20 ± 1	19 ± 1	19 ± 1	22 ± 1	23
Units weatherized	5,216	4,329	3,536	3,298	3,441
Single family					
Pre-weatherization annual usage (therms)	904 ± 11	927 ± 12	928 ± 13	968 ± 15	963 ± 15
Estimated annual savings (therms)	153 ± 7	141 ± 8	152 ± 9	186 ± 12	174
Estimated annual % savings	17 ± 1	15 ± 1	16 ± 1	19 ± 1	18
Units weatherized	3,291	2,829	2,348	2,318	2,260
2-4 unit					
Pre-weatherization annual usage (therms)	922 ± 24	939 ± 28	897 ± 28	994 ± 34	934 ± 30
Estimated annual savings (therms)	226 ± 19	247 ± 22	226 ± 23	289 ± 35	292
Estimated annual % savings	25 ± 2	26 ± 2	25 ± 3	29 ± 4	31
Units weatherized	1,925	1,500	1,188	980	1,181

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

Electricity	2012	2013	2014	2015	2016
All site built homes (SF & SMF)					
Pre-weatherization annual usage (kWh)	9,127 ± 132	9,108 ± 132	9,058 ± 142	8,994 ± 153	8,596 ± 156
Estimated annual savings (kWh)	959 ± 99	1,151 ± 109	1,223 ± 125	1,133 ± 170	1345
Estimated annual % savings	11 ± 1	13 ± 1	14 ± 1	13 ± 2	16
Units weatherized	6,896	5,906	4,850	4,703	4,711
Single family					
Pre-weatherization annual usage (kWh)	9,937 ± 155	9,715 ± 150	9,795 ± 160	9,598 ± 170	9,419 ± 179
Estimated annual savings (kWh)	1,107 ± 119	1,252 ± 123	1,446 ± 144	1,219 ± 190	1540
Estimated annual % savings	11 ± 1	13 ± 1	15 ± 1	13 ± 2	16
Units weatherized	4,901	4,342	3,599	3,661	3,490
2-4 unit					
Pre-weatherization annual usage (kWh)	7,114 ± 216	7,417 ± 254	6,944 ± 262	6,889 ± 309	6,246 ± 250
Estimated annual savings (kWh)	589 ± 177	865 ± 241	586 ± 250	837 ± 393	787
Estimated annual % savings	8 ± 2	12 ± 3	8 ± 4	12 ± 6	13
Units weatherized	1,995	1,564	1,251	1,042	1,221

5.3 WEATHER NORMALIZATION OF UTILITY BILLING DATA

To account for influence of year-to-year weather variation on household energy use, we fitted electricity and natural gas consumption models to 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.

It is worth noting that 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 tends 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 individually installed 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 a large number of 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 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 very a different savings estimate for the same measure. Finally, measures are sometimes typically installed together or are associated with particular household characteristics that can make it difficult for this type of analysis to tease out 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 with 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 are 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 rate 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 7-year average of the previous historical 5 years plus 2 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

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 FY16. Future savings are discounted at a rate of 3 percent per year.

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