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Evaluation of the Weatherization Assistance Program During Program Years 2009-2011 (American Recovery and Reinvestment Act Period): Energy Impacts for Single Family Homes

Michael Blasnik
Greg Dalhoff
David Carroll
Ferit Ucar Ph.D.
Dan Bausch

March 2015

OAK RIDGE NATIONAL LABORATORY
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ORNL Principal Investigator
Dr. Bruce Tonn

Evaluation Team Task Manager
Michael Blasnik

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Environmental Sciences Division

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Michael Blasnik, Blasnik & Associates
Greg Dalhoff, Dalhoff & Associates
David Carroll, APPRISE
Ferit Ucar Ph.D., APPRISE
Dan Bausch, APPRISE

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Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
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The purpose of this report is to disseminate the findings from an analysis of the energy savings, cost savings, and cost-effectiveness for single family site-built homes treated by DOE's Weatherization Assistance Program (WAP) during Program Years 2009, 2010, and 1011.

The original design for this research was developed by staff from the Oak Ridge National Laboratory (ORNL) as one component of the American Recovery and Reinvestment Act (ARRA) Period Evaluation of the National Weatherization Assistance Program (*Evaluation of the Weatherization Assistance Program during Program Years 2009-2011 – American Recovery and Reinvestment Act Period, ORNL/TM-2011/87).* This evaluation was designed to be consistent with, but was independent of, the Weatherization Assistance Program Evaluation for Program Years 2007 and 2008.

ORNL contracted with the research team of APPRISE Incorporated, the Energy Center of Wisconsin, Michael Blasnik and Associates, and Dalhoff Associates LLC to conduct the evaluation. The evaluation team implemented the specified data collection and analysis activities to develop statistics for this report.

Grantee and Subgrantee Data Collection

The Energy Center of Wisconsin (ECW) collected information on program funding and clients served from 51 grantees and 881 subgrantees, as well as detailed information on weatherization jobs from 388 subgrantees. The cooperation of and contributions made by the WAP program grantees and subgrantees were essential to the completion of the study.

The ECW staff responsible for the grantee and subgrantee data collection for the PY 2010 study were:

Julie Adamski
Jaime Barbian
Ingo Bensch
Ben Brush
Kristine Busche
Claire Cowan
Heather Driscoll
Jeremy Francis
LaShanta Goodwin
Ashleigh Keene
Karen Koski
Jeannette LeZaks
Andy Mendyk
Scott Pigg
Leslie Post
Jaimie Rule
Nick Sayen

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ACRONMYS AND UNITS

CDD	Cooling Degree Days
CFM50	Cubic Feet per Minute @ 50 pascals
CFR	Code of Federal Regulations
DOE	Department of Energy
ECM	Energy Conservation Measure
HDD	Heating Degree Days
kWH	Kilowatt Hour
MMBTU	Million British Thermal Units
NCDC	National Climatic Data Center
ORNL	Oak Ridge National Laboratory
PRISM	Princeton Scorekeeping Method
PY	Program Year
SFSB	Single Family Site-built
SIR	Savings-to-Investment Ratio
SOW	Scope of Work
TH	Therm
WAP	Weatherization Assistance Program

EXECUTIVE SUMMARY

The purpose of this report is to disseminate the findings from an analysis of the energy savings, cost savings, and cost-effectiveness for single family site-built homes treated by DOE's Weatherization Assistance Program (WAP) during the Recovery Act Period - Program Years 2009, 2010, and 2011. The focus of this study is on PY 2010. The analysis characterizes the population of single family homes[1] served by the program, estimates the gross and net change in energy usage for treated homes, makes projections for the first year and longer-term cost savings, and assesses the cost-effectiveness of the program in terms of direct energy benefits.

This is one of four energy impact reports developed for the PY 2010 WAP Evaluation. The full set of reports covers all housing types (single family homes, mobile homes, and multifamily buildings) and summarizes overall program performance for all building types in terms of energy and nonenergy benefits. The reports give policymakers detailed information on program performance for each building type, as well as information on the overall program performance.

Background

The U.S. Department of Energy's (DOE) Weatherization Assistance Program was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the Program as currently stated in the Code of Federal Regulations (CFR) 10 CFR 440.1 is "to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden." (Code of Federal Regulations, 2011)

At the request of DOE, Oak Ridge National Laboratory (ORNL) developed a comprehensive plan for a national evaluation of WAP that was published in 2011. DOE furnished funding to ORNL for the evaluation of the program during Program Years 2009-2011 (the American Recovery and Reinvestment Act Period). The Scope of Work (SOW) for the evaluation includes the following components:

Impact Assessment – Characterization of the weatherization network and low-income households, measurement and monetization of the energy and nonenergy impacts of the program, and assessment of the factors associated with higher levels of energy savings, cost savings, and cost-effectiveness.

Process Assessment – Direct observation of how the weatherization network delivers services, assessment of how service delivery compares to national standards, and documentation of how weatherization staff and clients perceive service delivery.

Synthesis Study – Synthesis of the findings to assess the program's success in meeting its goals and identify key areas for program enhancement.

This analysis of single family home energy impacts is part of the Impact Assessment.

[1] Single Family Homes are defined as housing units in buildings with 1 to 4 units. In the PY 2008 Evaluation, Single Family Homes were defined as housing units in buildings with one unit. The definition used in the 2008 Evaluation is consistent with the Census Bureau definition of single family homes. The definition used in this evaluation is consistent with the WAP program definition of single family homes.

Study Overview

The single family energy impact report furnishes information on the households and housing units served by the program, documents the services delivered to those households and housing units, measures the change in energy consumption and energy costs experienced by those clients, and compares the cost of the installed measures to the energy cost savings. The study procedures included:

- Development of a representative sample of clients served by the program using data from DOE, grantees, and subgrantees.
- Collection of information from subgrantees on client characteristics, installed measures, and measure costs for sampled clients.
- Collection of energy usage information from energy suppliers and through direct metering in clients' homes.
- Statistical analysis of pre- and post-weatherization energy usage to develop robust estimates of the net energy impacts associated with service delivery.
- Projection of measure lifetimes and energy costs to estimate cost savings and program cost-effectiveness.

This combined set of procedures furnishes estimates of the energy and cost impacts associated with the WAP program, identifies the explanatory factors associated with higher levels of energy impacts, and assesses the cost-effectiveness of measure packages and the overall program.

Program Characterization

The evaluation team collected information on the clients served and the services delivered by the WAP program. PY 2010 program statistics are available from the Department of Energy and WAP grantees (i.e., states). Detailed information about clients and client services was supplied by program subgrantees (i.e., local agencies). These data were used to characterize WAP clients in terms of housing unit type, geography, household demographics, housing unit characteristics, and program services.

WAP serves low-income households in all types of housing units and in all parts of the country. According to DOE statistics, the network of WAP funded subgrantees served 331,865 housing units in PY 2010 with DOE funding. Table 1 shows the distribution of treated units by housing unit type. About 65 percent of the treated units were single family site-built homes. Table 2 shows the distribution of treated single family homes by Climate Zone. The Cold Climate Zone had the largest share of treated single family units (36%) and the Hot/Dry Climate Zone has the smallest share (9%).

Table 1 PY 2010 WAP Clients by Housing Unit Type

Housing Unit Type	PY 2010 Weighted Count of Clients	Percent of PY 2010 Clients
Single Family Site-built (1-4)	215,445	65%
Single Family Mobile Home	48,267	15%
Multifamily (5+)	68,153	20%
TOTAL	331,865	100%

Table 2 PY 2010 WAP Clients in Single Family Homes by Climate Zone

Climate Zone	PY 2010 Units	Percent of PY 2010 Units
Very Cold Climate	40,870	19%
Cold Climate	78,381	36%
Moderate Climate	40,459	19%
Hot/Humid Climate	36,047	17%
Hot/Dry Climate	19,688	9%
TOTAL	215,445	100%

The WAP clients who live in single family homes are diverse. For example:

- The median household income was $15,607. However, almost 10 percent of WAP clients had income of $7,200 or less and more than 10 percent of WAP clients had income of $33,700 or more.

- The average WAP household had 2.5 members, but single person elderly households were 23 percent of households served by the program.

- White non-Hispanic households were 59 percent of the population, black non-Hispanic households were 28 percent, Hispanic households were 11 percent, and about 2 percent were other racial/ethnic groups.

WAP client housing units also are diverse. Nationally, the average WAP client home is a single story detached home with 1,281 square feet of living space. However, while over 90 percent of the homes in the hot climate zones have one story, more than half of those in the Cold Climate Zones have two or more stories. One-fourth of WAP client homes were built before 1940 and one-third were built after 1970.

Table 3 shows how WAP client homes varied with respect to a number of important housing unit characteristics. It is most common for WAP client homes to use a natural gas central heating system without any secondary source of heat, to use gas water heating equipment, and to have a central air conditioning system with ducts to individual rooms. However, many WAP clients use other heating fuels, have heating systems where the equipment is located in each room (e.g., electric baseboard heat), use electric or wood or other supplemental heat, and have window/wall air conditioners. Low-income households live in all kinds of housing unit configurations and the WAP program serves that diverse array of individual circumstances.

Table 3 Characteristics of Single Family Homes Served by WAP in PY 2010

Characteristic	Statistics for Single Family Homes		
Year Built	Pre 1940 = 26%	1940-1969 = 40%	1970 or Later = 34%
Space Heating Fuel	Gas = 62%	Electric = 19%	Delivered = 19%
Heating System	Central = 86%	Room = 13%	Other = 1%
Supplemental Heat	Electric = 15%	Wood = 5%	Other = <1%
Air Conditioning	Central = 46%	Window/Wall = 30%	None = 24%
Water Heating Fuel	Natural Gas = 57%	Electric = 35%	Other = 8%

The WAP program conducts extensive testing of clients' homes, both to identify cost-effective energy saving opportunities and to ensure that the combustion equipment is operating safely. One important finding from testing is that the pre-weatherization energy saving potential varies considerably across homes served by the program. The testing shows that homes vary considerably in terms of pre-weatherization conditions, including: air leakage rates, furnace efficiency, presence and amount of attic insulation, presence and amount of wall insulation, duct leakage rates, and refrigerator efficiency.

After testing, WAP subgrantees install a comprehensive set of measures matched to the needs of each home. Major measures such as bypass air sealing, attic insulation, wall insulation, heating equipment replacement, and refrigerator replacement are expected to have the most significant impact on the homes in which they are installed. However, not every home needs every major measure. For example, a home with attic insulation that meets or exceeds standards for the climate in which it is located would not save much energy if more insulation were added. For that reason, only measures that are projected to have a savings-to-investment ratio (SIR) greater than 1.0 are installed as energy conservation measures (ECMs).

WAP subgrantees also install some health and safety measures that are not expected to result in cost-effective energy savings. For example, some homes have a furnace or water heater that is not operating safely and needs to be replaced to protect the health and safety of clients. Installation of new equipment may save some energy if the replacement unit is more efficient than the existing unit. However, in some homes, the existing equipment may not have even been operable; in those cases the new equipment may use more energy even if it operates more efficiently that the existing equipment. Testing procedures also may find that the home has insufficient ventilation to maintain a healthy indoor air quality; those homes may have mechanical ventilation added. Mechanical ventilation is expected to increase, rather than decrease, energy usage.

Table 4 shows the PY 2010 measure installation rates for the WAP program. It also shows the installation rates by Climate Zone. The measures with the highest installation rates were bypass air sealing, attic insulation, and lighting; all of these measures were installed in 60 percent or more of the treated homes. Duct sealing and other insulation (floor, rim joist, or foundation) were installed in 39 percent and 36 percent of homes respectively. Other listed measures had installation rates that varied from 12 percent (water heaters) to 28 percent (furnaces). Climate Zone installation rates varied from less than 1 percent for wall insulation in the Hot/Dry zone to 97 percent for bypass air sealing in the Hot/Humid zone.

Table 4 Measure Installation Rates for Single Family Homes Served by WAP in PY 2010

Measure	NATIONAL	Very Cold	Cold	Moderate	Hot/Humid	Hot/Dry
Air Sealing						
Bypass Air Sealing	89%	76%	96%	88%	97%	70%
Mechanical Ventilation	19%	19%	16%	17%	32%	5%
Duct Sealing	39%	39%	39%	43%	33%	49%
Insulation						
Attic Insulation	60%	67%	64%	62%	67%	19%
Wall Insulation	23%	32%	32%	14%	17%	<1%
Other Insulation (floor, rim joist, foundation)	36%	49%	48%	32%	9%	2%
Equipment						
Furnace Replacement	28%	33%	26%	30%	30%	18%
Programmable Thermostat	16%	21%	14%	10%	20%	12%
Water Heater Replacement	12%	20%	11%	10%	15%	9%
Other						
Windows	17%	11%	22%	19%	17%	18%
Refrigerator	20%	27%	18%	16%	24%	14%
Lighting	68%	68%	64%	56%	78%	87%

Each home treated by the WAP has different energy saving opportunities. The service delivery agency prioritizes measures for installation taking into account the pre-existing conditions in the home, the cost of installing each potential energy saving measure, and any health and safety issues that need to be addressed, subject to funding limits established by DOE and other program funders. The final savings achieved in each home will vary depending on the overall efficiency level of the home prior to weatherization, the amount invested in energy efficiency measures, and the quality of the measure selection and installation procedures.

Gas and Electric Savings in Homes with Gas Main Heat

The evaluation directly measured gas and electric usage for the treatment group and Comparison Group homes that use natural gas as their main heating fuel. Gross program savings were estimated by comparing pre-weatherization usage (weather-normalized) to the post-weatherization usage (weather-normalized) for homes treated during PY 2010. Net program savings were estimated by comparing the savings for treatment group homes to the savings for Comparison Group homes.[2] Table 5 shows that the gross gas savings for gas heated homes in PY 2010 were 155 therms per home per year. However, during the same period, the Comparison Group (PY 2011 clients) reduced their usage by 8 therms per home per year without receiving any treatments. Therefore, net savings due to the program are estimated to be 147 therms (15.5%) per home per year.

Table 5 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Gas Savings (therms/year)

Group	# Homes	Use Pre-WAP	Use Post-WAP	Gross Savings	Net Savings	% of Pre
Treatment Group	6,592	947	792	155 (±9)	147 (±9)	15.5% (±.9%)
Comparison	2,647	930	921	8 (±3)		

The analysis of natural gas impacts found several factors that help to explain the different levels of gas savings among program participants. Savings were higher for:

- Homes that received more major measures (Table 6).
- Homes with higher pre-weatherization gas usage (Table 7).
- Single family homes that are detached compared to attached homes (See Table 4.15).
- Homes with higher levels of spending on weatherization measures (See Table 4.17).

Table 6 shows that the amount of natural gas saved increased substantially as the number of major measures installed in the home increased. Homes that had three major measures installed saved about 2.5 times the amount of energy saved by homes that only had one major measure installed. Homes that were weatherized but that did not receive any of the major measures saved about 4.5 percent of pre-weatherization gas usage, while homes that received all four major measures had savings of 32.8 percent. The homes that had fewer measures installed had, on average, lower pre-weatherization usage, indicating that they had fewer energy saving opportunities.

[2] The Comparison Group includes homes treated by WAP during PY 2011. The analysis estimates the year-over-year change of these households in the two years prior to delivery of WAP services.

Table 6 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gas Savings for Homes with Natural Gas Main Heat by Measure Combination (therms/year)

Group/Breakout	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
No Major Measures	733	823	37 (±10)	4.5% (±1.2%)
Any One Major Measure	1,811	928	103 (±8)	11.1% (±.8%)
Any Two Major Measures	1,916	1,005	168 (±9)	16.7% (±.9%)
Any Three Major Measures	1,031	1,070	256 (±13)	24.0% (±1.2%)
All Four Major Measures	304	1,124	369 (±25)	32.8% (±2.2%)

Table 7 shows that homes with higher pre-weatherization usage had higher energy savings even when the analysis controlled for the number of major measures installed. Homes with pre-weatherization usage of 1,250-<1,500 therms received an average of 2.0 major measures and had average savings of 237 therms, while homes with pre-weatherization usage of 750-<1,000 therms received an average of 1.7 major measures and had average savings of 126 therms. The higher-usage homes saved almost twice as many therms of gas with only slightly more installed measures.

Table 7 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat by Pre-Weatherization Gas Usage (therms/year)

Pre-WAP Gas Use (therms/year)	# Major Measures	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	1.7	6,592	947	147 (±9)	15.5% (±.9%)
<750 therms/year.	1.4	2,181	557	64 (±6)	11.5% (±1.1%)
750-<1000	1.7	1,723	873	126 (±7)	14.4% (±.8%)
1000-<1250	1.9	1,227	1,111	199 (±14)	17.9% (±1.3%)
1250-<1500	2.0	683	1,362	237 (±27)	17.4% (±2.%)
>=1500 therms/year.	2.0	778	1,921	345 (±41)	17.9% (±2.1%)

Note: Comparison Group, not shown, also was stratified by usage.

Savings for gas heated homes varied considerably across Climate Zones, but higher savings were not always associated with a higher number of heating degree days (Table 8). The average gas savings in the Cold Zone were higher than the average gas savings for the Very Cold Zone. One possible reason is that the pre-weatherization test data show that air infiltration rates were higher for homes in the Cold Zone than for homes in the Very Cold Zone.

It does appear that energy savings are related to the average pre-weatherization usage of homes treated in each Climate Zone. The Cold Climate Zone had the highest pre-weatherization usage, the highest average savings, and the highest average percent savings. The pre-weatherization usage in the Hot/Humid Climate Zone was only about one-half of that in the Cold Climate Zone and, despite installing more major measures per home, the average savings in the Hot/Humid Climate Zone were less than one-half the savings in the Cold Climate Zone.

The number of major measures also appears to have an impact on energy savings. The homes in the Hot/Humid and Hot/Dry Climate Zones had similar pre-weatherization usage. However, an average of 1.9

major measures was installed in homes in the Hot/Humid Climate Zone compared to an average of only 0.8 major measures in the Hot/Dry Climate Zone. The average energy savings in the Hot/Dry Climate Zone were much lower than the savings in the Hot/Humid Climate Zone.

Table 8 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat by Climate Zone (therms/year)

Climate	# Major Measures	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	1.7	6,592	947	147 (±9)	15.5% (±.9%)
Very Cold	1.8	2,149	1,040	157 (±13)	15.1% (±1.3%)
Cold	1.8	2,990	1,091	188 (±13)	17.2% (±1.2%)
Moderate	1.6	792	828	125 (±24)	15.1% (±2.9%)
Hot/Humid	1.9	368	558	81 (±23)	14.6% (±4.1%)
Hot/Dry	0.8	293	545	12 (±17)	2.1% (±3.2%)

Note: Comparison Group, not shown, also was stratified by climate zone.

Weatherization of gas heated homes also can result in savings of electricity. Air sealing and insulation can reduce the use of a furnace fan in the winter and demand for air conditioning in the summer. In addition, many WAP homes also have baseload measures such as refrigerators and energy efficient lights installed. Table 9 shows that the gross electric savings for gas heated homes in PY 2010 was 833 kWh and the net savings were estimated to be 716 kWh (7.8%).

Table 9 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Natural Gas Main Heat by End Use (kWh/year)

Usage Component	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
Treatment Group	7,271	9,222	8,388	833 (±52)	716 (±71)	7.8% (±0.8%)
Comparison	2,877	9,406	9,289	117 (±53)		

Electric Savings in Homes with Electric Main Heat

The evaluation directly measured electric usage for treatment group and Comparison Group homes that use electric main heating fuel. Gross program savings were estimated by comparing pre-weatherization usage (weather-normalized) to the post-weatherization usage (weather-normalized) for homes treated during PY 2010. Net program savings were estimated by comparing the savings for treatment group homes to the savings for Comparison Group homes.[3] Table 10 shows that the gross savings for electric heat homes in PY 2010 was 2,229 kWh. During the same period, the Comparison Group reduced usage by 457 kWh without receiving any treatments; net savings due to the program are estimated to be 1,841 kWh (9.3%).

3 The Comparison Group includes homes treated by WAP during PY 2009. The analysis estimates the year-over-year change of these households in the two years prior to delivery of WAP services.

Table 10 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Electric Main Heat (kWh/year)

Usage Component	# Homes	Elec Use Pre-WAP	Gross Savings	Net Savings	% of Pre
Treatment	1,292	19,746	2,299 (±192)	1,841 (±270)	9.3% (±1.4%)
Comparison	503	19,849	457 (±206)		

As with gas heated homes, both tabular data analysis and regression models show that certain factors are associated with higher levels of savings for WAP clients who use electricity as their main heating fuel. Savings were higher for:

- Homes that got more major measures (Table 11).
- Homes with higher pre-weatherization electric usage (Table 12).

Table 11 shows that increasing the number of major measures installed in a home increased the net savings. Since the overall sample size for homes with electric main heat is small, the confidence intervals are large and the differences between certain subgroups are not statistically significant. However, the data show that homes with no major measures had the lowest savings, and homes with three or four measures had the highest savings.

Table 11 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Electric Savings for Electric Main Heat (kWh/year) by Number of Major Measures

# Major Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
No Major Measures	237	18,679	976 (±453)	5.2% (±2.4%)
One Major Measure	506	19,351	1,637 (±267)	8.5% (±1.4%)
Two Major Measures	271	20,641	2,485 (±407)	12.0% (±2.0%)
Three or Four Major Measures	91	23,554	3,109 (±861)	13.2% (±3.7%)
All Electric Heat Units	1,292	19,746	1,841 (±270)	9.3% (±1.4%)

Table 12 shows that higher savings were observed for homes with higher usage. Homes that used 15,000-<20,000 kWh prior to weatherization had average savings of 1,259 kWh only about one-half the savings for homes that used 20,000-<25,000 kWh.[4]

4 The difference is statistically significant at the 90% confidence level.

Table 12 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Electric Main Heat by Pre-Weatherization Electric Usage

Pre-WAP Use	# Major Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
<15,000 KWh/yr	1.0	368	11,831	934 (±201)	7.9% (±1.7%)
15-<20,000	1.1	370	17,419	1,259 (±392)	7.2% (±2.3%)
20-<25,000	1.4	265	22,320	2,421 (±564)	10.8% (±2.5%)
25-<30,000	1.3	149	27,280	2,296 (±744)	8.4% (±2.7%)
>=30,000 kWh/yr	1.4	140	35,896	5,083 (±1,139)	14.2% (±3.2%)

Note: Comparison Group, not shown, also was stratified by pre-WAP electric use.

Energy Savings in Homes That Heat with a Delivered Fuel

The procedure for estimating the energy savings for homes that heat with a delivered fuel involved the following steps:

- Direct Metering of Homes – Energy use was directly metered for a sample of 120 single family homes during the 2010-2011 heating season.

- Measured Energy Savings – Gross energy savings were estimated by comparing pre-weatherization metered usage to post-weatherization metered usage for treated homes. Net energy savings were estimated by comparing the change in energy consumption for the treatment group to the change in usage for the Comparison Group.

- Comparative Analysis – The measured energy savings for delivered fuel homes were compared to projected savings for those same homes using the model developed for homes heated with natural gas. The analysis found that there was only a small difference between the measured savings and projected savings for delivered fuel homes.

- Projected Energy Savings – The natural gas energy savings models were used to project energy savings for the population of delivered fuel homes treated in PY 2010.

Table 13 shows the estimated energy savings for delivered fuel homes for PY 2010. These homes represent about 20 percent of the population of single family site-built homes treated in PY 2010. The average energy savings of 18.4 MMBtu for fuel oil main heat homes is higher than the average energy savings of 14.7 MMBtu for natural gas main heat homes (Table 5). Homes heated with propane and other fuels had lower average savings than did natural gas main heat homes. Homes that heated with other fuels (e.g., wood, kerosene, or coal) had the lowest projected heating savings.

Table 13 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Savings for Delivered Fuel Main Heat

Main Heating Fuel	Heating Fuel Savings (MMBtu/year)	Electric Savings (kWh/year)
Fuel Oil	18.4	558
Propane	13.4	958
Other	13.1	850
All Delivered Fuels	**15.9**	**745**

Program Energy Cost Savings and Cost-Effectiveness

The evaluation estimated the cost savings and cost-effectiveness in the following way:

- Energy Savings – The time series of energy savings were estimated for each sampled housing unit based on first year savings and the estimated life of the measure.

- Cost Savings – Current and projected energy prices were used to transform the energy savings time series to a cost savings time series for each sampled housing unit.

- Service Delivery Costs – Subgrantees furnished information on the service delivery costs for each sampled housing unit.

- Cost-Effectiveness – Program cost-effectiveness was estimated by comparing the net present value of energy savings to the service delivery costs for energy measures.

The analysis in this report is restricted to a comparison of the energy benefits to the service delivery costs for energy measures and incidental home repairs. The overarching impact report will compare energy and nonenergy benefits to total program costs.

This report presents information on energy savings for PY 2010. In this report, the energy cost savings and cost-effectiveness are presented from three different perspectives.

- Impact on PY 2010 Clients – The first scenario documents how the program impacted PY 2010 clients. It shows the clients' first year energy cost savings based on actual energy prices in 2010 and the estimated net present value of their energy cost savings based on actual energy prices for 2010 through 2012, projected energy prices beginning in 2013, and the discount rates in effect in 2010.

- PY 2013 Policy Perspective – The second scenario is the most relevant to policymakers making use of this report at the time of publication. It shows the energy cost savings and cost-effectiveness of a program implemented in PY 2013 using energy price projections beginning in 2013, and the discount rates in effect in 2013.

- Long Term Policy Perspective – The third scenario is useful for longer-term program decision-making. It shows the energy cost savings and cost-effectiveness of a program using energy price projections beginning in 2013, and long-term average discount rates.

Each of these three scenarios is useful for understanding the program from a different perspective. However, the PY 2010 Client Perspective is the most useful for documenting what the program accomplished while the PY 2013 Policy Perspective is probably the most useful for policymakers making decisions about the program going forward. Tables 14 and 15 reflect the assumptions under the PY 2010 Client Perspective and Tables 16 and 17 reflect the assumptions under the PY 2013 Policy Perspective.

Table 14 shows the estimated average annual energy costs and first year cost savings for PY 2010 clients by main heating fuel type. On average, WAP clients had pre-weatherization energy bills of $1,863 and energy savings of $223 (12.0%). The cost savings for fuel oil and propane heated homes is expected to be almost two times the cost savings for homes heating with other fuels. Though energy savings do not vary much across main heating fuel types, the cost per unit of energy for fuel oil and propane is more than twice the cost per unit for natural gas.

Table 14 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Energy Costs and Cost Savings by Main Heating Fuel (2010 Dollars)

Heating Fuel	Annual Energy Costs			Annual Savings (First Year)			
	Fuel	Electric	Total$	Fuel	Electric	Total$	% Savings
Natural Gas	$671	$963	$1,634	$110	$77	$187	11.4%
Electricity	-	$1,692	$1,692	-	$197	$197	11.7%
Fuel Oil	$1,961	$1,025	$2,986	$336	$56	$392	13.1%
Propane	$1,834	$971	$2,806	$295	$82	$377	13.4%
Other*	$689	$989	$1,678	$113	$76	$188	11.2%
All Clients	**$750**	**$1,113**	**$1,863**	**$124**	**$99**	**$223**	**12.0%**

*Other heating fuels include wood, kerosene, and coal.

Table 15 furnishes a projection of the energy cost-effectiveness of the program for single family site-built homes. It compares the net present value of lifetime energy cost savings to the energy measure costs to calculate the savings-to-investment ratio (SIR) by main heating fuel. The SIR is estimated to be 1.01 for the overall program. The SIR is greater than 1.0 for clients who heat with fuel oil or propane; higher priced fuels result in higher cost savings and a higher SIR.

Table 15 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2010 Dollars)

Heating Fuel	Energy Cost Savings (Present Value of Lifetime Savings)			Costs & Cost-Effectiveness		
	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
Natural Gas	$2,237	$765	$3,002	$3,661	-$659	0.82
Electricity	-	$3,219	$3,219	$3,713	-$494	0.87
Fuel Oil	$8,182	$567	$8,749	$4,258	$4,492	2.05
Propane	$4,940	$814	$5,754	$4,259	$1,495	1.35
Other	$2,499	$761	$3,259	$3,913	-$654	0.83
All Clients	**$2,571**	**$1,231**	**$3,803**	**$3,777**	**$25**	**1.01**

While it is useful to know how the program performed for PY 2010 clients, today's policymakers need to make decisions based on current energy prices and price projections, and current discount rates. Table 16 shows the projected average annual energy costs and first year cost savings for PY 2013 clients by main heating fuel type. On average, WAP clients would be projected to have pre-weatherization energy bills of $1,874 and first year energy savings of $224 (11.9%). When compared to the PY 2010 energy cost savings, Table 16 shows that the average projected energy cost savings for a program implemented in PY 2013 are about the same as the energy cost savings experienced by clients served in 2010.

Table 16 Projected PY 2013 WAP Impacts for Single Family Site-Built Homes Energy Costs and Cost Savings by Main Heating Fuel (2013 Dollars)

Heating Fuel	Annual Energy Costs			Annual Savings (First Year)			
	Fuel	Electric	Total$	Fuel	Electric	Total$	% Savings
Natural Gas	$649	$962	$1,611	$106	$76	$182	11.3%
Electricity	-	$1,667	$1,667	-	$193	$193	11.6%
Fuel Oil	$2,426	$1,075	$3,501	$416	$58	$473	13.5%
Propane	$1,572	$975	$2,547	$253	$82	$335	13.1%
Other*	$727	$1,000	$1,727	$119	$76	$195	11.3%
All Clients	**$762**	**$1,113**	**$1,874**	**$126**	**$98**	**$224**	**11.9%**

*Other heating fuels include wood, kerosene, and coal.

Table 17 shows that, from the 2013 Policy Perspective, the net present value of energy cost savings are higher because the specified discount rate for FY 2013 is lower than the specified discount rate for FY 2010; a lower discount rate means that future energy cost savings have a higher net present value. Using the PY 2013 assumptions, the SIR is estimated to be 1.12 for the overall program, somewhat higher than the SIR of 1.01 experienced by the clients served by the PY 2010 program.

Table 17 Projected PY 2013 WAP Energy Impacts for Single Family Site-Built Homes Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2013 Dollars)

Heating Fuel	Energy Cost Savings (Present Value of Lifetime Savings)			Costs & Cost-Effectiveness		
	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
Natural Gas	$2,678	$859	$3,536	$3,867	-$331	0.91
Electricity	-	$3,725	$3,725	$3,922	-$197	0.95
Fuel Oil	$9,827	$631	$10,458	$4,498	$5,960	2.33
Propane	$5,716	$914	$6,631	$4,499	$2,132	1.47
Other	$2,884	$851	$3,735	$4,134	-$399	0.90
All Clients	**$3,065**	**$1,403**	**$4,468**	**$3,990**	**$478**	**1.12**

The energy savings analysis showed that certain treatment characteristics were associated with higher levels of energy savings. The cost-effectiveness analysis shows that higher energy savings do not always result in a higher cost-effectiveness ratio. For example:

- Climate Zone – The Cold Zone had the highest average energy savings and the second lowest average energy measures costs; it had the highest SIR. (See Table 7.3)

- Major Measures – Homes that received more major measures saved more energy. Estimated cost-effectiveness increased as the number of major measures increased, but not at the same rate as energy savings. (See Table 7.4)

- Pre-Weatherization Usage – Homes with the highest level of pre-weatherization usage had the highest energy savings and the highest SIR. (See Table 7.5)

- DOE vs. nonDOE Funds – Homes that were treated with both DOE and nonDOE funds had higher energy savings than did homes that were treated with DOE funds alone. However, homes that used only DOE funds had slightly higher cost-effectiveness ratios. (See Table 7.6)

These analyses show that there are important differences in the outcomes for different WAP subpopulations. Furthermore, there are significant differences between findings with respect to energy savings, cost savings, and cost-effectiveness. The energy savings analysis is clear: by treating homes with higher pre-weatherization usage and installing more measures, the program can save more energy per home. The cost savings analysis shows that the highest direct benefit to clients (i.e., reduction in energy bills) is achieved by focusing on the clients who used the highest price fuels (i.e., fuel oil and propane). Finally, the cost-effectiveness analysis shows that the highest cost-effectiveness ratios are achieved by maximizing cost savings per dollar spent, but that is not always the same as maximizing energy savings. (See Table 7.7).

It is clear that WAP policies can have a significant impact on the average levels of energy savings, cost savings, and cost-effectiveness for the program by encouraging changes in the way that the program is implemented. However, it is also clear that there are important trade-offs among those three goals that might result from any individual policy change. Finally, it is important to remember that this analysis has focused only on energy cost savings and the cost of energy efficiency measures and incidental repairs. Policy changes that are designed to change the level of energy savings, cost savings, or cost-effectiveness may have either positive or negative effects on program nonenergy benefits.[5]

[5] Nonenergy benefits include benefits to clients (e.g., reduced late payment charges, increased home value, and improved health), benefits to ratepayers (e.g., lower bad debt write-offs), and benefits to society (e.g., reduced emissions and increased employment).

1. INTRODUCTION

The purpose of this report is to disseminate the findings from an analysis of the energy savings, cost savings, and cost-effectiveness for single family site-built homes treated by DOE's Weatherization Assistance Program (WAP) during Program Years 2009, 2010, and 2011 (the American Recovery and Reinvestment Act Period). The main focus of this study is on PY 2010. The analysis uses data from a number of sources to characterize the population of single family homes[6] that were served by the program, estimate the gross and net change in energy usage for treated homes, make projections for the first year and longer-term cost savings associated with the energy savings, and assess the cost-effectiveness of the program in terms of direct energy benefits.

This is one of a number of energy impact reports developed for the National WAP Evaluation. The full set of energy impact reports consists of:

- Energy Impacts for Single Family Homes
- Energy Impacts for Mobile Homes
- Energy Impacts for Multifamily Buildings
- Energy and Nonenergy Impacts of the Weatherization Assistance Program

To the extent possible, the WAP program applies consistent procedures across all clients. However, there are substantial differences in energy equipment, building configuration, and retrofit opportunities across building types. By furnishing reports for each building type, the evaluation is able to give policymakers an understanding of the specific challenges associated with maximizing energy impacts from each building type. The summary report then furnishes comprehensive information on the program's energy and nonenergy impacts.

1.1 NATIONAL WEATHERIZATION ASSISTANCE PROGRAM EVALUATION OVERVIEW

The U.S. Department of Energy's (DOE) Weatherization Assistance Program was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the Program as currently stated in the Code of Federal Regulations (CFR) 10 CFR 440.1 is "to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden." (*Code of Federal Regulations, 2011*)

At the request of DOE, Oak Ridge National Laboratory (ORNL) developed a comprehensive plan for a national evaluation of WAP that was published in 2011. DOE furnished funding to ORNL for a national evaluation for Program Years 2009, 2010, and 2011 (the American Recovery and Reinvestment Act Period), with a particular emphasis on PY 2010. ORNL subcontracted evaluation research to APPRISE Incorporated and its partners the Energy Center of Wisconsin, Michael Blasnik and Associates, and Dalhoff Associates LLC. The Scope of Work (SOW) for the evaluation includes the following components:

[6] Single Family Homes are defined as housing units in buildings with 1 to 4 units. In the PY 2008 Evaluation, Single Family Homes were defined as housing units in buildings with one unit. The definition used in the 2008 Evaluation is consistent with the Census Bureau definition of single family homes. The definition used in this evaluation is consistent with the WAP program definition of single family homes.

- Impact Assessment – Characterization of the weatherization network and the households that are income-eligible for WAP, measurement and monetization of the energy and nonenergy impacts of the program, and assessment of the factors associated with higher levels of energy savings, cost savings, and cost-effectiveness.

- Process Assessment – Direct observation of how the weatherization network delivers services and assessment of how service delivery compares to national standards and documentation of how weatherization staff and clients perceive service delivery.

- Synthesis Study – Synthesis of the findings from this evaluation into a comprehensive assessment of the success of the program in meeting its goals and identification of key areas for program enhancement.

This analysis of single family home energy impacts is part of the program Impact Assessment.

1.2 SINGLE FAMILY ENERGY IMPACT STUDY OVERVIEW

The single family energy impact report furnishes information on the households and housing units served by the program, documents the services delivered to those households and housing units, measures the change in energy consumption and energy costs experienced by those clients, and compares the cost of the installed measures to the energy cost savings.

The data collection and analysis conducted to develop this report involved a series of complementary tasks, including:

- Client Sample – The evaluation team worked with grantees and subgrantees to select a representative sample of clients served by the program in PYs 2009, 2010, and 2011.

- Diagnostics and Measures – Subgrantees supplied information on diagnostic tests conducted, installed measures, and measures costs for a sample of homes that were treated by the WAP program.

- Energy Data Collection – The evaluation team collected information from energy suppliers and through direct metering in clients' homes to assess the amount of energy used in the clients' homes before and after the installation of weatherization measures.

- Energy Data Analysis - Statistical procedures were used to develop normalized estimates of the usage difference in the pre- and post-weatherization periods and develop robust estimates of the net energy impacts associated with service delivery.

- Energy Cost Savings and Cost-Effectiveness Analysis – The evaluation team collected energy price data and projections, transformed energy savings into cost savings, and estimated program cost-effectiveness.

This combined set of procedures was designed to furnish estimates of the energy and cost impacts associated with the WAP, to identify the explanatory factors associated with higher levels of energy impacts, and to assess the cost-effectiveness of individual measure packages and the overall program.

The study assessed whether there were important differences in energy impacts, cost savings, and cost-effectiveness by Climate Zone. Throughout the report, tables furnish results by Climate Zone. Figure 1.1 shows how states were assigned to Climates Zones for purposes of this study.

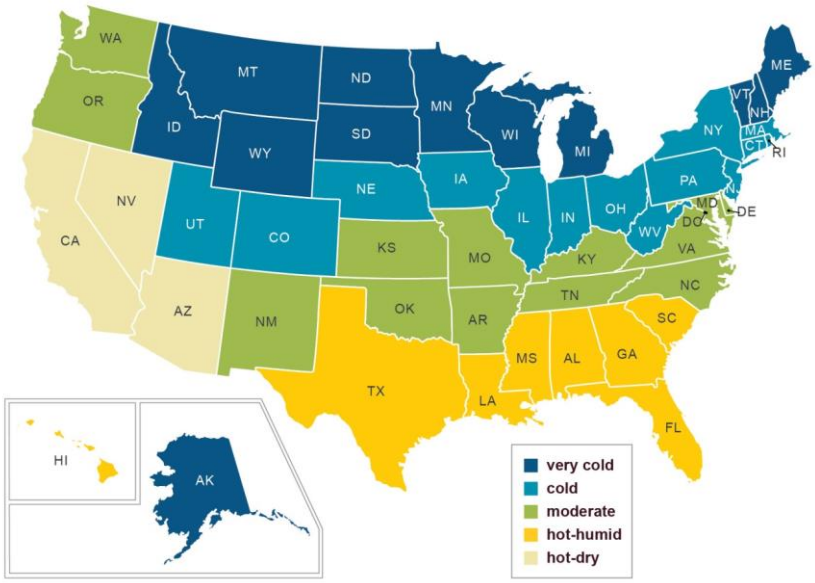


Figure 1.1: Climate Zone Map for the PY 2010 Evaluation

1.3 ORGANIZATION OF THE SINGLE FAMILY ENERGY IMPACT REPORT

The report consists of eight sections, including:

- Section 2 – Overview of Data Collection Methodology: Documents the data sources that were used to prepare this report.

- Section 3 – Program Production, Participants, Housing Units, and Treatments: Furnishes information on the number of clients in single family homes served by the WAP, the household and housing unit characteristics of these clients, the diagnostics performed, and the services delivered.

- Section 4 – Energy Impacts for Homes with Gas Main Heat: Furnishes estimates of the natural gas and electric impacts for homes with natural gas main heat.

- Section 5 – Energy Impacts for Homes with Electric Main Heat: Furnishes estimates of the electric impacts for homes with electric main heat.

- Section 6 – Energy Impacts for Homes with Delivered Fuel Main Heat: Reports on how submeter data and program production data were used to estimate the energy impacts for single family homes that use a delivered fuel as their main source of heating.

- Section 7 – Cost Savings, Measure Costs, and Cost-Effectiveness: Compares the investments made in the treated homes to the energy costs savings that accrue to clients and summarizes how the program performed with respect to weatherization of single family homes in terms energy savings, cost savings, and cost-effectiveness.

This report is designed to complement other Energy Impact Reports and to contribute to the Summary Report on Energy and Nonenergy Impacts of the WAP.

2. OVERVIEW OF DATA COLLECTION METHODOLOGY

The purpose of the single family energy impact study is to measure the energy savings, cost savings, and cost-effectiveness for single family site-built homes treated by WAP during Program Years 2009, 2010, and 2011. The main focus of the study is on PY 2010. The study used data from a number of sources, including:

- Grantees (i.e., States)
- Subgrantees (i.e., Local Agencies)
- Electric and Gas Utilities
- Delivered Fuel Submeter Studies
- EIA Energy Price Data and Projections
- NCDC Weather Data

This section of the report describes the data collection procedures and outcomes for grantees, subgrantees, and electric and gas utilities. The analysis methods used in this study were specified in the program evaluation plan and are consistent with energy program evaluation best practices. The analysis procedures used to estimate the program impacts for each main heating fuel type are discussed in the relevant impact sections of the report.

2.1 SUBGRANTEE AND CLIENT SAMPLE

The first step in the data collection process was to select a representative sample of clients served in PYs 2010 and 2011.[7] The evaluation used a two-stage sampling procedure. In the first stage, a sample of subgrantees was selected. In the second stage, a sample of clients was selected from sampled subgrantees.

2.1.1 Subgrantee Sampling Procedures

The Evaluation Team selected a two-stage sample of 451 agencies. First, the sample included all subgrantees (N=95) that received SERC (Sustainable Energy Resources for Consumers) program funding. Second, a sample of subgrantees was selected with probability proportionate to PY 2010 funding. The sampling procedure was:

- Grantee Allocation – Each grantee was allocated a share of the sample of 356 subgrantees based on its share of PY 2010 program funding.[8]

- Subgrantee Sample – For each grantee, a set of subgrantees was sampled with probability proportionate to size based on PY 2010 planned program funding.

The outcome of this procedure was that states with higher WAP funding had more sampled subgrantees and the larger subgrantees had a higher probability of selection. These procedures furnished a representative and statistically efficient sample of clients.

[7] The sample of clients for PY 2009 was collected as part of the PY 2008 National Weatherization Assistance Program Evaluation. The procedures and statistics presented in this section refer to PY 2010 and PY 2011 clients.

[8] This report focuses on the clients served by the 50 state grantees and the District of Columbia. The grantee sample included two territory grantees and one tribal grantee. Separate reports are being prepared for those grantees.

2.1.2 Client Sampling Procedures

The Evaluation Team contacted each of the sampled agencies to get information on clients served in PYs 2010 and 2011. The client sampling procedures involved the following steps:

- Client List – Each sampled subgrantee furnished a list of clients for PYs 2010 and 2011. (Note: In many cases, the grantee furnished a database of clients from which the subgrantee list could be developed.)

- Client Sample – Subgrantee lists were stratified into two groups: utility main heat (i.e., electric or natural gas) and delivered fuel main heat (i.e., fuel oil, propane, wood, or coal). Sampling procedures selected a targeted percentage of clients in each of the two strata (i.e., utility main heat and the delivered fuel main heat); the targeted percentage varied by Climate Zone.

2.1.3 Subgrantee and Client Sampling Statistics and Response Rates

The sample consisted of 51 state grantees (including the District of Columbia) and 448 of their subgrantees. The following statistics describe the sample and the response rates for those grantees and subgrantees:

- Grantees (States and District of Columbia)
    - Population – 51 grantees received WAP funding in PY 2010.
    - Census – All 51 grantees were included in the sample.
    - Response – All 51 grantees (100%) responded to information requests
- Subgrantees
    - Population – 1,020 subgrantees were listed in grantee plans, but only 929 completed units in PY 2010.
    - Sample – 448 of the 929 subgrantees with PY 2010 units were sampled.
    - Response – 438 of the 448 sampled subgrantees (98%) furnished client lists.

The Evaluation Team selected a sample of 39,115 PY 2010 clients from the 438 sampled subgrantees that furnished a list of clients; 27,330 of those clients lived in single family homes.

2.2 SUBGRANTEE DATA COLLECTION

Subgrantees were asked to furnish two kinds of client data to support the evaluation, utility account information and client service delivery data. (Note: In some cases, the utility account information was included in the grantee database.)

2.2.1 Utility Account Information

Subgrantees were asked to furnish main heating fuel, utility account numbers, and copies of data release waivers for sampled clients who heated with either natural gas or electricity. The following statistics describe the response rate to this data request:

- Sample – 448 sampled subgrantees were asked to furnish a list of clients.

- Client List Response – 438 of 448 sampled subgrantees (98%) furnished client lists.

- Utility Data Response – 409 of 448 sampled subgrantees (91%) furnished utility data for sampled clients.

The following statistics describe the response rate in terms of clients:

- Sample – The Evaluation Team selected a sample of 24,736 PY 2010 clients who lived in a single family home heated with natural gas or electricity from the 438 sampled subgrantees that furnished client lists.

- Responding Subgrantees – The 409 subgrantees that responded to the utility data request had 22,288 of these 24,736 sampled clients (90%).

- Main Heating Supplier – The 409 subgrantees that responded furnished the heating energy supplier information for 19,600 of their 22,288 single family home clients (88%). That represents 79% of all sampled clients.

- Electric Data Supplier - The 409 subgrantees that responded furnished electric supplier information for 19,225 of their 22,288 single family home clients (86%). That represents 78% of all sampled single family home clients.

Some subgrantees collected supplier information only for the main heating fuel and did not collect information for the client's electric company if it was not the main heating fuel.

2.2.2 Client Service Delivery Data

Subgrantees were asked to furnish client service delivery information for all PY 2010 sampled clients. The requested service delivery data included:

- Household demographics
- Housing unit characteristics
- Pre-Weatherization conditions
- Installed measures and costs
- Post-Weatherization conditions

The following statistics describe the response rate to this data request:

- Sample – 448 sampled subgrantees were asked to furnish a list of clients.

- Client List Response – 438 of 448 sampled subgrantees (98%) furnished a list of clients.

- Service Delivery Data Response – 390 of 448 sampled subgrantees (87%) furnished client service delivery data.

The following statistics describe the response rate in terms of clients:

- Sample – The Evaluation Team selected a sample of 24,680 PY 2010 clients who lived in single family homes from the 438 sampled subgrantees that furnished client lists.

- Responding Subgrantees – The 390 subgrantees that responded to the client service delivery data request had 23,125 of the 24,680 sampled clients (94%).

- Client Data – The 390 subgrantees that responded furnished service delivery data for 21,018 of their 23,125 single family home clients (91%). That represents 85% of all sampled single family home clients.

Note that subgrantees did not always furnish detailed records for every client who was sampled.

2.3 NATURAL GAS AND ELECTRIC USAGE DATA COLLECTION

For all sampled clients who heated with either natural gas or electricity, the evaluation team requested data from the company that supplied the client's main heating fuel. The supplier was asked to furnish monthly data for the period 1/1/2008 through 12/31/2012. The following statistics describe the response rates:

- Natural Gas or Electric Main Heating Fuel

    - Companies – 453 natural gas and electric companies were identified for one or more sampled PY 2010 single family home clients.

    - Company Response – 373 of the 453 companies (82%) furnished data for one or more of the sampled clients.

    - Client Response – Data were received for 14,070 of the 19,126 PY 2010 single family clients for whom a supplier was listed (74%). That is 63% of the 22,302 sampled single family home clients who heat with either natural gas or electricity.

- Electric Usage for Natural Gas Main Heat Clients

    - Companies – 343 electric companies were identified as the electric supplier for one or more PY 2010 single family home clients who heat with natural gas.

    - Company Response – 289 of the 343 electric companies (84%) furnished data for one or more of the sampled clients.

    - Client Response - Data were received for 10,374 of the 14,367 PY 2010 single family clients for whom an electric supplier was listed (72%). That is 61% of the 16,985 sampled clients who heat with natural gas.

These statistics furnish information on clients for whom *any* data were furnished. Not all usage records were adequate for all parts of the billing analysis procedures.

3. PROGRAM PRODUCTION, PARTICIPANTS, HOUSING UNITS, AND TREATMENTS

This section of the report uses detailed client and service delivery data furnished by the sampled subgrantees to characterize the population of households and housing units served by the program, including:

- Household Demographics
- Housing Unit Characteristics
- Pre-Weatherization Conditions
- Installed Measures
- Post-Weatherization Conditions

Weatherization Costs

The evaluation furnishes information on all housing units served by the WAP program in PY 2010. This report focuses on characterizing single family site-built homes.

3.1 METHODOLOGY

For PY 2010, WAP grantees reported information to DOE on program production. However, grantees were not asked to report detailed information on the characteristics of the households and housing units served, nor were they asked to report detailed information on installed measures and measure costs. The data collected for this evaluation furnishes detailed statistics on the characteristics of clients served by the program in PY 2010.

The primary data source for this section of the report was furnished by subgrantees for a sample of clients. In total, 385 subgrantees furnished detailed information for 35,030 clients who were served by the WAP in PY 2010, including 24,680 single family site-built homes. Table 3.1 shows the number of sampled clients by Climate Zone and Table 3.2 shows the number of sampled clients by Housing Unit Type.

Table 3.1 PY 2010 Sampled Clients by Climate Zone

Climate Zone	PY 2010 Sampled Clients	Percent of PY 2010 Sample
Very Cold Climate	6,430	19%
Cold Climate	12,249	35%
Moderate Climate	7,124	20%
Hot/Humid Climate	5,646	16%
Hot/Dry Climate	3,581	10%
TOTAL	35,030	100%

Table 3.2 PY 2010 Sampled Clients by Housing Unit Type

Housing Unit Type	PY 2010 Sampled Clients	Percent of PY 2010 Sample
Single Family Site-Built (1-4 Units)	24,680	70%
Single Family Mobile Home	5,250	15%
Large Multifamily (5+)	5,100	15%
TOTAL	35,030	100%

The sample of clients supplied by WAP subgrantees was weighted to account for sampling rates and to adjust for survey nonresponse. The procedures included the following steps:

- Base Weight – The base weight was the inverse of the client's probability of selection.
- State-Level Adjustment – For each state, the client weights were adjusted to match state production control totals by housing unit type.

Table 3.3 shows the weighted count of WAP clients by Climate Zone; it shows that 56 percent of the weatherized units were in the Very Cold and Cold Climate Zones. Table 3.4 shows the weighted count of WAP clients by Housing Unit Type; it shows that single family site-built homes were 65 percent of the total units weatherized in PY 2010.

Table 3.3 PY 2010 Weighted Clients by Climate Zone

Climate Zone	PY 2010 Weighted Count of Clients	Percent of PY 2010 Clients
Very Cold Climate	58,584	18%
Cold Climate	127,386	38%
Moderate Climate	56,006	17%
Hot/Humid Climate	55,157	17%
Hot/Dry Climate	34,732	10%
TOTAL	331,865	100%

Table 3.4 PY 2010 Weighted Clients by Housing Unit Type

Housing Unit Type	PY 2010 Weighted Count of Clients	Percent of PY 2010 Clients
Single Family Site-Built	215,445	65%
Single Family Mobile Home	48,267	15%
Large Multifamily (5+)	68,153	21%
TOTAL	331,865	100%

The distribution of the housing unit types weatherized varies somewhat by Climate Zone. Table 3.5 shows the weighted percent of units in each Climate Zone by housing unit type. The Moderate Climate Zone had the largest percentage of single family homes served and the Hot/Dry Climate Zone had the largest percentage of large multifamily buildings served.

Table 3.5 PY 2010 Weighted Clients by Climate Zone and Housing Unit Type

Climate Zone	Single Family	Mobile Home	Large Multifamily	All Housing Unit Types
Very Cold Climate	70%	17%	13%	100%
Cold Climate	62%	11%	27%	100%
Moderate Climate	72%	20%	8%	100%
Hot/Humid Climate	65%	14%	20%	100%
Hot/Dry Climate	57%	13%	30%	100%
TOTAL	65%	15%	21%	100%

Table 3.6 shows the number and percent of single family homes by Climate Zone. Slightly more than half of the 215,445 treated single family homes were in the Very Cold and Cold Climate Zones.

Table 3.6 PY 2010 WAP Weighted Clients in Single Family Homes by Climate Zone

Climate Zone	PY 2010 Units	Percent of PY 2010 Units
Very Cold Climate	40,870	19%
Cold Climate	78,381	36%
Moderate Climate	40,459	19%
Hot/Humid Climate	36,047	17%
Hot/Dry Climate	19,688	9%
TOTAL	215,445	100%

3.2 HOUSEHOLD CHARACTERISTICS

Table 3.7 furnishes national and Climate Zone statistics on the household characteristics for PY 2010 clients in single family homes. The overall finding is that the single family homes served by the WAP are primarily homeowners, with incomes at or near the poverty level that have a vulnerable individual in the home. The racial and ethnic distribution of households is consistent with the distribution of single family homeowners in each Climate Zone.

Some important household characteristics vary by Climate Zone, including:

- Income – Households in the Hot/Humid Climate Zone have the lowest average income; more than one-half have income at or below the poverty line.

- Vulnerability Status – The Hot/Humid Climate Zone has the highest percentage of households with an elderly member. The Hot/Dry Climate Zone has the highest percentage of households with a child.

- Homeowners – Despite having the lowest average income, households in the Hot/Humid Climate Zone are the most likely to be homeowners. In the Hot/Dry Climate Zone, 40 percent of households are renters. In all of the other Climate Zones, fewer than 20 percent of clients are renters.

Race/Ethnicity – White non-Hispanic households are in the majority in most Climate Zones, but black non-Hispanic households are in the majority in the Hot/Humid Climate Zone and Hispanic households are in the majority in the Hot/Dry Climate Zone.

The WAP program serves many different kinds of households in terms of income, tenure, age, vulnerability status, and household size.

Table 3.7 PY 2010 Clients in Single Family Homes Household Characteristics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Income and Poverty						
Median Income	$15,607	$17,908	$15,937	$13,843	$13,248	$17,928
Median % of Poverty	109%	121%	113%	102%	98%	109%
% < 100% of Poverty	44%	37%	42%	48%	52%	45%
Vulnerability Status						
% w/Elderly Individual	41%	34%	38%	48%	53%	38%
% w/Disabled Individual	30%	29%	24%	39%	35%	31%
% w/Children	33%	39%	28%	30%	32%	45%
Household Status						
% Homeowner	82%	83%	82%	84%	90%	60%
Mean Household Size	2.46	2.64	2.48	2.20	2.23	1.82
% Single Parent	20%	17%	22%	17%	27%	17%
% Single Elderly	23%	20%	22%	27%	31%	18%
Race/Ethnicity						
% White non-Hispanic	59%	84%	76%	58%	26%	35%
% Black non-Hispanic	28%	8%	17%	35%	52%	7%
% Hispanic	11%	3%	6%	4%	20%	53%
% Asian	1%	<1%	1%	<1%	1%	2%
% Native American	1%	4%	<1%	2%	<1%	4%
% Other	<1%	1%	<1%	<1%	1%	0%

Table 3.8 furnishes details on the distribution of income and poverty for households.

- Income – The Moderate and Hot/Humid Climate Zones serve households with lower incomes than households in the other zones; almost all of the households have incomes at or below $30,000 per year and median income is less than $14,000 per year. In the Hot/Dry Climate Zone, in comparison, median income is almost $18,000 per year and 10 percent of households have incomes of more than $37,000 per year.

- Poverty – About 25 percent of households had incomes above 150 percent of poverty. In general, the Moderate and Hot/Humid Climate Zones served households at lower poverty levels than households in the other zones, but even in those zones a significant share of clients had incomes above 150 percent of poverty.

Changes in the program eligibility guidelines that were implemented for PY 2009 are now reflected in program statistics. In PY 2010, the program served a significant number of clients who would not have been eligible for the program in PY 2008.

Table 3.8 PY 2010 Clients in Single Family Homes Distribution of Income and Poverty by Climate Zone

	Percent of Population				
Variable	**10%**	**25%**	**Median**	**75%**	**90%**
Income					
Very Cold Zone	$7,221	$ 11,931	$17,908	$24,816	$33,714
Cold Zone	$2,088	$ 9,516	$15,937	$24,264	$33,048
Moderate Zone	$2,832	$8,984	$13,843	$20,135	$28,565
Hot/Humid Zone	$3,000	$8,340	$13,248	$20,052	$28,059
Hot/Dry Zone	$6,552	$10,381	$17,928	$27,084	$37,063
ALL ZONES	$4,596	$9,708	$15,607	$23,332	$32,308
Percent of Poverty					
Very Cold Zone	44%	80%	121%	158%	183%
Cold Zone	19%	73%	113%	153%	191%
Moderate Zone	17%	70%	102%	139%	172%
Hot/Humid Zone	21%	66%	98%	133%	165%
Hot/Dry Zone	37%	71%	109%	161%	197%
ALL ZONES	30%	73%	109%	149%	183%

Table 3.9 shows how ownership status varies by demographic group. Homes with an elderly member were most likely to be owner-occupied; over 90 percent were homeowners. Single parent households had the lowest home ownership rates; only 75 percent were homeowners. These may seem like high ownership rates for households participating in a low-income program. However, though only about 50 percent of low-income households are homeowners, almost 80 percent of low-income households that live in single family homes are homeowners.[9]

[9] Statistics developed from the 2005 RECS and reported in the WAP Eligible Population Report.

Table 3.9 PY 2010 Clients in Single Family Homes Home Ownership by Demographic Group

Demographic Group	% Owners	% Renters
Elderly Households	91%	9%
Disabled Households	82%	18%
Households with Children	78%	22%
Single Parent Households	75%	25%
Single Elderly Households	90%	10%

3.3 HOUSING UNIT CHARACTERISTICS

Table 3.10 furnishes national and Climate Zone statistics on the housing unit characteristics for PY 2010 clients in single family homes. The table furnishes national average statistics. However, what is clear from the table is that there are important differences in the configuration, foundation type, and age of homes by Climate Zone.

Table 3.10 PY 2010 Clients in Single Family Homes Housing Unit Characteristics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Housing Unit						
Median Heated Space	1,281	1,364	1,320	1,247	1,200	1,212
Mean Heated Space	1,400	1,472	1,437	1,386	1,299	1,271
% One Story	63%	48%	46%	80%	94%	88%
% Detached	83%	88%	77%	88%	83%	78%
Foundation Type						
% with Basement	51%	76%	78%	29%	4%	3%
% with Crawl Space	42%	41%	29%	65%	50%	20%
Housing Vintage						
% pre 1940	26%	36%	35%	17%	6%	2%
% 1940-1969	40%	35%	42%	43%	38%	29%
% 1970 or later	34%	29%	23%	40%	56%	69%
PreWX Status						
Mean CFM 50	3,133	2,789	3,227	3,489	3,429	1,948

Some important housing unit characteristics vary by Climate Zone, including:

- Stories – In the Very Cold and Cold Climate Zones, about half of the housing units are one story, while in the Moderate, Hot/Humid, and Hot/Dry Climate Zones, most of the homes are one story.

- Foundation Type – In the Very Cold and Cold Climate Zones most homes have a basement, while in the Moderate and Hot/Humid Climate Zones the majority of homes have a crawl space. In the Hot/Dry regions, most homes are built on a concrete slab and do not have either a basement or crawl space.

- Housing Unit Age – The majority of housing units in the Very Cold and Cold Climate Zones were built prior to 1970 (71% and 77% respectively), while the majority of housing units in the Hot/Humid and Hot/Dry Climate Zones were built in 1970 or later (56% and 69% respectively).

- Air Leakage – Homes in the Hot/Dry Climate Zone had the lowest air leakage rates while homes in the Moderate and Hot/Humid Climate Zones had the highest air leakage rates.

Table 3.11 shows the distribution of homes with respect to pre-weatherization air leakage rates. In most Climate Zones more than 50 percent of the homes had significant potential for reduction of air leakage (i.e., air leakage rates higher than 2,000 CFM50). Even in the Hot/Dry Climate Zone, at least 25 percent of the homes needed reduction in air leakage rates.

Table 3.11 PY 2010 Clients in Single Family Homes Distribution of PreWX Status by Climate Zone

	Percent of Population				
Variable	**10%**	**25%**	**Median**	**75%**	**90%**
CFM 50					
Very Cold Zone	1,296	1,730	2,489	3,510	4,634
Cold Zone	1,564	2,123	3,000	3,950	4,984
Moderate Zone	1,619	2,250	3,113	4,372	5,545
Hot/Humid Zone	1,534	2,148	3,140	4,183	5,720
Hot/Dry Zone	934	1,257	1,681	2,412	3,375
ALL ZONES	1,408	1,940	2,844	3,919	5,070

Table 3.12 furnishes national and climate zone statistics on the heating and cooling systems for PY 2010 clients in single family homes. The overall findings are that WAP clients are most likely to have a gas-fired central heating system, air conditioning, and a gas water heater. The detailed Climate Zone statistics show that the energy use patterns for households served by the WAP program vary across the country. Important findings include:

- Heating Fuel – Natural gas is the most common heating fuel for WAP homes, nationally and in all regions except for the Hot/Humid Climate Zone. Electric heat is most often used in the Moderate and Hot/Humid Climate Zones. About 30 percent of homes in the Very Cold Climate Zone and about 20 percent of the homes in the Cold Climate Zone use delivered fuels (i.e., fuel oil, propane, or wood)

- Main Heating Equipment – Over 90 percent of the households served in the Very Cold and Cold Climate Zones had central heating systems, while that rate was closer to 75 percent in the Moderate and Hot Zones. About 25 percent of clients in these zones had room heating equipment.

- Air Conditioning – The share of clients with air conditioning is lowest in the Very Cold Climate Zone and highest in the Hot/Humid Climate Zone.

- Water Heat – More than one-half of clients used natural gas as their main water heating fuel in the Very Cold, Cold, and Hot/Dry Climate Zones. Electricity was the most common main water heating fuel in the Moderate and Hot/Humid Climate Zones.

Climate zone differences in the types of fuels and equipment used have an important impact on both service delivery procedures and the cost-effectiveness of weatherization measures.

Table 3.12 PY 2010 Clients in Single Family Homes Heating and Cooling System Characteristics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Heating Fuel						
% Natural Gas	62%	64%	73%	47%	43%	78%
% Electric	19%	5%	6%	37%	49%	11%
% Fuel Oil	9%	14%	16%	4%	<1%	1%
% Propane	8%	14%	3%	9%	8%	7%
% Other	2%	2%	1%	3%	<1%	3%
Heating System Type						
% Central Forced Air	69%	77%	72%	59%	67%	65%
% Boiler (hydronic/steam)	12%	15%	23%	3%	<1%	0%
% Wall/Room Heater	10%	4%	1%	14%	19%	27%
% Electric Baseboard	3%	3%	2%	6%	1%	<1%
% Heat Pump	5%	<1%	1%	16%	6%	7%
% Portable Space Heater	1%	<1%	<1%	2%	5%	1%
% Cooking Stove	0%	<1%	<1%	<1%	1%	0%
% No Heating Source	1%	1%	<1%	1%	3%	1%
Supplemental Heat						
% Electric	15%	10%	12%	20%	21%	12%
% Wood	5%	16%	3%	6%	2%	9%
Air Conditioning Type						
% Central AC	46%	15%	30%	59%	62%	52%
% Window/Wall	25%	26%	28%	28%	29%	9%
% Evaporative Cooler	5%	3%	4%	1%	3%	17%
% None	24%	55%	39%	12%	6%	22%
Water Heating Fuel						
% Natural Gas	57%	57%	68%	40%	40%	81%
% Electric	35%	31%	23%	56%	55%	13%
% Other	8%	12%	9%	5%	6%	5%

3.4 WAP INSTALLED MEASURES

Table 3.13 shows the diagnostic approach used by subgrantees to identify which measures should be installed in each home. At the national level, 42 percent of client homes were assessed using a priority list

and 58 percent were treated using an audit tool. In the Hot Climate Zones subgrantees were more likely to use a priority list, while in the Cold and Moderat Climate Zones, they were more likely to use a calculation procedure.

Table 3.13 PY 2010 Clients in Single Family Homes Diagnostics Approach by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Diagnostic Approach						
% Priority List	42%	28%	38%	34%	59%	88%
% Calculation Procedure	58%	72%	62%	66%	41%	12%
% Other	<1%	<1%	<1%	<1%	0%	0%

Table 3.14 shows the rate at which air sealing and shell measures were installed in PY 2010.

- Air Sealing – Subgrantees reported air sealing in almost 90 percent of homes. In 26 percent of homes an air leakage reduction of 1,000 or more CFM50 was verified by pre- and post-weatherization blower door tests. The highest reductions were in the Moderate and Hot/Humid zones. Very few homes in the Hot/Dry Climate Zone were documented to have high air leakage rate reductions.

- Attic Insulation – Attic insulation was reported for 60 percent of homes. In all Climate Zones except the Hot/Dry zone, insulation rates ranged from 62 to 67 percent. In the Hot/Dry Climate Zone, only 19 percent of homes were reported to have received attic insulation.

- Wall Insulation – About 23 percent of homes had wall insulation installed. The rate was over 30 percent in the Very Cold and Cold Climate Zones, but was less than 20 percent in the Moderate and Hot/Humid Climate Zones. Almost no wall insulation was reported by agencies in the Hot/Dry Climate Zone.

- Other Insulation – Insulation installed at the bottom of the thermal envelope was usually a function of the foundation type for the home.

- Mechanical Ventilation – Mechanical ventilation (e.g., a kitchen or bathroom exhaust fan) was installed in 19 percent of clients' homes. The highest rate was in the Hot/Humid Climate Zone (32%) and the lowest rate was in the Hot/Dry zone (5%).

Air sealing and attic insulation are common measures installed in homes. Wall insulation and other insulation types are less common, but higher installation rates are observed in the colder climate zones. Mechanical ventilation was most often installed in the Hot/Humid zone.

Table 3.14 PY 2010 Clients in Single Family Homes Air Sealing and Shell Measures by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Air Sealing						
<500*	31%	43%	27%	29%	28%	30%
500-<1,000*	18%	24%	19%	19%	16%	3%
1,000+*	26%	26%	25%	30%	33%	4%
No Data	25%	7%	29%	22%	24%	63%
Any Air Sealing	89%	76%	96%	88%	97%	70%
Attic Insulation						
% Installed	60%	67%	64%	62%	67%	19%
Wall Insulation						
% Installed	23%	32%	32%	14%	17%	<1%
Other Insulation						
% Floor	17%	10%	24%	27%	8%	2%
% Rim	19%	34%	31%	4%	1%	0%
% Foundation	10%	20%	13%	2%	1%	0%
% Any Installed	36%	49%	48%	32%	9%	2%
CFM50						
Mean Reduction	920	800	931	1,043	1,090	303
Ventilation						
% Installed	19%	19%	16%	17%	32%	5%

*Pre/Post CFM50 Reduction

Table 3.15 shows the rate at which heating and water heating equipment measures were installed in PY 2010. For each equipment type, the table shows whether or not the equipment was estimated to be a cost-effective energy conservation measure (i.e., had an estimate savings-to-investment ratio of 1.0 or more). In some cases, the program records did not indicate whether the equipment replacement was an energy conservation measure (ECM).

Table 3.15 PY 2010 Clients in Single Family Homes Heating and Water Heating Equipment Measures by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Heating Equipment Replacement						
Furnace (non-ECM)	7%	4%	11%	8%	6%	<1%
Furnace (ECM)	15%	18%	11%	19%	22%	3%
Furnace (unknown)	6%	11%	4%	3%	2%	15%
Any Furnace	28%	32%	26%	29%	30%	18%
Heating Ducts (% of systems with ducts)						
Duct sealing	39%	39%	39%	43%	33%	49%
Duct insulation	4%	3%	6%	3%	2%	1%
Water Heating Equipment						
Heater (non-ECM)	4%	5%	6%	4%	2%	2%
Heater (ECM)	5%	10%	3%	4%	7%	2%
Heater (unknown)	3%	5%	2%	2%	6%	5%
Any Water Heater	13%	20%	11%	10%	14%	9%

The key findings from Table 3.15 include:

- Heating Equipment – Heating equipment replacement was reported for about 28 percent of client homes, with more than one-half listed as an energy conservation measure (ECM). Equipment replacement rates were close to 30 percent in most Climate Zones. Only 18 percent of heating equipment was replaced in the Hot/Dry Climate Zone.

- Ducts – Duct sealing was reported in 39 percent of homes. Duct sealing rates were somewhat lower in the Hot/Humid Climate Zone (33%) and somewhat higher in the Hot/Dry Climate Zone (49%).

- Water Heating Equipment – A small share of homes had water heater equipment measures; nationally about 13 percent of equipment was replaced.

Equipment measures are less common than air sealing and insulation. Subgrantees reported relatively few replacements of heating systems and water heaters where the replacement was judged to be a cost-effective energy efficiency measure, 15 percent and 5 percent respectively. However, overall equipment replacement rates were 28 percent for furnaces and 13 percent for water heaters because equipment also was replaced for health and safety reasons.

Table 3.16 shows the rate at which other measures were installed in PY 2010. Findings include:

- Windows - Less than 20 percent of homes had window replacements; the highest replacement rate was in the Cold Climate Zone (22%) and the lowest was in the Very Cold Climate Zone (11%). Very few homes (3%) received storm windows.

- Air Conditioning Equipment – Nationally, about 8 percent of homes had their air conditioning equipment replaced and most of those were considered to be ECM measures. The replacement rate was highest in the Hot/Humid Climate Zone (23%) and lowest in the Very Cold Climate Zones (1%).

- Other Equipment – About two-thirds of homes (68%) received energy efficient lighting and about 20 percent of home received replacement refrigerators.

Since many WAP clients received air conditioning equipment, energy efficient lighting, and refrigerators, it is expect that homes will have electric savings even if they do have electric heat.

Table 3.16 PY 2010 Clients in Single Family Homes Other Measures by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Windows						
Window (non-ECM)	2%	2%	6%	<1%	<1%	<1%
Window (ECM)	9%	8%	6%	15%	16%	3%
Window (unknown)	6%	1%	10%	4%	1%	15%
Window (any reason)	18%	11%	22%	19%	17%	18%
Storm Window	3%	4%	3%	6%	2%	1%
Air Conditioner						
AC Unit (non-ECM)	<1%	1%	<1%	1%	<1%	<1%
AC Unit (ECM)	5%	1%	<1%	9%	17%	2%
AC Unit (unknown)	2%	<1%	<1%	3%	6%	7%
Any AC Unit	8%	1%	1%	13%	23%	9%
Other Equipment						
Programmable T-stat	16%	21%	14%	10%	20%	12%
Lighting	68%	68%	64%	56%	78%	87%
Refrigerator	20%	27%	18%	16%	24%	14%

Statistical analysis of energy savings shows that four measures – furnace replacement, attic insulation, wall insulation, and major air sealing (i.e., more than 1,000 CFM50 air leakage reduction) – are responsible for a large share of the total energy savings for single family homes. However, WAP measure selection procedures allow installation of a measure only when the measure is estimated to have an SIR of greater than 1.0 for the home being served. Table 3.17 shows the distribution of homes by the number of

major measures by climate zone. On average, 1.5 major measures were installed per home. The installation rate was much lower for the Hot/Dry Climate Zone than for the other zones.

Table 3.17 PY 2010 Clients in Single Family Homes Percent of Homes by Number of Major Measures and Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Major Measures						
No Major Measures	17%	14%	15%	17%	15%	61%
One Major Measure	34%	34%	32%	38%	35%	28%
Two Major Measures	31%	31%	32%	31%	32%	9%
Three Major Measures	14%	16%	16%	11%	13%	2%
Four Major Measures	4%	5%	5%	2%	4%	0%
All Jobs	100%	100%	100%	100%	100%	100%
Mean # of Measures	1.5	1.6	1.6	1.4	1.5	0.5

3.5 WEATHERIZATION JOB COSTS

Subgrantees have developed systems to track the costs of each weatherization job. These systems allow subgrantees to track the average cost per job and the share of funding that is allocated to health and safety measures. In addition, many grantees and subgrantees leverage DOE funding with other funding sources, including LIHEAP funds, other Federal funds, and utility system benefit charge funds. Subgrantees that have leveraged funding have cost tracking systems that allocate job costs among different funding sources.

Table 3.18 shows the mean and median total job cost for PY10 by climate zone. These are the costs allocated to individual jobs. These statistics do not include program administration or training costs. They also exclude program operations costs incurred at the agency for functions like intake and job scheduling. The mean cost per job is $4,537. Average costs in the Very Cold and Hot/Humid Climate Zones are about 20 percent above the national average. Average costs in the Hot/Dry Climate Zone are about one-half the national average. As has been discussed throughout this section of the report, the pre-weatherization conditions vary significantly by Climate Zone. That is likely to account for many of the differences in spending levels observed in these data.

Table 3.18 PY 2010 Clients in Single Family Homes Mean and Median Cost Per Job by Climate Zone

Climate Zone	Mean Job Cost	Median Job Cost
Very Cold Climate	$5,543	$5,074
Cold Climate	$4,242	$4,214
Moderate Climate	$4,308	$3,936
Hot/Humid Climate	$5,421	$5,104
Hot/Dry Climate	$2,482	$1,376
TOTAL	$4,537	$4,312

Table 3.19 shows the distribution of total job cost for PY10 by Climate Zone. The table shows that there is substantial variation in the cost of each job. As discussed throughout this section, there are differences both in the average home conditions across Climates Zones and in the average home conditions within Climate Zones. The program does not treat every home in the same way. Subgrantees carefully examine the pre-weatherization conditions of each home and select the set of measures that are estimated to furnish cost-effective energy savings, and to address any outstanding health and safety issues in the home. The variability in jobs costs across climate zones and within climate zones is the expected outcome of that process.

Table 3.19 PY 2010 Clients in Single Family Homes Distribution of Job Cost by Climate Zone

	Percent of Population				
Variable	**10%**	**25%**	**Median**	**75%**	**90%**
Job Cost					
Very Cold Zone	$1,826	$3,112	$5,074	$7,334	$9,907
Cold Zone	$1,221	$2,352	$4,214	$5,241	$7,334
Moderate Zone	$1,098	$2,115	$3,936	$5,965	$7,638
Hot/Humid Zone	$2,249	$3,518	$5,104	$6,757	$9,188
Hot/Dry Zone	$276	$519	$1,376	$3,587	$6,777
ALL ZONES	$1,081	$2,321	$4,312	$6,039	$8,336

One important factor in job cost is the number of measures installed in each home. Table 3.20 shows the average job cost by the number of major measures installed. The average job cost for those homes that did not get any of the listed major measures was $2,415. Those homes were likely to get air sealing measures, but did not achieve a CFM50 reduction of 1,000 or higher. They also were likely to have received one or more of the other measures listed in Tables 3.14, 3.15, and 3.16. As the number of major measures increased, the average job cost increased.

Table 3.20 PY 2010 Clients in Single Family Homes Mean Job Costs by Number of Major Measures and Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Job Cost						
No Major Measures	$2,415	$3,141	$2,246	$2,266	$3,063	$1,372
One Major Measure	$4,000	$4,550	$3,643	$3,633	$4,423	$3,624
Two Major Measures	$5,309	$6,083	$4,510	$5,163	$5,878	$7,142
Three Major Measures	$6,713	$8,016	$5,669	$6,371	$7,268	$9,584
Four Major Measures	$8,534	$9,914	$7,119	$9,049	$9,328	N/A
All Jobs*	$4,679	$5,626	$4,206	$4,303	$5,247	$2,682

*Mean costs in Table 3.20 are different from those in Table 3.18 because jobs with missing measure data are excluded.

Table 3.20 shows that, nationally, each additional measure added about $1,500 (on average) to the cost of the weatherization job. However, the incremental cost varied by measure type and Climate Zone. Table 3.21 shows the average cost per job for homes that got one major measure. At the national level, the average cost for jobs with a furnace replacement was about $3,100 more than the average for jobs with no major measures. The average cost for jobs with attic insulation was only about $1,100 more than the average cost for jobs with no major measures.

Table 3.21 PY 2010 Clients in Single Family Homes Mean Job Costs by Major Measure and Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Job Cost						
No Major Measures	$2,415	$3,141	$2,246	$2,266	$3,063	$1,372
CFM50 Only	$4,088	$4,537	$3,897	$3,544	$4,801	$2,824
Attic Insulation Only	$3,578	$4,099	$3,240	$3,188	$4,072	$2,715
Wall Insulation Only	$3,928	$4,058	$3,590	$3,530	$6,000	N/A
Furnace Only	$5,531	$6,578	$4,943	$5,470	$5,183	$5,564
One Major Measure	$4,000	$4,550	$3,643	$3,633	$4,423	$3,624

The WAP program installs energy saving measures and addresses health and safety problems that are identified in the home. Table 3.22 shows the share of job costs allocated between ECM and nonECM (i.e., health and safety) costs. On average, 15 percent of job costs were spent on nonECM measures. Jobs in the Hot/Dry Climate Zone had the highest nonECM share of spending (23%). Jobs in the other Climate Zones all nonECM costs that averaged about 14 to 15 percent of total job costs.

Table 3.22 PY 2010 Clients in Single Family Homes ECM and non ECM Costs by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Costs per Job						
Mean ECM Costs	$4,004	$4,790	$3,582	$3,677	$4,696	$2,052
Mean NonECM Costs	$686	$759	$636	$656	$746	$615
Mean nonECM %	15%	14%	15%	15%	14%	23%
Mean TOTAL Costs*	$4,690	$5,549	$4,218	$4,333	$5,442	$2,667

*Mean costs in Table 3.22 are different from those in Table 3.18 because jobs with missing ECM data are excluded.

Many grantees make other funds available for weatherization (e.g., LIHEAP, SBC funds, and other Federal program funds) that are used to pay for some measures in DOE funded weatherization jobs. In addition, sometimes WAP subgrantees receive direct grants (i.e., not through the WAP grantee) for leveraged funds that also are used to pay for some measures in DOE funded weatherization jobs. Table 3.23 shows the share of the costs for DOE jobs that were allocated to nonDOE funds. On average, nonDOE funds covered about 13 percent of job costs. The Very Cold Climate Zone and the Hot/Dry Climate Zone had the highest level of nonDOE funding relative to total funding.

Table 3.23 PY 2010 Clients in Single Family Homes DOE and non DOE Costs for DOE Jobs by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Costs per Job						
Mean DOE Costs	$3,965	$4,519	$3,815	$3,855	$4,806	$2,092
Mean NonDOE Costs	$574	$998	$432	$453	$633	$389
Mean nonDOE %	13%	$18%	10%	11%	12%	16%
Mean TOTAL Costs*	$4,539	$5,517	$4,247	$4,308	$5,439	$2,481

*Mean costs in Table 3.23 are different from those in Table 3.18 because jobs with missing DOE data are excluded.

Sections 4 and 5 of this report have statistics that show the relationship between spending and energy savings. Section 7 of this report has statistics that show the relationship between spending and program cost-effectiveness.

4. ENERGY IMPACTS FOR HOMES WITH GAS MAIN HEAT

The WAP evaluation directly measured gas and electric usage for treated homes that use natural gas as their main heating fuel. This section presents the findings with respect to overall energy impacts as well as breaking out savings by:

- End Use – The share of savings attributable to changes in heating, cooling, and baseload usage levels.
- Installed Measures – Differences in savings for groups of homes that received different major measures and common combinations of measures.
- Pre-Weatherization Usage Level – Variation in the amount of savings and the percent savings for groups of households characterized by pre-weatherization usage levels.
- Climate Zone – Comparison of average savings across the different Climate Zones.
- Expenditures and Leveraging – Variation in savings by levels of spending on efficiency measures, total job costs, job funding sources, and agency funding sources.

These analyses help to show how program services and impacts vary by population subgroup. A further statistical analysis of explanatory factors related to observed energy savings were performed to estimate the energy savings attributable to individual program measures. The model developed by this analysis was used to extrapolate the savings from the gas analysis sample to the full population of gas heated homes served by the program, as well as the delivered fuel homes served by the program.

4.1 METHODOLOGY

The gas and electric savings were analyzed using multiple approaches. The primary analysis approach was a standard pre/post treatment/comparison design using weather-normalized utility billing data. The weather-normalization approach employed was similar to PRISM[10] and produces estimates of weather-adjusted annual energy consumption for each home based on monthly usage data and daily outdoor temperatures using a variable degree day base regression analysis. The Energy Impact Methodology Report contains details about the data cleaning procedures, as well as the procedures for assigning weather stations to homes and performing the weather-normalization.

Gross energy savings for each home were calculated as the difference in the normalized annual consumption between the pre-treatment and post-treatment periods. A Comparison Group of untreated homes was also analyzed to reflect changes in usage which may have occurred without the program. The Comparison Group was created using later participants – homes treated in PY 2011 were used as a Comparison Group for the PY 2010 analysis. Comparison Group usage was analyzed by subtracting one year from the actual treatment date to create pseudo pre-treatment and post-treatment periods after removing all actual post-treatment usage data. Net program savings were then calculated as the average gross savings for participants minus the average savings (i.e., change in usage) found for the Comparison Group.

The results of the weather-normalization analysis were also summarized in a variety of ways to address research questions and were further explored using statistical models to estimate savings by measure and the relationship between observed savings and other factors.

[10] See "PRISM: An Introduction," Margaret Fels, Energy and Buildings 9, #1-2, pp. 5-18 (1986).

4.1.1 Alternate Analysis Approaches

In addition to the pre/post treatment/comparison approach just described, the usage data were also analyzed using two alternative approaches as both a cross-check of the primary results and to assess whether further insights could be gained:

1. The first alternative approach was to employ a pooled fixed effects regression analysis[11] to estimate net savings. As the name implies, this approach involves pooling all of the monthly billing data together across all homes into a single statistical model to explain monthly variations in energy use as a function of weather (degree day variables) and program interventions. The analysis included several alternative modeling specifications.

2. The second approach employed a variation on the pooled model that aggregates the energy use and weather data for each home and then statistically analyzes this aggregate data set to estimate program impacts. This method was developed at ORNL and is referred to as the ORNL aggregate model.

The potential advantage of both of these modeling approaches is that the data from homes that have too little usage data to develop good savings estimates using the primary normalization approach can still be included as part of these pooled models. One of the prime motivating factors behind the development of the ORNL aggregate model was due to high sample attrition rates that sometimes occur using the standard house-level approach.

4.1.2 Sample Attrition

A total of 16,984 single family site-built gas heated homes were sampled for analysis. Table 4.1 summarizes the disposition of this sample for the gas and electric use analysis. The utility data collection process was successful in obtaining gas and electric data for 58% of the sampled homes. One significant challenge in collecting data was that subgrantees did not collect utility company names for about 12 percent of gas accounts and about 15 percent of electric accounts. The usage data provided were not sufficient for developing savings estimates for 14 percent of the analysis homes for both gas and electricity. Most of this attrition was due to too little pre-retrofit data – the analysis required a minimum of 183 days of gas data and 270 days of electric data (in addition to some requirements about weather). The weather-normalization itself indicated a poor model fit in either the pre or post periods for 2 percent of the gas sampled cases and less than 1 percent of electric cases (baseload only models were included). Many of these cases had less than a full year of data in either the pre or post periods. An additional 4 percent of sampled cases in the gas analysis had gas usage too low to be considered gas heated and occupied during both periods (and three cases had usage too high to be considered single family). Less than 1 percent of electric cases were classified as having usage either too low to be occupied or too high to be single family. Less than 1 percent of the sampled homes were removed from the analysis because they were declared savings outliers[12].

[11] This approach goes by multiple names in the energy program evaluation literature including times-series cross sectional regression modeling, Analysis of Covariance (ANACOVA), fixed effects modeling, and sometimes, more broadly, just econometric modeling.

[12] Outliers were defined as having percent savings more than 2.5 inter-quartile ranges from the median percent savings for the analysis group (participant or comparison).

Table 4.1 PY 2010 WAP Single Family Site-Built Homes Gas and Electric Usage Sample Attrition - Gas Main Heat

	Gas Analysis		Electric Analysis	
Sample Group / Attrition Cause	**Homes**	**% of Sample**	**Homes**	**% of Sample**
Sampled	16,985	100%	16,985	100%
Utility Company Unknown	2,005	12%	2,618	15%
No Usage Data Available	5,000	29%	4,435	26%
Insufficient Data	2,409	14%	2,322	14%
Poor Model Fit	275	2%	89	<1%
Usage Outlier: Vacant, Unheated, Not SF	625	4%	91	<1%
Savings Outlier	78	<1%	158	<1%
Total Usable Cases	6,592	39%	7,273	43%

The same screening criteria were applied to the Comparison Group analysis, and the attrition rates were generally similar with the exception that the Comparison Group has more cases with insufficient data and more outliers (still just 1.5%). The higher outlier rate in the Comparison Group was expected since outliers were defined using information on the distribution of savings within each group and the variation in "savings" was smaller for the Comparison Group.

4.2 KEY PROGRAM FACTORS FOR HOMES WITH GAS MAIN HEAT

Table 4.2 summarizes information about climate, demographics, housing stock, and major measures for the full single family site-built sample compared to homes with gas heat. The last two columns summarize these same characteristics for the gas and electric usage analysis samples. The table shows that gas heated homes were more likely to be located in the Cold Climate Zone and less likely to be in the Moderate or Hot/Humid zones than other homes, but are generally similar in terms of demographics, housing characteristics, and program measures. Gas heated homes are a little more likely to have central heat and are also more likely than other homes to have their heating system replaced and walls insulated.

Because of the attrition, the gas usage analysis sample has more homes in the Cold and Very Cold Climate Zones, more homeowners, higher household incomes, slightly larger homes, and homes that received slightly more insulation than the full population. The electric analysis sample is similar to the gas sample, although better represents the Moderate and Hot/Dry climates. The impacts of these differences between the analysis sample and population are addressed in developing program population impact estimates in Section 4.10.

Table 4.2 Characteristics of Single Family Site-Built Homes PY 2010

Characteristic	All Homes	Gas heated Homes		
		All Gas heated	Gas Analysis Sample	Electric Analysis Sample
Climate				
Very Cold	19%	20%	34%	28%
Cold	36%	43%	46%	50%
Moderate	19%	14%	10%	11%
Hot/Humid	17%	12%	7%	6%
Hot/Dry	9%	12%	4%	5%
Demographics				
Median Income	$15,600	$15,975	$16,952	$16,997
Percent of Poverty	107%	107%	114%	113%
Homeowner	81%	78%	87%	86%
Elderly	41%	37%	40%	39%
# Occupants	2.5	2.6	2.5	2.6
Housing Characteristics				
Heated Area	1,388	1,396	1,451	1,448
Median Age	57	57	57	57
HDD65	4,793	5,000	5,675	5,584
CDD65	1,274	1,195	996	1,011
Central Heating	89%	90%	95%	94%
Central A/C	40%	38%	37%	35%
Major Measures				
Heater Replacement	28%	31%	33%	35%
Attic Insulation	63%	63%	69%	70%
Wall Insulation	25%	27%	31%	30%
Air Sealing >1000 CFM50	36%	35%	39%	37%
Refrigerator Replaced	20%	20%	21%	21%

Note: Results weighted by sample design selection probabilities.

4.3 ENERGY SAVINGS OVERALL AND BY END USE

Table 4.3 summarizes natural gas impacts and shows a breakout of savings by weather-normalization component – heating[13] vs. baseload (nonheating) gas consumption. The overall gas savings are estimated at 147 therms per year, equal to 15.5 percent of pre-program gas usage. Space heating accounted for 78 percent of the gas usage and achieved 86 percent of the total gas savings. The heating savings averaged 17.1 percent of pre-program heating use. There was also a 9.6 percent reduction in the baseload portion of gas usage (e.g., water heating and cooking).

[13] The space heating portion of the load actually includes some of the water heating load (and any other seasonal end uses) as gas water heating usage increases in the winter due to lower incoming cold water temperatures and other factors. See "*Seasonality of Nonheating Consumption and Its Effect on PRISM Results", Fels, M.F., J. Rachlin, and R.H. Socolow, Energy and Buildings, V:1-2, pp.139-148, 1986*" for an in-depth discussion of these findings.

Table 4.3 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Gas Savings Total and by End Use (therms/year)

Group/Breakout	# Homes	Gas Use Pre-WAP	Gas Use Post-WAP	Gross Savings	Net Savings	% of Pre
Total Use	6,592	947	792	155 (±9)	147 (±9)	15.5% (±.9%)
Comparison	2,647	930	921	8 (±3)		
Heating Use	6,592	737	612	126 (±8)	126 (±9)	17.1% (±1.2%)
Comparison	2,647	721	721	-1 (±4)		
Baseload Use	6,592	210	180	29 (±2)	20 (±3)	9.6% (±1.5%)
Comparison	2,647	209	200	9 (±3)		

The distribution of participants' pre-program total gas use is shown in Figure 4.1. The median annual gas use for participants was 908 therms and one-half of all homes used between 673 and 1,201 therms. Ten percent of homes used less than 504 therms and ten percent used more than 1,563 therms. The Comparison Group distribution (not shown) was similar.

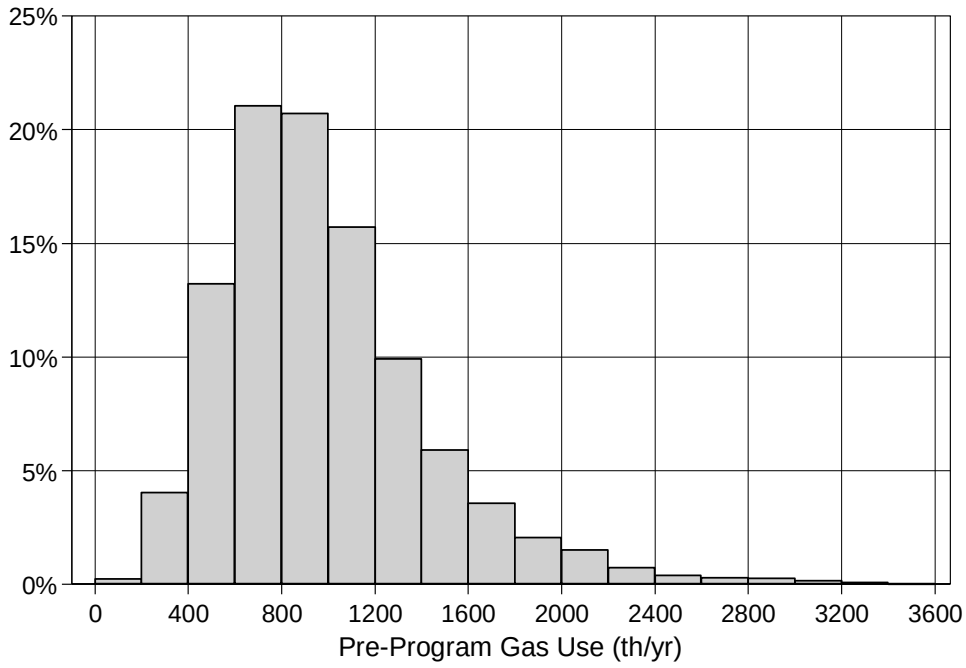
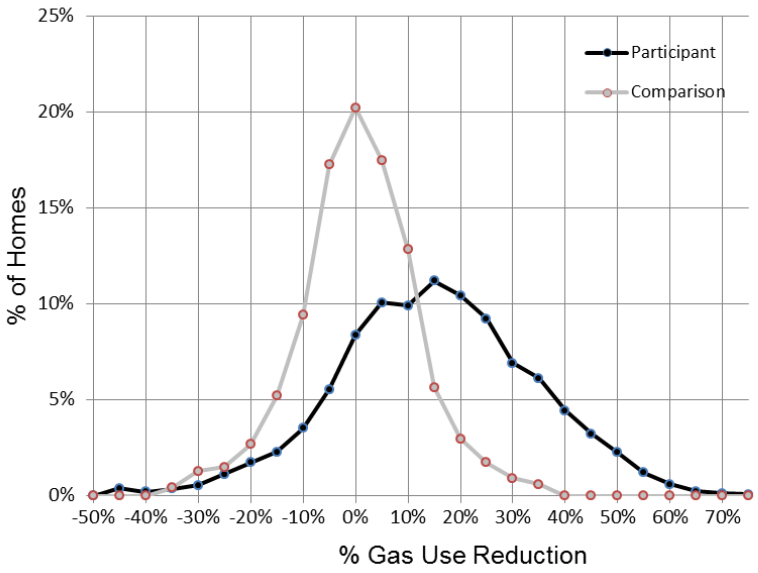


Figure 4.1: Distribution of Pre-Program Gas Use for Single Family Participants

The distribution of percent gas savings for participants and the Comparison Group are shown in Figure 4.2. The Comparison Group line graph shows the distribution of the year-over-year change in energy usage that was observed for households that did not receive weatherization services. The line graph for those households is centered on 0% and the peak shows that 20 percent of comparison households had a weather-normalized change in gas usage of +/-2.5%. The three peak points indicate that slightly more than half of comparison households had a change in gas use of +/-7.5%. Of the remaining Comparison Group homes, 20 percent had a usage increase of more than 7.5% and 25 percent had a usage decline of more than 7.5%. Some of the sources of these changes in gas use may include: increases or decreases in the number of household members (e.g., child is born or moves out; elderly parent moves in), changes in the number of people at home during the day (e.g., someone gets a job; someone loses a job), or changes in the way the home is used (e.g., a room is closed off to save money; the household starts using a porch as living space). These types of changes affect households at all income levels and in all areas. Table 4.3 showed that these changes tended to "even out" across homes, averaging less than a 1 percent change in gas use for Comparison Group homes.

Figure 4.2: Distribution of Percent Gas Use Reduction – Participants and Comparison Group



The line graph for the Participant Group is different from the Comparison Group in two ways. First, the graph for the Participant Group is shifted to the right, reflecting the overall savings (median percent change in use was 15.1%). Second, the graph for the Participant Group is more spread out; only about 10 percent of participant households had a change in usage within +/-2.5% percent from the median change compared to about 20 percent for the Comparison Group households. Participant Group savings should be expected to vary more widely than the Comparison Group due to differences in expected treatment impacts across homes – some homes received relatively few major measures while others received many measures depending on existing conditions.

These graphs taken together demonstrate the impact of the WAP program on treated homes.

- Weather-normalized usage for Participant Group households fell by 16.4 percent and by 0.9 percent for Comparison Group households; the net impact of weatherization was to shift the gas savings graph to the right by about 15.5 percent.

- Treated homes received different sets of measures. (See Tables 3.14 through 3.17). Homes with few measures are expected to have small energy savings while those homes that received a full set of measures are expected to have large energy savings, other things being equal. Since each Participant Group home is expected to have a different level of savings, the distribution for the change in energy use is more variable (spread out) for Participant Group homes than for Comparison Group homes.

A common question about savings is why some participants appear to increase their usage after weatherization; how can savings be negative? The distribution of the change in use for the Comparison Group may help explain this apparent anomaly. As shown in Figure 4.2 above, some Comparison Group homes increased usage by 20 percent or more due to nonprogram factors. So, if a home *would have had* an increase in usage of 20 percent without treatment, but had only a 5 percent increase in usage after treatment, the net program impact is 15 percent savings compared to what *would have occurred* without weatherization.

Table 4.4 summarizes electric impacts by end use among gas heated homes. The terms "Heating/Winter" and "Cooling/Summer" are used to describe the end uses rather than just heating and cooling because some electric end uses vary seasonally, and so a portion of their consumption is statistically allocated to the heating or cooling component. Almost three- quarters of the electric use and about one-half of electric savings are classified as baseload.

Table 4.4 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Natural Gas Main Heat by End Use (kWh/year)

Usage Component	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
Total Use	7,271	9,222	8,388	833 (±52)	716(±71)	7.8% (±0.8%)
Comparison	2,877	9,406	9,289	117 (±53)		
Heating/Winter Use	7,271	1,027	804	224 (±24)	224 (±40)	21.8% (3.9%)
Comparison	2,877	944	944	0 (±34)		
Cooling/Summer Use	7,271	1,507	1,278	228 (±25)	130 (±43)	8.6% (±2.9%)
Comparison	2,877	1,669	1,570	99 (±35)		
Baseload Use	7,271	6,688	6,307	381 (±43)	362 (±72)	5.4% (±1.1%)
Comparison	2,877	6,793	6,774	19 (±69)		

The heating/winter electric use averaged about 1,000 kWh annually in these gas heated homes. Much of this usage could be accounted for by a gas furnace fan and seasonality in other loads such as lighting. It should be noted that about 15 percent of these gas heated homes had estimated electric heating usage large enough to indicate likely use of at least some electric heat. The estimated annual heating component was between 2,000 and 4,000 kWh in 10 percent of the homes and exceeded 4,000 kWh in 5 percent of the homes. Net electric heating component savings in these homes averaged 9 percent (245 kWh) for homes with estimated heating use between 2,000 and 4,000 kWh and 23 percent (1,540 kWh) for homes

with heating use greater than 4,000 kWh. The net heating component savings for homes using less than 2,000 kWh were not statistically significant.

The mean annual cooling/summer use was 1,507 kWh. In part, this is associated with use of air conditioning in gas heated WAP homes, but it also relates to seasonality in energy use for refrigerators, fans, and other seasonal loads. The mean annual cooling/summer load in homes that reported central air conditioning was more than two times the load for homes that did not reporting having central air conditioning – 2,603 kWh vs. 1,212 kWh. (Note: the presence or absence of central air conditioning was only reported in 28 percent of homes.) Homes reported to have central air conditioning had average cooling savings of 420 kWh (±77 kWh), equal to 16.1 percent of pre-program cooling use. Homes without central air conditioning averaged a statistically insignificant 46 kWh (±61 kWh), equal to 3.8 percent of pre-program cooling use.

The distribution of participants' pre-program total electric use is shown in Figure 4.3. The median annual electric use for participants was 8,230 kWh with one-half of all homes using between 5,634 and 11,683 kWh. Ten percent of homes used less than 4,035 kWh and ten percent used more than 15,899 kWh. The Comparison Group distribution was very similar.

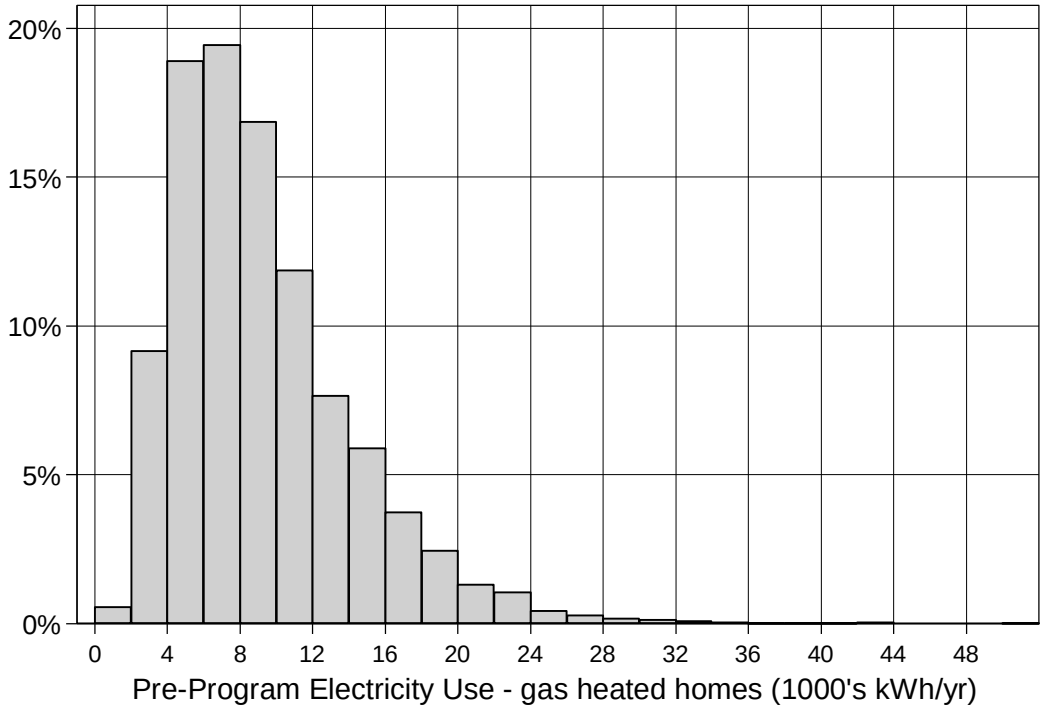


Figure 4.3: Distribution of Pre-Program Electric Use for Gas heated Single Family Participants

The distribution of percent electric savings for gas heated participants and comparison households are shown together in Figure 4.4. The Comparison Group line graph shows the distribution of the year-over-year change in electric usage that was observed for households that did not receive weatherization services. The line for those households is centered on 0% and shows that about 13 percent of households had a weather-normalized change in electric usage +/-2.5% For about 20 percent of the households, the change was either less than -22.5% or greater than +22.5%. Such changes in electric use may be due to: changes in appliances or plug loads present, changes in occupancy or occupancy patterns, or other changes in the way the home is used. Changes such as these occur in all types of households at all income levels. Table 4.4 shows that, with all of those potential changes, the average weather-normalized usage for Comparison Group households declined by about 117 kWh per year (1.2%).

The line graph for the Participant Group is different from the line graph for the Comparison Group in two ways. First, the graph for the Participant Group is shifted to the right with its median value at 7.5%, showing that the Participant Group households reduced their energy consumption by more than the Comparison Group households. Second, the Participant Group savings vary somewhat more – similar to what was found for the gas usage analysis.

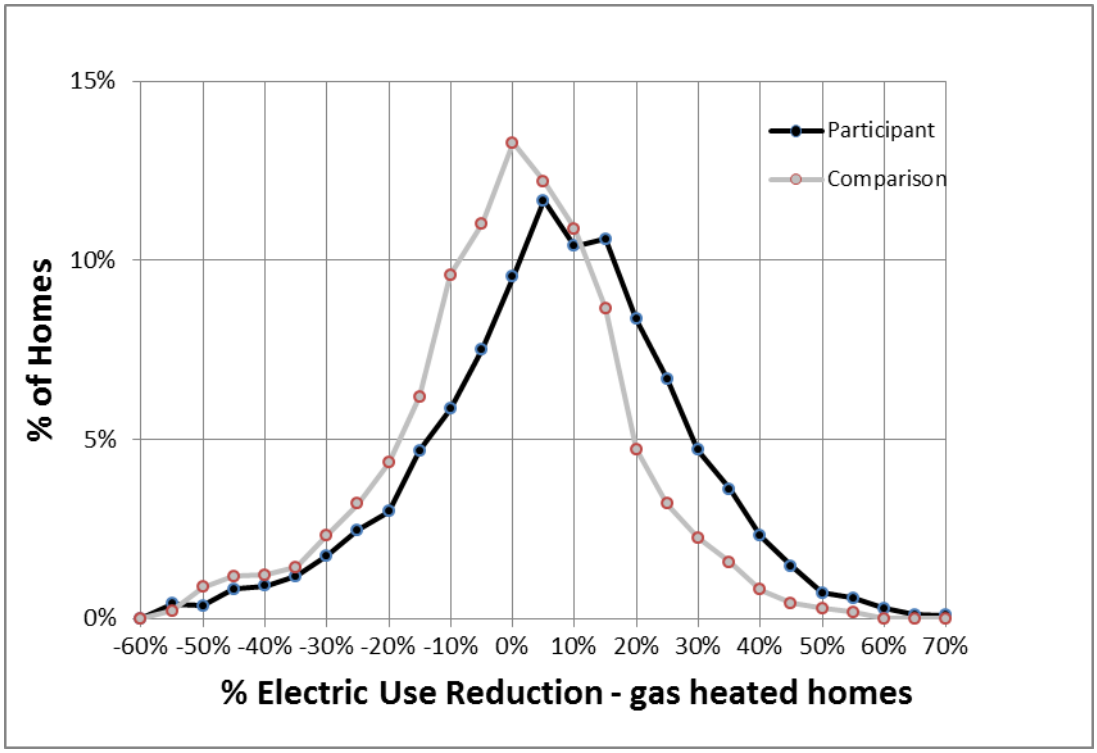


Figure 4.4: Distribution of Percent Electric Use Reduction – Gas heated Participants and Comparison Group

These graphs demonstrate the impact of the WAP on electric usage in treated homes.

- Weather-normalized electric usage for Participant Group households fell by 9.0 percent and by 1.2 percent for Comparison Group households; the net impact of weatherization was to shift the electric savings graph to the right by about 7.8 percent.

- Treated homes received different sets of measures and had different opportunities for savings (See Tables 3.14 through 3.17), leading to a wider distribution for the change in electric use for the Treatment Group homes than for Comparison Group homes.

Just as in the gas usage analysis, some households appear to use more electricity after weatherization. As with the change in gas usage, an apparent increase in electric usage for a home does not imply that the program caused the usage to increase but may often be the result of a home where consumption would have increased without the program.

4.4 PARTICIPANT AND TREATMENT CHARACTERISTICS BY LEVEL OF NATURAL GAS SAVINGS

Table 4.5 summarizes the same participant and treatment characteristics that were shown in Table 4.2 but broken out on the level of gross gas savings. Three categories were created:

- Low Savers = Participants who had savings less than the 25th percentile of savings (<24 therms)
- High Savers = Participants who had savings more than the 75th percentile of savings (>268 therms), and
- Mid-savers = Participants who had savings between these limits.

The table shows that largest differences between high- and low-saving homes were in the measure installation rates - high savers were much more likely than low savers to receive a heating system replacement, wall insulation, large air leakage reductions, and attic insulation. The installation rate differences are largest for wall insulation and heating system replacement. High savers were also more likely to live in an older house in the Cold Climate Zone. Low savers were more likely to live in the Hot Climate Zones. Demographics were essentially identical across the savings categories.

Table 4.5 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Characteristics of Natural Gas Main Heat Homes with Low, Medium and High Gas Savings

Characteristic	Low Saver	Mid-Saver	High Saver
Climate			
Very Cold	33%	35%	32%
Cold	39%	43%	58%
Moderate	11%	11%	8%
Hot/Humid	8%	8%	2%
Hot/Dry	9%	3%	0%
Demographics			
Median Income	$16,596	$17,129	$17,139
Homeowner	86%	87%	86%
Elderly	40%	40%	40%
# Occupants	2.6	2.5	2.6
Housing Characteristics			
Heated Area	1,461	1,436	1,483
Median Age	57	57	67
HDD65	5,352	5,664	6,023
CDD65	1,123	1,008	843
Central Heating	92%	95%	98%
Central AC	37%	44%	28%
Major Measures			
Heater Replacement	20%	32%	50%
Attic Insulation	56%	71%	78%
Wall Insulation	17%	28%	50%
Air Sealing >1000 CFM50	32%	34%	55%
Refrigerator Replaced	22%	20%	21%

Note: Results weighted by sample design selection probabilities.

4.5 ENERGY SAVINGS BY INSTALLED MEASURES

WAP provides a customized set of measures for each home prescribed by an energy auditor who follows the local program design and measure selection approach based on cost-effectiveness and health and safety requirements. An explanatory-factors analysis, described in Section 4.10, identified four major measures that appeared to drive a significant fraction of the observed gas savings: heating system replacement, wall insulation, attic insulation, and major air sealing[14]. Table 4.6 summarizes the gas savings results with participants grouped by the major measures they received in fifteen combinations.

[14] Major air sealing was defined as a leakage reduction measured by blower door testing of at least 1,000 CFM50.

Table 4.6 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gas Savings for Homes with Natural Gas Main Heat By Measure Combination (therms/year)

Group/Breakout	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
No Major Measures	733	823	37 (±10)	4.5% (±1.2%)
One Major Measure				
Heater Replacement	314	952	140 (±20)	14.7% (±2.1%)
Attic Insulation	1,103	858	88 (±6)	10.2% (±.7%)
Wall Insulation	118	1,122	187 (±45)	16.7% (±4.0%)
Seal: >1000 CFM50	276	1,073	77 (±19)	7.2% (±1.8%)
Any One Major Measure	1,811	928	103 (±8)	11.1% (±.8%)
Two Major Measures				
Heater & Attic	651	919	177 (±11)	19.3% (±1.2%)
Heater & Wall	38	931	229 (±44)	24.6% (±4.7%)
Heater & Seal	121	1,120	208 (±36)	18.6% (±3.3%)
Attic & Wall	414	944	178 (±16)	18.8% (±1.7%)
Attic & Seal	579	1,098	133 (±17)	12.1% (±1.6%)
Wall & Seal	113	1,116	192 (±26)	17.2% (±2.3%)
Any Two Major Measures	1,916	1,005	168 (±9)	16.7% (±.9%)
Three Major Measures				
Heater & Attic & Seal	293	1,048	253 (±21)	24.1% (±2.0%)
Heater & Attic & Wall	239	960	249 (±18)	25.9% (±1.8%)
Heater & Wall & Seal	36	907	215 (±98)	23.7% (±10.8%)
Attic & Wall & Seal	463	1,154	266 (±18)	23.1% (±1.5%)
Any Three Major Measures	1,031	1,070	256 (±13)	24.0% (±1.2%)
All Four Major Measures	304	1,124	369 (±25)	32.8% (±2.2%)

There appears to be a strong relationship between the installation of major measures and the average savings achieved. Some key findings include:

- No Major Measures – The 13 percent of treated homes that received none of the major measures saved 37 therms (4.5%). These homes had the lowest average gas use and most likely presented fewer opportunities for major measures. These homes typically received some air sealing but not as extensive as in other homes. These homes also may have received other measures including: duct sealing, floor insulation, hot water measures, window and door work, refrigerator and lighting replacements, and other repairs and health and safety measures.

- One Major Measure – The 31 percent of homes that received only one major measure averaged 103 therms of savings (11.1%). Wall insulation and heating system replacements as single

measures provided savings closer to 15 percent while the attic insulation group saved 10.2 percent and the air sealing group saved 7.2 percent.

- Two Major Measures – The 33 percent of homes that received two major measures had higher pre-treatment gas use and higher savings than homes that received just one measure. The higher savings associated with wall insulation and heating system replacements was further in evidence – wall insulation and heating system replacement together had the highest savings of about 25 percent, while measure pairs that included just one of those measures achieved savings ranging from 17 percent to 19 percent and homes that received neither of those two measures averaged 12 percent savings.

- Three Major Measures – The 18 percent of homes that received three major measures had higher average gas use and savings than homes that received fewer measures with savings ranging from 23 percent to 26 percent across groups.

- Four Major Measures – The 5 percent of homes that received all four measures had the highest gas use and highest savings – averaging 33 percent savings.

The net savings and 90% confidence intervals are graphed in Figure 4.5 and grouped by number of major measures.

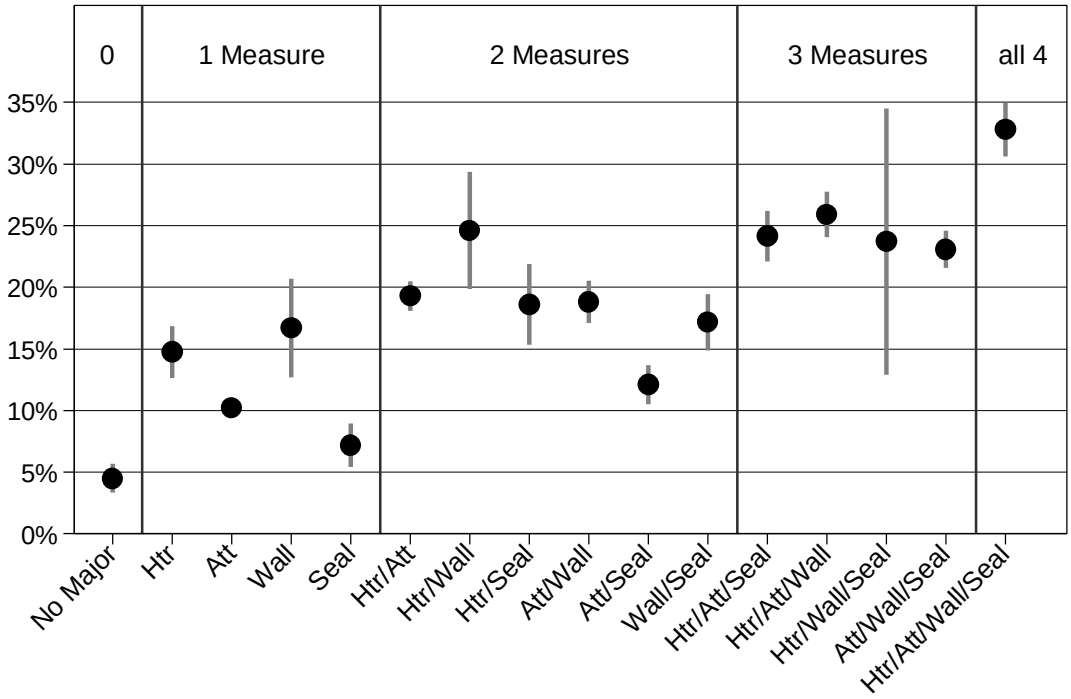


Figure 4.5: Percent Gas Savings by Measures Installed

Table 4.7 summarizes the electric savings associated with two key electric baseload measures – refrigerator replacements and lighting retrofits. The homes that received refrigerator replacements had much higher savings than did the other homes. Homes that are reported to have received lighting measures had only slightly higher savings – only 42 kWh/year. A closer examination of reported lighting

measure data indicated that several states with very low reported lighting installation rates also had large electric utilities that funded low-income programs. It is highly likely that many of these homes actually did receive lighting retrofits but under the auspices of a different program which was not reported to WAP. To the extent this practice was widespread the savings from lighting will be obscured.

Table 4.7 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Electric Savings for Homes with Natural Gas Main Heat By Measure Combination (kWh/year)

Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
No Lighting or Refrigerator*	1,775	9,125	572 (±102)	6.3% (±1.1%)
Lighting, but No Refrigerator	3,286	9,528	614 (±89)	6.4% (±0.9%)
Refrigerator (either Lighting)	1,257	8,813	1,188 (±85)	13.5% (±1.0%)

* Note: Many homes where no lighting retrofits were reported are believed to have received some lighting retrofits from utility funded programs.

4.6 ENERGY SAVINGS BY PRE-WEATHERIZATION USAGE LEVEL

Previous research has shown that homes with higher levels of pre-weatherization usage get higher energy savings. This relationship may be driven in part by greater opportunities to install major measures in homes with higher pre-participation energy use. Table 4.8 summarizes gas use and savings by level of pre-weatherization gas use. (Note: The Comparison Group was stratified into the same categories to provide an appropriate net savings adjustment.)

Table 4.8 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat by Pre-Weatherization Gas Usage (therms/year)

Pre-WAP Gas Use (therms/year)	# Major Measures	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	1.7	6,592	947	147 (±9)	15.5% (±.9%)
<750 therms/yr	1.4	2,181	557	64 (±6)	11.5% (±1.1%)
750 - <1000	1.7	1,723	873	126 (±7)	14.4% (±.8%)
1000 - <1250	1.9	1,227	1,111	199 (±14)	17.9% (±1.3%)
1250 - <1500	2.0	683	1,362	237 (±27)	17.4% (±2.1%)
>=1500 therms/yr	2.0	778	1,921	345 (±41)	17.9% (±2.1%)

Note: Comparison Group, not shown, also was stratified by usage.

Gas savings increase dramatically with pre-weatherization usage: therm savings are five times larger for the highest users than for the lowest users, and percent savings increase substantially over this range. The number of major measures installed per home does not increase as dramatically as do the savings with increasing pre-program gas use, implying that savings per measure increase as pre-program usage increases.

Table 4.9 shows electric savings by pre-weatherization electric usage level for homes with gas main heat. The relationship between pre-weatherization electric usage and savings is not quite as linear as it is for gas usage and gas savings, but high-use homes still achieve much larger savings than do low-use homes. High electric use can be the result of many end uses other than lighting or refrigeration, which drive much of the baseload savings. Refrigerator replacement rates were actually a little higher for low-use homes and lower for high-use homes. The higher savings among the highest usage bins include larger reductions in

the heating and cooling components of load. States also have a wider range of approaches to refrigerator replacement and lighting retrofit decisions, which can further obscure the relationship between usage and measure installation rates.

Table 4.9 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Electric Savings for Homes with Natural Gas Main Heat by Pre-Weatherization Electric Use (kWh/year)

Pre-WAP Usage	Refrigerator Replacement %	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
All Clients	20%	7,271	9,222	716 (±71)	7.8% (±0.8%)
<4,000 kWh/yr	24%	705	3,103	134 (±53)	4.3% (±1.7%)
4-<6,000	23%	1,375	5,032	341 (±74)	6.8% (±1.5%)
6-<8,000	21%	1,414	6,992	399 (±85)	5.7% (±1.2%)
8-<10,000	18%	1,226	8,988	503 (±137)	5.6% (±1.5%)
10-<12,000	19%	863	10,962	852 (±163)	7.8% (±1.5%)
12-<14,000	18%	556	12,949	1,003 (±230)	7.7% (±1.8%)
>=14,000 kWh/yr	17%	1,132	18,077	1,969 (±266)	10.9% (±1.5%)

Note: Comparison Group, not shown, was also stratified by usage.

4.7 CLIMATE ZONE ANALYSIS

The Climate Zones were defined to provide insight into how energy use and program savings vary due to climate. One might expect that gas usage and savings potential would be higher in the colder zones while electric usage and savings potential would be higher in warmer zones for homes with air conditioning. Table 4.10 summarizes gas impacts for homes with natural gas main heat by climate zone. The climate zones with the higher pre-weatherization gas usage have higher gas savings, but the highest gas use and savings are found in the Cold Climate Zone and not the Very Cold Climate Zone.

Table 4.10 also shows the average number of major measures installed in each home by Climate Zone. The Hot/Humid and Hot/Dry Climate Zones had similar pre-weatherization average usage. However, an average of 1.9 major measures were installed in each home in the Hot/Humid Climate Zone and only 0.8 major measures were installed in each home in the Hot/Dry Climate Zone. The energy savings were much higher in the Hot/Humid zone than in the Hot/Dry zone.

Table 4.10 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat by Climate Zone (therms/year)

Climate Zone	# Major Measures	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	1.7	6,592	947	147 (±9)	15.5% (±.9%)
Very Cold	1.8	2,149	1,040	157 (±13)	15.1% (±1.3%)
Cold	1.8	2,990	1,091	188 (±13)	17.2% (±1.2%)
Moderate	1.6	792	828	125 (±24)	15.1% (±2.9%)
Hot/Humid	1.9	368	558	81 (±23)	14.6% (±4.1%)
Hot/Dry	0.8	293	545	12 (±17)	2.1% (±3.2%)

Note – Comparison Group, not shown, was also stratified by Climate Zone.

The apparent anomaly of Cold Climate homes using more gas than Very Cold Climate homes may be explained by the relationship between the thermal efficiency of homes and climate. Homes have generally been better built (i.e., have more insulation and are tighter) in colder climates than moderate climates for reasons of both energy efficiency and basic comfort. (It is more common to find leaky and uninsulated homes in Pennsylvania than in Minnesota.)

Table 4.11 shows the homes in the Very Cold Climate Zone were tighter than homes in milder climate zones (with the exception of the Hot/Dry Climate Zone where slab on grade foundations and masonry/stucco walls lead to tight homes). The annual energy use expressed per square foot of floor area and per heating degree day (a.k.a., EUI or Energy Use Intensity) is a common metric for comparing the relative efficiency of homes across sizes and climates. The last column in the table shows that EUI was substantially lower in the Very Cold Climate Zone compared to the Cold and Moderate zones and EUI was much higher in the Hot/Humid and Hot/Dry zones than the other zones.

Table 4.11 PY 2010 WAP Single Family Site-Built Homes House Characteristics by Climate Zone - Gas Main Heat Analysis Sample

Climate	Air Leakage Pre-WAP CFM50	Heated Area	HDD65	Gas EUI Btu/ft²/HDD
All Clients	3,599	1,451	5,765	13.6
Very Cold	2,849	1,475	7,263	10.5
Cold	3,110	1,446	5,685	14.2
Moderate	3,746	1,526	4,225	14.2
Hot/Humid	4,176	1,344	1,864	24.3
Hot/Dry	2,313	1,374	2,071	18.7

Table 4.12 summarizes gas use and savings into finer categories by heating degree days. Pre-weatherization gas use and savings increased as the number of heating degree days increases up to the 6,000-<7,000 HDD65 range and then declined substantially in climates colder than 7,000 HDD65.

Table 4.12 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gas Savings for Natural Gas Main Heat by Heating Degree Days

Heating Degree Days	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	6,592	947	147 (±9)	15.5% (±0.9%)
<,3000 HDD65	697	565	56 (±16)	9.9% (±2.9%)
3,000-<4000	168	651	100 (±15)	15.3% (±2.2%)
4,000-<5000	905	985	140 (±20)	14.2% (±2.1%)
5,000-<6000	1,471	1,014	191 (±16)	18.9% (±1.5%)
6,000-<7000	1,952	1,140	186 (±17)	16.3% (±1.5%)
>=7,000 HDD65	1,399	1,017	150 (±10)	14.7% (±1.0%)

Note: Comparison Group, not shown, also was stratified by HDD65.

Table 4.13 shows the gross and net overall electric impacts for gas heated homes by Climate Zone. The highest electric use and savings appear to be in the Hot/Humid Climate Zone.

Table 4.13 PY 2010 WAP Energy Impacts for Single Family Site-Built HomesElectric Savings for Natural Gas Main Heat by Climate Zone (kWh/year)

Climate	Refrigerator Replacement %	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
All Clients	20%	7,271	9,222	716 (±71)	7.8% (±0.8%)
Very Cold	28%	1,878	8,594	560 (±102)	6.5% (±1.2%)
Cold	19%	3,518	8,673	632 (±104)	7.3% (±1.2%)
Moderate	13%	943	11,315	937 (±270)	8.3% (±2.4%)
Hot/Humid	18%	526	11,537	1302 (±270)	11.3% (±2.3%)
Hot/Dry	14%	406	8,440	686 (±217)	8.1% (±2.6%)

Note: Comparison Group, not shown, also was stratified by Climate Zone.

Table 4.14 summarizes the same information as Table 4.13 but only for the estimated summer/cooling component of electric use. The higher savings in the Hot/Humid Climate Zone are largely due to the estimated savings in the cooling/summer usage of 563 kWh, equal to 14.3 percent of the average 3,925 kWh pre-WAP cooling/summer usage. The cooling usage and savings in the other climate zones were much smaller. The Hot/Dry Climate Zone includes many homes in milder climates since zones were assigned by state and the mostly mild California was classified as Hot/Dry.

Table 4.14 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Electric Summer/Cooling Savings for Natural Gas Main Heat by Climate Zone (kWh/year)

Climate	# Homes	Summer/Cooling Electric Use Pre-WAP	Net Savings	% of Pre
All Clients	7,271	1,507	130 (±43)	8.6% (±2.9%)
Very Cold	1,878	719	13 (±47)	1.8% (±6.5%)
Cold	3,518	1,037	71 (±29)	6.8% (±2.8%)
Moderate	943	2,391	174 (±97)	7.3% (±4.0%)
Hot/Humid	526	3,925	563 (±294)	14.3% (±7.5%)
Hot/Dry	406	2,127	251 (±192)	11.8% (±9.0%)

Note: Comparison Group, not shown, also was stratified by Climate Zone.

4.8 ANALYSIS OF OTHER FACTORS

Table 4.15 summarizes gas impacts based on whether the housing unit was attached (i.e., a row house) or detached. There were relatively few homes listed as attached and the net savings were about the same as those in detached homes.

Table 4.15 PY 2010 WAP Energy Impacts for Single Family Site-Built HomesGas Savings for Natural Gas Main Heat by Attached/Detached Housing

Attached/Detached Housing	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
Detached	3,305	986	157 (±12)	15.9% (±1.2%)
Attached (Row House)	164	1,062	152 (±52)	14.4% (±4.9%)

Table 4.16 compares savings for homes based on whether or not the job received nonDOE funds. The table also includes average spending on efficiency measures (ECM = energy conservation measure). Jobs that received nonDOE funds saved about 30 percent more therms than those that had just DOE funds (41 therms/year); this difference was statistically significant. The jobs completed solely with DOE funds had an average of $1,000 less spent on efficiency measures. The cost-effectiveness section examines this issue in more detail.

Table 4.16 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat by Funding Sources

Use of nonDOE Funds	# Homes	ECM Measure $/home	Gas Use Pre-WAP	Net Savings	% of Pre
Only DOE Funds	3,768	$3,818	1,012	141 (±9)	14.0% (±0.9%)
DOE & NonDOE Funds	2,265	$4,816	947	182 (±13)	19.2% (±1.3%)

Table 4.17 summarizes gas savings by the amount of spending on efficiency measures for each job. This cost breakout was available for about 70% of the cases in the analysis. The savings grow rapidly with increasing spending on ECMs – from 67 therms average savings when less than $2,000 was spent to 249

therms when more than $6,000 was spent. However, the spending appears to increase at a more rapid pace than savings.

Table 4.17 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat by Efficiency Measure Cost

Efficiency Measure Costs	# Homes	ECM Measure $/home	Gas Use Pre-WAP	Net Savings	% of Pre
<$2,000	1,044	$1,175	837	67 (±10)	8.0% (±1.1%)
$2,000-<$4,000	1,427	$3,001	876	130 (±10)	14.8% (±1.1%)
$4,000-<$6,000	1,216	$4,924	894	166 (±10)	18.5% (±1.1%)
>=$6,000	1,063	$8,146	1,025	249 (±17)	24.3% (±1.7%)

Table 4.18 shows a breakout of gas savings by whether or not total job costs exceeded $8,000. The $8,000 figure was selected based on the prior study of PY 2008 where it represented the top 10% of jobs. On average, the high-cost jobs saved 2.2 times as much gas than lower-cost jobs while efficiency measure costs increased by 2.5 times.

Table 4.18 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Gas Savings for Natural Gas Main Heat By High Cost ($8000) Job

Total Job Cost	# Homes	ECM Measure $/home	Gas Use Pre-WAP	Net Savings	% of Pre
Total Job Cost < $8,000	5,034	$3,448	962	133 (±7)	13.8% (±0.7%)
Total Job Cost >= $8,000	809	$8,486	1,124	290 (±19)	25.8% (±1.7%)

4.9 ENERGY SAVINGS FOR PROGRAM YEARS 2009 AND 2011

Program Year 2010 was the primary focus of the impact analysis and the only year for which detailed treatment data were collected from local agencies. But basic data, including utility account number and treatment dates, also were collected for homes that participated in Program Years 2009 and 2011.

The PY 2011 data were collected primarily for creating the Comparison Group for the PY 2010 analysis. However, PY 2011 net impacts can be assessed if the PY 2010 data are analyzed as a "post/post" Comparison Group based on the principles of difference-in-difference estimation. Similarly, the PY 2009 data were collected primarily for creating the Comparison Group for the PY 2008 program evaluation, but net impacts can be assessed if the PY 2008 data are analyzed as a "post/post" Comparison Group.

Table 4.19 summarizes the gas savings results for PY 2009 and PY 2011. For comparison, the PY 2010 gas savings averaged 147 therms net (and 155 therms gross), equal to 16% of the 947 therms of pre-program annual gas use.

Table 4.19 PY 2009 and PY 2011 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Gas Savings for Natural Gas Main Heat (Therms/year)

Program Year	# Homes	Gas Use Pre-WAP	Gas Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2009	2,750	998	813	185 (±11)	173 (±10)	17.4% (±1.0%)
Comparison	4,210	848	836	12 (±4)		
PY 2011	3,157	996	807	189	186 (±7)	18.7% (±0.7%)
Comparison	6,148	842	839	2		

Table 4.20 summarizes the electric savings results for gas heated homes in PY 2009 and PY 2011. For comparison, the PY 2010 savings were 716 kWh/year net (833 kWh/year gross), equal to 8% of the 9,222 kWh/year pre-program electric use.

Table 4.20PY 2009 and PY 2011 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Natural Gas Main Heat (kWh/year)

Program Year	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2009	2,211	9,663	8,715	948 (±81)	796 (±124)	8.2% (±1.3%)
Comparison	3,693	9,276	9,124	152 (±106)		
PY 2011	3,200	9,015	8,237	778	772 (±72)	8.6% (±0.8%)
Comparison	6,274	8,385	8,379	6		

4.10 EXPLANATORY FACTORS AND ESTIMATED ENERGY SAVINGS FOR ALL GAS HEATED HOMES

The breakouts of savings presented throughout this section have summarized program impacts for various groups of interest. But such breakouts may provide a false impression of cause and effect. For example, differences in savings between Climate Zones or by pre-program usage levels may be accounted for as much by differences in the mix of measures installed than by the specific characteristic used to define groups. To better assess how different factors affect energy savings, regression modeling was used to explore how variations in observed savings relate to the measure installed and other factors.

In addition to providing potentially useful estimates of measure savings and other insights into factors associated with savings, the regression analysis of savings were also used to estimate the overall savings for the population of gas heated homes and for homes heated by delivered fuels (e.g., oil and propane). Table 4.2 summarized characteristics of homes in the analysis sample compared to those in the gas heated population and to all homes in the program. There were some differences in measure installation rates and other factors. The regression model developed using the billing analysis sample estimated the savings for homes without usable savings results, based on the location and climate of the home and the mix of measures installed.

The explanatory factors model also played a key role in developing cost savings estimates since energy prices vary geographically, yet sample attrition led to many states having few or even no cases with usable results. To develop savings estimates for all homes in all states, a multi-level or mixed-effects[15] modeling approach was employed that estimates fixed effects for program measures but then also

[15] The xtmixed command in the statistics package Stata was used to fit these models.

estimates state-level effects that were nested within climate region effects. This approach estimates state-level impacts that are a pooled combination of state-level savings in the sample and impacts estimated by the mix of measures. The savings for states with large samples were primarily based on those results, while savings for states with few results were primarily driven by the mix of measures adjusted for climate region effects. For the states with no billing analysis savings results, savings were estimated entirely based on the mix of measures and climate.

The explanatory factors model was developed by examining a wide range of measures and other factors for potential inclusion in a model of observed savings. Factors were assessed based on explanatory power, practical and statistical significance, and having the "right" sign. In addition, a comparable analysis was performed for the PY 2008 impact analysis and so that model was used as a template for the current analysis. Once the major measures of wall insulation, attic insulation, heating system replacement, and air leakage reduction were included in the model, most remaining measures and factors provided little additional explanatory power and some had the wrong sign (e.g., negative savings). Program measures not included in the final model included:

- All hot water related-measures – showerheads, aerators, tank wraps, pipe insulation, temperature turn down, DHW replacement
- Foundation wall insulation (savings varied by foundation type but foundation type information was not available in half of the homes)
- Rim/band joist insulation (estimated savings of 14 therms but wide confidence interval)
- Duct insulation
- Window measures: replacement, storm windows, window repairs, etc.
- Heating system repairs and tune-ups

The exclusion of a measure from the model does not necessarily indicate that the measure provides no savings but only that there were insufficient data to estimate the savings well or that other factors may have confounded the estimation of savings. For example, if a measure tends to be installed more often in efficient homes, then the statistical estimate of the savings from that measure will be biased low and may even have the wrong sign.

The gas savings results from the explanatory factors model are summarized in Table 4.21. Findings include:

- Air Sealing – Air sealing is estimated to have provided the largest fraction of program savings – an average of 47 therms per home equal to 35% of total gas savings.
- Heating System Replacement - Heating system replacement is estimated to have the largest gas savings per installation at 91 therms, but only contributed 28 therms to overall program savings because replacements were only performed in 31% of homes.
- Major Measures - Overall, the four major measures of air sealing, heating system replacement, attic insulation, and wall insulation are estimated to account for more than 90% of the observed gas savings.

- Mechanical Ventilation - Ventilation improvements, such as the installation of an exhaust fan in a tighter home, were estimated to increase gas use by 15 therms per installation on average.

Overall, the gas explanatory factors model estimates that the program produced average annual natural gas savings of 135 therms – 12 therms less than the 147 therms net savings of the billing analysis sample. This reduction in savings reflects the differences in measure installation rates and locations between the sample and the program population.

Table 4.21 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gas Savings (therms/year) by Measure for Natural Gas Main Heat

Measure	% of Homes	Savings per installation	Contribution to Overall Savings	% of Total Savings
Air Sealing	100%	47	47	35%
Attic Insulation	63%	51	32	24%
Wall Insulation	27%	77	21	16%
Heater Replacement	31%	91	28	21%
Duct Sealing	34%	9	3	2%
Setback Thermostat	16%	24	4	3%
Floor Insulation	14%	10	2	1%
Ventilation	15%	-15	-2	-2%
Other / Unattributed	100%	1	1	0%
Total			135	100%

An explanatory factors model was also developed to estimate electric savings in gas heated homes. The results of this analysis are summarized in Table 4.22. Findings include:

- Problems with Lighting Savings Analysis - The lighting retrofit savings are too low given prior evaluation results and the pattern of reported lighting retrofit work. It appears that many homes reported as not receiving lighting retrofits likely received the retrofits from another program – many were reported in states known to have large-scale utility programs. If such under-reporting were common, then the savings from lighting measures would be shifted to the "Other/Unattributed" category.

- Refrigerators - Refrigerator replacements are the only common measure identified by the regression analysis with estimated savings of 637 kWh for the 20% of homes receiving replacements.

- Air Conditioners - Air conditioner replacement was rare but was estimated to produce substantial savings when performed. In addition to misreported lighting savings, the Other/Unattributed category would include savings from reduced electric use of the gas furnace fan, reductions in cooling use from building shell measures and duct sealing/insulation, or reduction in the use of electric space heaters.

Overall national electric savings in gas heated homes are estimated at 730 kWh – slightly larger than the 716 kWh estimated from the billing analysis sample.

Table 4.22 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Electric Savings (kWh/year) by Measure for Natural Gas Main Heat

Measure	% of Homes	Savings per installation	Contribution to Overall Savings	% of Total Savings
Lighting*	69%	10*	7*	1%*
Refrigerator Replacement	20%	637	127	17%
Air Conditioner Replacement	2%	767	15	2%
Other / Unattributed	100%	581	581	80%
Total			730	100%

* Note: Lighting savings estimate is believed to be biased low due to homes receiving lighting retrofits from utility programs not being reported.

5. ENERGY IMPACTS FOR HOMES WITH ELECTRIC MAIN HEAT

The WAP evaluation directly measured electric usage for treated homes that use electricity as their main heating fuel. This section presents the findings with respect to overall energy impacts as well as breaking out savings by:

- End Use Savings – The share of electric savings attributable to heating, cooling, and baseload usage.
- Installed Measures – Differences in energy savings for groups of homes that received different packages of installed measures.
- Pre-Weatherization Usage Level – Differences in energy savings and installed measures associated with different levels of pre-weatherization usage.
- Climate Zone – Comparison of energy savings and installed measures usage by Climate Zone.

These analyses help to show that program services and impacts vary by population subgroup. The relatively small sample size of electrically heated homes limited this analysis when compared to the analyses conducted for the homes heated with natural gas.

5.1 METHODOLOGY

The electric savings in homes with electric heat were analyzed using the same approach employed for the electric savings analysis in gas heated homes – a standard pre/post treatment/comparison design using weather-normalized utility billing data. The relatively small size of the electric heat analysis sample and the uneven distribution across climate zones limited the extent of the analysis and exploration.

5.1.1 Sample Attrition

There were 5,317 single family site-built electric heat homes sampled for analysis. Table 5.1 summarizes the disposition of this sample for the electric use analysis. The utility data collection process was successful in obtaining electric data for 47 percent of the sampled homes. One significant challenge in collecting data was that subgrantees did not collect utility company names for about 22 percent of electric accounts. The usage data provided were not sufficient for developing savings estimates for 11 percent of the electric analysis homes. Most of this attrition was due to too little pre-retrofit data – the analysis required a minimum 270 days of electric data (in addition to some requirements about weather). The weather-normalization itself indicated a poor model fit in either the pre or post periods for less than 1 percent of the sampled cases. An additional 11 percent of sampled cases in the analysis had electric usage too low to be considered primarily electrically heated and occupied during both periods. Less than 1 percent of the sampled homes were removed from the analysis because they were declared savings outliers[16].

[16] Outliers were defined as having percent savings more than 2.5 inter-quartile ranges from the median percent savings for the analysis group (participant or comparison).

Table 5.1 PY 2010 WAP Single Family Site-Built Homes Electric Usage Sample Attrition – Electric Main Heat

	Electric Analysis	
Sample Group / Attrition Cause	**Homes**	**% of Sample**
Sampled	5,317	100%
Utility Company Unknown	1,171	22%
No Usage Data Available	1,629	31%
Insufficient Data	609	11%
Poor Model Fit	17	<1%
Usage Outlier: Vacant, Unheated, Not SF	573	11%
Savings Outlier	26	<1%
Usable Cases	1,292	24%

The same screening criteria were also applied to the Comparison Group analysis and the group ended up with a similarly small number of cases eliminated due to bad fits or outliers, but more cases declared as not electrically heated or vacant.

5.2 KEY PROGRAM FACTORS FOR HOMES WITH ELECTRIC MAIN HEAT

Table 5.2 summarizes information about climate, demographics, housing stock, and major program measures for the full single family site-built sample compared to homes with electric heat and the electric heat usage analysis sample. The table shows that electric heat homes were concentrated in the Moderate Climate Zone and also more likely to be in the Hot/Humid Climate Zone and less likely to be in the Cold or Very Cold Climate Zones. Participants who lived in electric heated homes tended to have lower incomes than did participants with other heating fuels. Their homes were a little smaller and newer than other homes, and were more likely to have central air conditioning. Electric heated homes were much less likely to receive wall insulation and less likely to receive a heating system replacement compared to the overall program population.

The analysis sample attrition has created a group with more homes from the Cold and Very Cold Climate Zones, homes that received fewer heating system replacements and fewer refrigerator replacements than did the full electric heat population. These differences in climate and measure installation rates may lead to different savings in the analysis sample compared to the overall population.

Table 5.2 Characteristics of PY10 Single Family Site-Built Homes

Characteristic	All Homes	Electric Heat Population	Electric Heat Analysis Sample
Climate			
Very Cold	19%	5%	7%
Cold	36%	12%	15%
Moderate	19%	38%	40%
Hot/Humid	17%	41%	34%
Hot/Dry	9%	5%	4%
Demographics			
Median Income	$15,600	$13,877	$13,657
Homeowner	81%	83%	90%
Elderly	41%	45%	49%
# Occupants	2.5	2.4	2.4
Housing Characteristics			
Heated Area	1,388	1,335	1,391
Median Age	57	37	37
HDD65	4,793	3,252	3,524
CDD65	1,274	1,891	1,760
Central Heating	89%	88%	93%
Central A/C	40%	63%	66%
Major Measures			
Heater Replacement	28%	23%	15%
Attic Insulation	63%	64%	64%
Wall Insulation	25%	13%	12%
Air Sealing >1,000 CFM50	36%	32%	30%
Refrigerator Replaced	20%	19%	16%

Note: Results weighted by sample design selection probabilities.

5.3 ENERGY SAVINGS OVERALL AND BY END USE

Table 5.3 summarizes overall electric savings and savings separated into baseload, heating/winter, and cooling/summer usage. Net electricity savings averaged 1,841 kWh, equal to 9.3 percent of total pre-program usage. These percent savings are much lower than the 15.5 percent found for gas heated homes but much of this difference is due to the greater number of electric end uses that are not affected by WAP measures. The savings in the heating portion of electric use were estimated to average 10.9 percent, which is considerably less than the 17.1 percent heating savings found in gas heated homes. These lower savings might be expected to some extent given the lower installation rates of wall insulation and heating system replacements for homes with electric heat. In addition, the estimated baseload component savings estimate appears somewhat large (1,000 kWh/year.) given the low rate of refrigerator replacement in the sample. Some of these baseload savings may actually be heating savings but the weather-normalization process may have misallocated some of the consumption.

Table 5.3 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Electric Main Heat by End Use (kWh/year)

Usage Component	# Homes	Elec Use Pre-WAP	Gross Savings	Net Savings	% of Pre
Total Use	1,292	19,746	2,299 (±192)	1,841 (±270)	9.3% (±1.4%)
Comparison	503	19,849	457 (±206)		
Heating/Winter Use	1,292	6,502	1,077 (±172)	711 (±213)	10.9% (±3.3%)
Comparison	503	6,541	366 (±151)		
Cooling/Summer Use	1,292	2,101	226 (±59)	130 (±129)	6.2% (±6.1%)
Comparison	503	2,253	95 (±123)		
Baseload Use	1,292	11,143	996 (±160)	1,000 (±254)	9.0% (±2.3%)
Comparison	503	11,054	-4 (±203)		

The distribution of participants' pre-program total electric use is shown in Figure 5.1. The median annual electric use for electric heated participants was 19,308 kWh with one-half of all homes using between 14,963 and 24,069 kWh. Ten percent of homes used less than 11,583 kWh and ten percent used more than 30,845 kWh. The Comparison Group distribution was generally similar with a median of 19,676 kWh and quartiles of 15,865 kWh and 25,144 kWh.

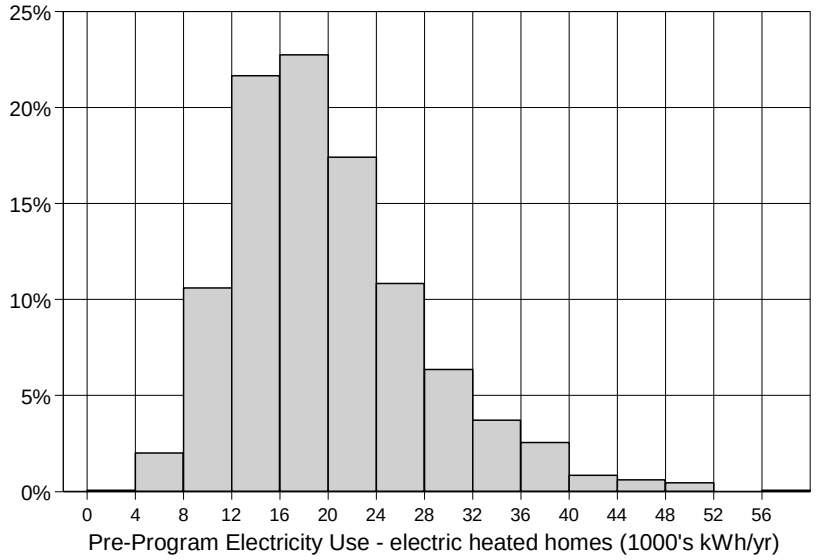


Figure 5.1: Distribution of Pre-Program Electric Use for Electric Heat Single Family Participants

The distribution of percent savings for electric heat participants and comparison households is shown in Figure 5.2. The Comparison Group line graph shows the distribution of the year-over-year change in electric usage that was observed for households that did not receive weatherization services. The line for those households is approximately centered on 0% and shows that about half of these households had a weather-normalized change in electric usage between +/-7.5% (the three middle points). For about 17 percent of the households, the change was less than -17.5% or greater than +17.5%. These changes in

consumption may be due to a variety of causes, including: changes in appliances or plug loads, changes in the use of supplemental heating sources, changes in the number of household members or occupancy patterns, and other changes in the way the home is used. Table 5.3 shows that the overall average impact of all of these nonprogram changes in the Comparison Group was a decrease in electric use of 457 kWh per year (2.3%).

The line graph for the Participant Group is shifted to the right of the Comparison Group line indicating that the program produced savings. The Participant Group electric use changes are a little more spread out than those for the Comparison Group although the distribution is less spread out than those for gas heated homes.

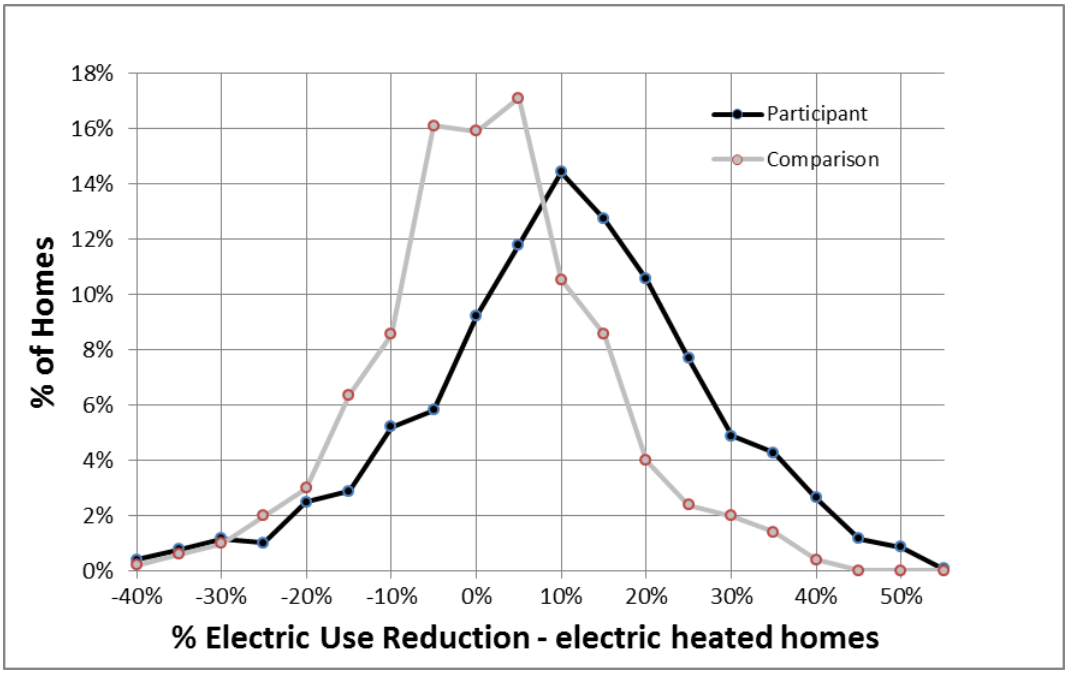


Figure 5.2: Distribution of Percent Electric Savings – Electric Heat Participants and Comparison Group

A common question about savings is why some participants appear to increase their usage after weatherization – how can savings be negative? The distribution of the change in use for the Comparison Group may help explain this apparent anomaly. As shown in Figure 5.2 above, some Comparison Group homes increased usage by 20 percent or more due to nonprogram factors. So, if a home *would have had* an increase in usage of 20 percent without treatment, but had only a 5 percent increase in usage after treatment, the net program impact is 15 percent savings over what would have occurred without weatherization.

5.4 MEASURE-LEVEL ENERGY IMPACTS

Table 5.4 summarizes electric use and savings for homes with different numbers of major measures using the same major measures as defined for gas heated homes: air sealing, attic insulation, wall insulation, and heating equipment replacement. Because the sample size is smaller and relatively few of the homes received wall insulation or heating system replacements, only the total number of major measures is

examined, not the individual combinations. The electric usage and savings increase with the increasing number of major measure installations.

Table 5.4 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Electric Savings for Electric Main Heat (kWh/year) by Number of Major Measures

# Major Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
No Major Measures	237	18,679	976 (±453)	5.2% (±2.4%)
One Major Measure	506	19,351	1,637 (±267)	8.5% (±1.4%)
Two Major Measures	271	20,641	2,485 (±407)	12.0% (±2.0%)
Three or Four Major Measures	91	23,554	3,109 (±861)	13.2% (±3.7%)
All Electric Heat Units	1,292	19,746	1,841 (±270)	9.3% (±1.4%)

5.5 ENERGY IMPACTS BY PRE-WEATHERIZATION USAGE LEVEL

The relationship between pre-weatherization total electric use and electric savings in electrically heated homes was explored by calculating savings by usage level. The results are shown in Table 5.5. The annual kWh savings increase with higher pre-WAP electric use, although the percent savings relationship is less linear. The average number of major measures installed varies relatively little.

Table 5.5 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Electric Main Heat by Pre-Weatherization Electric Usage

Pre-WAP Use	# Major Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
<15,000 kWh/yr	1.0	368	11,831	934 (±201)	7.9% (±1.7%)
15-<20,000	1.1	370	17,419	1,259 (±392)	7.2% (±2.3%)
20-<25,000	1.4	265	22,320	2,421 (±564)	10.8% (±2.5%)
25-<30,000	1.3	149	27,280	2,296 (±744)	8.4% (±2.7%)
>=30,000 kWh/yr	1.4	140	35,896	5,083 (±1,139)	14.2% (±3.2%)

Note: Comparison Group, not shown, also was stratified by pre-WAP electric use.

5.6 CLIMATE ZONE IMPACTS

Because of the smaller number of electric heat homes in the sample, the even smaller size of the Comparison Group, and the especially small samples for all but the Moderate and Hot/Humid Climate Zones, climate-related impacts were examined for two categories — colder areas and warmer areas, the distinction being whether annual average heating degree days (Base 65) was greater than or less than 3,500. Table 5.6 summarizes the results for these two climates. The overall electric savings are similar in the colder and warmer climates. An analysis by end use component found greater savings in the heating/winter loads in the colder climates, but greater savings in the estimated baseload and cooling/summer loads in the warmer climates.

Table 5.6 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Electric Main Heat by Climate (kWh/year)

Pre-WAP Use	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
Warm (<3,500 HDD65)	689	18,577	1,837 (±375)	9.9% (±2.0%)
Cold (>=3,500 HDD65)	603	21,410	2,021 (±392)	9.4% (±1.8%)

Note: Comparison Group, not shown, also was stratified by HDD65.

5.7 PROGRAM YEAR 2011 ELECTRICITY SAVINGS

Table 5.7 summarizes the electric savings results for electric heated homes that participated in PY 2009 and PY 2011. For comparison, the PY 2010 savings were 1,841 kWh/year net (2,299 kWh/year gross), equal to 9.3% of the 19,746 kWh annual pre-program electric use. The PY 2009 and PY 2011 savings appear to be consistent with the PY10 results given the unclear magnitude or direction of the Comparison Group adjustment.

Table 5.7 PY 2009 and PY 2011 WAP Energy Impacts for Single Family Site-Built Homes Gross and Net Electric Savings for Electric Main Heat

Program Year	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2009	226	19,480	16,894	2,585 (±743)	2,323 (±765)	11.9% (±3.9%)
Comparison	341	17,945	17,682	262 (±299)		
PY 2011	624	19,456	17,406	2,050 (±251)	*	*
Comparison	*	*	*	*		

*Statistics under development. Will be included in the final report.

5.8 ESTIMATED ENERGY SAVINGS FOR ALL ELECTRIC HEATED HOMES

Similar to the approach described in Section 4.10, an explanatory factors model was also developed to assess electric savings in electric heated homes. The small sample size led to fairly large uncertainty in the savings estimates for specific measures, but the approach was still considered worth using to develop national estimates based on measures. Air sealing, attic insulation, and refrigerator replacement impacts were all statistically significant at the 95% confidence level or better (air sealing the most precisely estimated), while air conditioner replacement and duct insulation/sealing had greater uncertainty. The results of this analysis are summarized in Table 5.8.

Table 5.8 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Electric Savings (kWh/year) by Measure for Electric Main Heat

Measure	% of Homes	Savings per installation	Contribution to Overall Savings	% of Total Savings
Air Sealing	100%	474	474	23%
Attic Insulation	65%	591	383	19%
Duct Insulation and/or Sealing	34%	539	181	9%
Air Conditioner Replacement	7%	950	66	3%
Refrigerator Replacement	19%	721	136	7%
Other / Unattributed	100%	800	800	39%
Total			2,040	100%

Air sealing and attic insulation are estimated to account for 42 percent of the savings. National program electric savings in homes with electric heat are estimated to be 2,040 kWh/year, nearly 10% larger than the 1,841 kWh found from the billing analysis sample. This differential shows that there are important differences between the analysis sample and the larger program population in terms of measure installation rates and/or locations.

6. ENERGY IMPACTS FOR HOMES WITH DELIVERED FUEL MAIN HEAT

About 25 percent of treated homes are heated with delivered fuels – fuel oil, propane, kerosene, and wood. Since the consumption of delivered fuels for a particular time period cannot be directly measured from purchase records, and such records are often incomplete and difficult to access, the evaluation directly metered the pre- and post-weatherization usage for a sample of homes that heat with fuel oil and compared the impacts for these homes to those that heat with natural gas. The purpose of this metering study was to test whether savings among oil heated homes differ significantly from savings among gas heated homes.

The oil metering study was implemented during the 2010/11 heating season. The study involved installing devices to track heating system operation among 120 single-family homes with oil heat in eight states in the Northeast where oil heat is most prevalent. The study provided daily heating system run time information for each site, which was then combined with information about nozzle sizes and pressures and daily weather data to estimate weather-normalized pre- and post-weatherization annual fuel oil consumption. To control for other nonprogram factors, the sample was divided among homes weatherized by the program and a control group of (previously weatherized) homes that were not affected by the program during the period of interest. Delays in weatherization work, inability to obtain nozzle sizes, and other issues led to some attrition: the final study group consisted of 52 treated homes and 35 comparison group homes in seven states. The metering study is described in more detail in Appendix B.

The key results of the study are summarized in Table 6.1 below. The treatment group showed about a 20 percent decline in usage, while usage in the control group rose slightly. Net percentage savings are estimated to be 22.5 ± 6.0%.

Table 6.1 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Fuel Oil Savings for Monitored Single Family Homes

Group	N	Pre Use (MMBtu)	Post Use (MMBtu)	Savings (MMBtu)	% Savings
Treatment	52	116 ± 13	93 ± 14	22.6 ± 3.9	19.5 ± 4.0%
Control	35	87 ± 12	89 ± 13	- 2.6 ± 3.7	- 2.9 ± 4.3%
Net Savings				26.0 ± 6.3	22.5 ± 6.0%

Net MMBtu savings calculated as Treatment MMBtu savings – Control % savings * Treatment Pre Use.
Net % savings calculated as Net Treatment MMBtu savings / Treatment Pre Use.

To test whether the observed savings among the oil heated homes significantly differ from what the billing analysis shows for gas heated homes, the gas explanatory factors model described in Section 4.10 was applied to the homes in the oil metering study. This calculation provided an estimate of expected *gas* savings – given the location of the home and the key weatherization measures that were installed – that could be directly compared to the observed oil savings from the metering study. Because the explanatory factors model was fit with just the participant group, the comparison was made to gross savings from the oil metering. The results of this analysis are summarized in Table 6.2.

Table 6.2 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Oil Heat Metering Results vs. Expected Savings

Analysis Method	Fuel Savings - gross (MMBtu/year)
Metering Study	22.0 (±5.0)
Projection from Gas Explanatory Factors Model	19.7 (±2.0)
Difference	+2.3 (±5.1)

The table shows that the average gross savings measured in the oil heated homes were a little larger than expected if these had been gas heated homes in the same locations that received the same mix of measures. The difference is about 10 percent but is not statistically significant. The results therefore support the hypothesis that fuel savings in oil heated homes are similar to those in gas heated homes when receiving the same measures in the same climates, although the point estimate suggests slightly larger savings for oil homes. But given the lack of statistical significance, the gas explanatory factors model savings estimation approach was applied to all homes heated with delivered fuels. Electric baseload savings in homes heated with delivered fuels were estimated based on a similar approach of modeling electric savings found in gas heated homes as a function of electric measures and applying that model to homes heated by delivered fuels.

Table 6.3 summarizes the resulting net energy savings for households that heat with delivered fuels. The differences in energy savings are a function of differences in measure installation rates and geography/climate.

Table 6.3 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Net Savings for Delivered Fuel Main Heat

Main Heating Fuel	Heating Fuel Savings (MMBtu/year)	Electric Savings (kWh/year)
Fuel Oil	18.4	558
Propane	13.4	958
Other	13.1	850
All Delivered Fuels	15.9	745

7. COST SAVINGS, MEASURE COSTS, AND COST-EFFECTIVENESS

The WAP evaluation assesses program cost-effectiveness along multiple dimensions that are related to the various goals of the program and how resources are allocated. Some of the main issues in this analysis include:

- Energy Savings – The evaluation developed estimates of the first year energy savings from the program and used the estimated life of individual measures to project total energy savings over time.

- Energy Cost Savings – The evaluation used data on current energy prices and price projections to estimate the cost savings associated with the projected energy savings.

- Nonenergy Benefits – The evaluation collected data and referencing literature sources to estimate and monetize the nonenergy benefits.

- Service Delivery Costs - The evaluation collected information from agencies to assess the service delivery costs for each home, including breakouts of energy efficiency measures, health and safety measures, and home repairs.

- Total Program Costs – The evaluation collected information from DOE, states, and agencies to document program administration and training costs.

- Cost-Effectiveness – Program cost-effectiveness has been computed from multiple perspectives that assess the benefits and costs in terms of both energy and nonenergy aspects of the program.

The analysis here focuses narrowly on two specific elements of cost-effectiveness: (1) the cost to install measures meant to save energy (and incidental repairs that enable their installation); and, (2) the value of the energy savings from those measures. As such, the measure of cost-effectiveness reported here excludes costs for health-and-safety measures and indirect program costs. It also excludes potential nonenergy benefits from the program. This focus is only concerned with the effectiveness of efficiency measures at saving energy.

7.1 PRICE AND DISCOUNT RATE SCENARIOS

This report presents information on energy savings for PY 2010. In this section, the energy cost savings and cost-effectiveness are presented from three different perspectives.

- Impact on PY 2010 Clients – The first scenario documents how the program impacted PY 2010 clients. It shows the clients' first year energy cost savings based on actual energy prices in 2010 and the estimated net present value of their energy cost savings based on actual energy prices for 2010 through 2012, projected energy prices beginning in 2013, and discount rates in effect in 2010.

- PY 2013 Policy Perspective – The second scenario is the most relevant to policymakers making use of this report at the time of publication. It shows the energy cost savings and cost-effectiveness of a program implemented in PY 2013 using energy price projections beginning in 2013 and discount rates in effect in 2013.

- Long-Term Policy Perspective – The third scenario is useful for longer-term program decision-making. It shows the energy cost savings and cost-effectiveness of a program using energy price projections beginning in 2013 and long-term average discount rates.

Each of these three scenarios is useful for understanding the program from a different perspective. However, the PY 2013 Perspective is probably the most useful for policymakers at this time.

7.2 IMPACT ON PY 2010 CLIENTS

This section presents the estimated energy cost savings and cost-effectiveness for clients who were served during PY 2010. The following parameters are used in this analysis.

- First Year Energy Savings – Procedures are presented in Sections 4, 5, and 6 of this report.
- First Year Cost Savings – Estimated by multiplying first year energy savings per client by the average price per unit for each state for 2010.
- Long-Term Energy Savings – Developed by applying measure life estimates to first year energy savings.
- Long-Term Cost Savings – Estimated by multiplying projected energy savings by actual energy prices (inflation-adjusted) for 2010-2012 and projected inflation-adjusted energy prices for each state.
- Net Present Value of Cost Savings – Developed by discounting the stream of future cost savings by the inflation-adjusted discount rate experienced in PY 2010.
- Energy Cost-Effectiveness – Compares the net present value of energy cost savings to the cost of installed energy measures.

Table 7.1 summarizes the average energy costs and annual cost savings for the first year after participation in WAP in 2010 dollars.

Table 7.1 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Energy Costs and Cost Savings by Main Heating Fuel (2010 Dollars)

Heating Fuel	Annual Energy Costs			Annual Savings (first year)			
	Fuel	Electric	Total$	Fuel	Electric	Total$	% Savings
Natural Gas	$671	$963	$1,634	$110	$77	$187	11.4%
Electricity	-	$1,692	$1,692	-	$197	$197	11.7%
Fuel Oil	$1,961	$1,025	$2,986	$336	$56	$392	13.1%
Propane	$1,834	$971	$2,806	$295	$82	$377	13.4%
Other	$689	$989	$1,678	$113	$76	$188	11.2%
All Clients	**$750**	**$1,113**	**$1,863**	**$124**	**$99**	**$223**	**12.0%**

Participant annual energy costs averaged $1,863 prior to WAP, and WAP reduced these costs by an average of $223, equal to a 12.0% reduction in total energy costs. The energy costs and value of the savings were almost twice as large in homes heated by fuel oil or propane than they were in homes heated by natural gas.

Table 7.2 summarizes the estimated life-cycle energy cost savings, the cost of installing energy efficiency measures, and the cost-effectiveness for the national program by main heating fuel. Cost-effectiveness is summarized in two ways:

- The net benefits, equal to the present value of the lifetime energy cost savings minus efficiency measure costs.

- The savings-to-investment ratio, SIR, which is present value of the lifetime energy cost savings divided by the efficiency measure costs. An estimated 90% confidence interval on the SIR is also presented based on a Monte Carlo simulation using estimated uncertainties of the inputs.

The table shows that the program is projected to generate an average of $3,803 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spent an average of $3,777 on efficiency measures in these homes, yielding a net benefit of $25 per home and an SIR of 1.01. In other words, the energy savings are worth 1% more than the cost of the efficiency measures. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.75 to 1.36. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.2 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness			
Heating Fuel	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio	SIR 90% c.i.
Natural Gas	$2,237	$765	$3,002	$3,661	-$659	0.82	0.52 - 1.20
Electricity	-	$3,219	$3,219	$3,713	-$494	0.87	0.73 - 1.02
Fuel Oil	$8,182	$567	$8,749	$4,258	$4,492	2.05	0.97 - 3.38
Propane	$4,940	$814	$5,754	$4,259	$1,495	1.35	0.75 - 2.09
Other	$2,499	$761	$3,259	$3,913	-$654	0.83	0.53 - 1.20
All Clients	**$2,571**	**$1,231**	**$3,803**	**$3,777**	**$25**	**1.01**	**0.75 - 1.36**

The SIR is greater than unity for oil and propane heated homes due to the high costs of these fuels. On a Btu basis, fuel oil costs 2.2 times more than natural gas, and propane costs 2.1 times more than natural gas.

A number of factors, including differences in investment levels and heating fuel mix have an impact on the cost-effectiveness of the program by Climate Zone. Cost-effectiveness results by Climate Zone are summarized in Table 7.3. The Cold Climate Zone produced the highest SIR because it had the second lowest average spending on efficiency measures while producing the highest cost savings. The Hot/Dry Climate Zone had the lowest SIR; this zone had the lowest average expenditures per job, but also had the lowest savings per job.

Table 7.3 PY 2010 WAP Energy Impacts for Single Family Site-Built Homes Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Climate Zone (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Climate	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
Very Cold	$3,740	$764	$4,503	$4,666	-$163	0.97
Cold	$3,804	$824	$4,628	$3,519	$1,109	1.31
Moderate	$1,658	$1,521	$3,179	$3,575	-396	0.89
Hot/Humid	$931	$2,491	$3,422	$4,637	-$1,215	0.74
Hot/Dry	$120	$923	$1,043	$1,819	-$776	0.57

One issue to consider is whether delivering more measures per home leads to greater cost-effectiveness. Table 4.6 shows that savings were higher among gas heated homes where more measures were installed. Table 7.4[17] helps assess whether the higher level of investment per home resulted in both higher levels of energy cost savings and cost-effectiveness. The SIR is smallest for homes that received none of the four major measures but about equal across all other numbers of major measures per home with a peak at four measures. The overall SIR of 0.77 is 0.05 lower than the 0.82 value shown in Table 7.2 for gas heated homes. This discrepancy is primarily due to this subset of the analysis sample – cases with energy measure cost data – having higher measure costs than the overall gas heated population. Due to this sample bias, the SIR values should be looked at relative to each other more than as absolute numbers in this and the remaining tables in this section.

[17] Note that cost-effectiveness results shown in Tables 7.4 through 7.8 differ from Tables 7.2 and 7.3 due to different analysis approaches. Tables 7.2 and 7.3 used the explanatory factors model to impute savings for all sampled homes with all heating fuels and then employed survey-based analysis to summarize energy savings and measure costs by fuel and state. This approach accounts for differences in measure installation rates across fuels, states, and sample attrition. Tables 7.4 through 7.9 used the analysis sample directly with survey-based estimation only for cases that had both usable gas savings results and reliable efficiency measure costs. There is no imputation or adjustment for sample attrition except that electric savings values are based on cases that have gas and measure cost information. The resulting sample is biased: it has higher measure costs and lower cost-effectiveness than the overall population.

Table 7.4 PY 2010 WAP Impacts for Single Family Site-Built Homes with Natural Gas Main Heat Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Number of Major Measures (analysis sample) (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
# Major Measures	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
None	$605	$446	$1,051	$2,033	-$982	0.52
One	$1,666	$781	$2,447	$3,300	-$852	0.74
Two	$2,615	$682	$3,297	$4,546	-$1,248	0.73
Three	$3,906	$959	$4,865	$5,781	-$916	0.84
Four	$5,544	$993	$6,537	$7,312	-$775	0.89
All Clients (N=4,750)	$2,512	$770	$3,281	$4,266	-$984	0.77*

* See footnote 17 on prior page for explanation of why program SIR is lower in this table than in Table 7.2.

Another issue examined is whether targeting homes with higher pre-weatherization usage results in higher cost-effectiveness. Table 4.8 showed that gas heated homes with higher pre-weatherization usage received more major measures and had higher savings. Table 7.5 shows how measure costs and cost-effectiveness vary with pre-weatherization gas use. The SIR increases with pre-weatherization gas use – more than doubling from the lowest to highest usage bin.

Table 7.5 PY 2010 WAP Impacts for Single Family Site-Built Homes with Natural Gas Main Heat Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Pre-Weatherization Gas Usage (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Pre-WAP Gas Use	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
<750 th/yr	$1,025	$842	$1,867	$3,695	-$1,827	0.51
750-<1000	$2,008	$665	$2,673	$4,162	-$1,489	0.64
1000-<1250	$3,266	$789	$4,055	$4,547	-$491	0.89
1250-<1500	$4,272	$690	$4,963	$5,038	-$75	0.99
>=1500 th/yr	$6,614	$739	$7,353	$5,464	$1,889	1.35

Table 7.6 summarizes the cost-effectiveness of program treatments based on whether the home was treated using just DOE funds or with DOE funds plus other funding sources. The DOE-only jobs were slightly more cost-effective than jobs that received other funds. The DOE-only jobs produced 84% of the bill savings at 79% of the energy measure cost compared to jobs that received funds from other sources; the SIR for DOE-only jobs was 0.80, compared to 0.75 for DOE+ jobs. The main differences in measure installation rates were for wall insulation (21% DOE-only vs. 27% DOE+), heating system replacement (26% DOE-only vs. 33% DOE+), and refrigerator replacement (17% DOE-only vs. 27% DOE+).

Table 7.6 PY 2010 WAP Impacts for Single Family Site-Built Homes with Natural Gas Main Heat Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Use of nonDOE Funds (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Job Funding	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
Only DOE Funds	$2,294	$744	$3,038	$3,818	-$781	0.80
DOE + NonDOE Funds	$2,798	$798	$3,596	$4,816	-$1,220	0.75

Table 7.7 summarizes cost-effectiveness for different levels of spending on efficiency measures. Cost-effectiveness declines as efficiency measure costs increase. A finer breakout of these results revealed that the SIR going below unity for jobs where efficiency measure costs exceeded $3,000.

Table 7.7 PY 2010 WAP Impacts for Single Family Site-Built Homes with Natural Gas Main Heat Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Efficiency Measure Cost (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Efficiency Measure Costs	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
<$2,000	$1,151	$583	$1,734	$1,176	$559	1.48
$2,000-<$4,000	$2,156	$705	$2,861	$2,999	-$139	0.95
$4,000-<$6,000	$2,724	$785	$3,509	$4,926	-$1,417	0.71
>=$6,000	$4,047	$1,054	$5,101	$8,165	-$3,064	0.62

7.3 PY 2013 POLICY PERSPECTIVE

This section presents the estimated energy cost savings and cost-effectiveness from the perspective of policy decisions made for PY 2013. The difference between the PY 2013 Policy Perspective and the Longer-Term Policy Perspective (discussed in the following section) is that a different discount rate is used. On an annual basis, OMB issues an estimate of the inflation-adjusted discount rate for the current program year. That rate can change significantly between one year and the next. The estimates used for this analysis refer to values published in OMB Circular A-94 for 2013. It's important to note that the OMB projected rates are currently at historic lows. However, near-term policy decisions across all Federal programs currently use these rates for budgetary decision-making. Consequently, the PY 2013 Policy Perspective is most useful for budget decisions being made at the present time.

The following parameters are used in this analysis.

- First Year Energy Savings – Procedures are presented in Sections 4, 5, and 6 of this report.
- First Year Cost Savings – Estimated by multiplying first year energy savings per client by the average projected price per unit for each state for 2013.
- Long-Term Energy Savings – Developed by applying measure life estimates to first year energy savings.

- Long-Term Cost Savings – Estimated by multiplying projected energy savings by projected inflation-adjusted energy prices for each state.

- Net Present Value of Cost Savings – Developed by discounting the stream of future cost savings by the inflation-adjusted discount rate projected for PY 2013.

- Energy Cost-Effectiveness – Compares the net present value of energy cost savings to the cost of installed energy measures.

Table 7.8 summarizes the average energy costs and annual cost savings for the first year after participation in WAP in 2013 dollars.

Table 7.8 Projected PY 2013 WAP Energy Impacts for Single Family Site-Built Homes Energy Costs and Cost Savings by Main Heating Fuel (2013 Dollars)

Heating Fuel	Annual Energy Costs			Annual Savings (first year)			
	Fuel	Electric	Total$	Fuel	Electric	Total$	% Savings
Natural Gas	$649	$962	$1,611	$106	$76	$182	11.3%
Electricity	-	$1,667	$1,667	-	$193	$193	11.6%
Fuel Oil	$2,426	$1,075	$3,501	$416	$58	$473	13.5%
Propane	$1,572	$975	$2,547	$253	$82	$335	13.1%
Other	$727	$1,000	$1,727	$119	$76	$195	11.3%
All Clients	**$762**	**$1,113**	**$1,874**	**$126**	**$98**	**$224**	**11.9%**

For PY 2013 participants, annual energy costs are expected to average $1,874 prior to WAP; it is projected that WAP would reduce these costs by an average of $224, equal to a 11.9% reduction in total energy costs. The energy costs and value of the savings are expected to be about two to three times as large in homes heated by fuel oil or propane than in homes heated by natural gas.

Table 7.9 summarizes the projected life-cycle energy cost savings, the cost of installing energy efficiency measures, and the cost-effectiveness for the national program by main heating fuel. Cost-effectiveness is summarized in two ways:

- The net benefits, equal to the present value of the lifetime energy cost savings minus efficiency measure costs

- The savings-to-investment ratio, SIR, which is present value of the lifetime energy cost savings divided by the efficiency measure costs. An estimated 90% confidence interval on the SIR is also presented based on a Monte Carlo simulation using estimated uncertainties of the inputs.

The table shows that a PY 2013 program would be expected to produce an average of $4,468 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spend an average of $3,990 on efficiency measures in these homes, yielding a net benefit of $478 per home and an SIR of 1.12. In other words, the projected energy savings would be worth 12% more than the cost of the efficiency measures. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.82 to 1.53. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.9 Projected PY 2013 WAP Energy Impacts for Single Family Site-Built Homes Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2013 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness			
Heating Fuel	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio	SIR 90% c.i.
Natural Gas	$2,678	$859	$3,536	$3,867	-$331	0.91	0.57 - 1.36
Electricity	-	$3,725	$3,725	$3,922	-$197	0.95	0.79 - 1.12
Fuel Oil	$9,827	$631	$10,458	$4,498	$5,960	2.33	1.08 - 3.84
Propane	$5,716	$914	$6,631	$4,499	$2,132	1.47	0.81 - 2.28
Other	$2,884	$851	$3,735	$4,134	-$399	0.90	0.58 - 1.31
All Clients	**$3,065**	**$1,403**	**$4,468**	**$3,990**	**$478**	**1.12**	**0.82 - 1.53**

The projected SIR is greater than unity for oil and propane heated homes due to the high costs of these fuels. On a Btu basis, in PY 2013 fuel oil costs 2.3 times more than natural gas and propane costs 2.0 times more than natural gas.

7.4 LONGER-TERM POLICY PERSPECTIVE

This section presents the estimated energy cost savings and cost-effectiveness from the perspective of policy decisions made in the future. The difference between the Longer-Term Policy Perspective and the PY 2013 Policy Perspective is that a different discount rate is used.
For more general policy analyses (e.g., what investment should be made in weatherization over the next five years), OMB Circular A-4 suggests that analysts use a 3% real discount rate.

For future participants, the first year savings are similar to those of the PY 2013 Policy Perspective. Annual energy costs are expected to average $1,874 prior to WAP, and it is projected that WAP would reduce these costs by an average of $224, equal to an 11.9% reduction in total energy costs.

Table 7.10 summarizes the projected life-cycle energy cost savings, the cost of installing energy efficiency measures, and the cost-effectiveness for the national program by main heating fuel. Cost-effectiveness is summarized in two ways:

- The net benefits, equal to the present value of the lifetime energy cost savings minus efficiency measure costs.

- The savings-to-investment ratio, SIR, which is present value of the lifetime energy cost savings divided by the efficiency measure costs. An estimated 90% confidence interval on the SIR is also presented based on a Monte Carlo simulation using estimated uncertainties of the inputs.

The table shows that future programs would be expected to produce an average of $3,619 worth of energy bill savings over the lifetime of the measures (discounted to 2013 dollars) and spend an average of $3,990 on efficiency measures in these homes, yielding a net loss of $371 per home and an SIR of 0.91. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.67 to 1.20. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.10 Projected Future WAP Energy Impacts for Single Family Site-Built Homes Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2013 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness			
Heating Fuel	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio	SIR 90% c.i.
Natural Gas	$2,135	$737	$2,872	$3,867	-$995	0.74	0.48 - 1.07
Electricity	-	$3,039	$3,039	$3,922	-$883	0.77	0.65 - 0.90
Fuel Oil	$7,839	$543	$8,382	$4,498	$3,884	1.86	0.91 - 3.05
Propane	$4,577	$785	$5,362	$4,499	$863	1.19	0.67 - 1.80
Other	$2,327	$729	$3,057	$4,134	-$1,077	0.74	0.48 - 1.05
All Clients	**$2,446**	**$1,174**	**$3,619**	**$3,990**	**-$371**	**0.91**	**0.67 - 1.20**

The projected SIR is greater than unity for oil and propane heated homes due to the high costs of these fuels. On a Btu basis, in PY 2013 fuel oil costs 2.3 times more than natural gas and propane costs 2.0 times more than natural gas.