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National Weatherization Assistance Program Impact Evaluation: Energy Impacts for Single Family Homes

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ACRONYMS AND ABBREVIATIONS

AC	Air Conditioning
ANACOVA	Analysis of Covariance
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BTU	British Thermal Unit
CDD	Cooling Degree Days
CFM50	Cubic Feet per Minute @ 50 Pascals
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
ECM	Energy Conservation Measure
EUI	Energy Use Intensity
FY	Fiscal Year
HDD	Heating Degree Days
IR	Infrared
kWh	Kilowatt Hour
LIHEAP	Low Income Home Energy Assistance Program
LMF	Large Multifamily
MMBtu	Mean Million British Thermal Units
NCDC	National Climatic Data Center
OMB	White House Office of Management and Budget
ORNL	Oak Ridge National Laboratory
PRISM	Princeton Scorekeeping Method
PY	Program Year
RECS	Residential Energy Consumption Survey
SFSB	Single Family Site Built
SIR	Savings to Investment Ratio
SOW	Scope of Work
SSE	Steady State Efficiency
Therms	100,000 British Thermal Units
TIPS	Targeted Investment Protocol System
WAP	Weatherization Assistance Program

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The work presented in this report was funded by the U.S. Department of Energy's (DOE) Office of Weatherization and Intergovernmental Programs (OWIP).

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 2007, 2008, and 2009.

The original design for this research was developed by staff from the Oak Ridge National Laboratory (ORNL) as one component of the National Evaluation of the Weatherization Assistance Program. (*National Evaluation of the Weatherization Assistance Program: Preliminary Evaluation Plan for Program Year 2006 – ORNL/CON-498).* As part of the evaluation plan development, the design team consulted with and received feedback from the Network Planning Committee; 41 individuals from the weatherization network.

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

Grantee and Subgrantee Data Collection

ECW collected information on program funding and clients served from 51 grantees and 879 subgrantees, as well as detailed information on weatherization jobs from 379 subgrantees. The cooperation 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 2008 study included:

The Energy Center of Wisconsin
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Andy Mendyk
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Energy Supplier Data Collection

APPRISE collected information on electric and gas usage data from 727 electric companies and 265 gas companies. The cooperation and contributions made by the electric and gas companies were essential to the completion of the study.

The APPRISE staff responsible for the electric and gas company data collection and analysis for the PY 2008 study included:

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Michael Blasnik
Greg Dalhoff
David Carroll

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 U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) during Program Years (PY) 2007, 2008, and 2009. The main focus of this study is on PY 2008. The analysis characterizes the population of single family homes 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 five energy impact reports developed for the National WAP Evaluation for PY 2008. The full set of reports covers all housing types (single family, mobile homes, and multifamily buildings) and summarizes overall program performance for all building types in terms of energy and non-energy benefits. The reports give policymakers both detailed information on program performance for each building type, as well as overarching program performance.

Background

WAP 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 2007. DOE furnished funding to ORNL in 2009 for the evaluation for PY 2007 and 2008, with a particular emphasis on PY 2008. 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 non-energy 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.

- Special Technical Studies – Examination of the performance of the program with respect to technical issues such as air sealing, duct sealing, furnace efficiency, and refrigerators.

- 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.

Study Overview

The single family energy impact study characterized the WAP program and measured WAP program impacts. 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, diagnostic tests conducted, 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 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.

The 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.

Program Characterization

The evaluation team collected information on the clients served and the services delivered by the WAP program. PY 2008 program statistics are available from the DOE 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 97,965 housing units in PY 2008 with DOE funding. Table 1 shows the distribution of treated units by housing unit type. Almost 60 percent of the treated units were single family site built homes. Table 2 shows the distribution of treated single family homes by Climate Zone. About two-thirds of the clients served in PY 2008 were in the Very Cold and Cold Climate Zones.

Table 1
PY 2008 WAP Clients by Housing Unit Type

Housing Unit Type	PY 2008 Weighted Count of Clients	Percent of PY 2008 Clients
Single Family Site Built	57,518	59%
Single Family Mobile Home	17,621	18%
Small Multifamily (2-4)	5,213	5%
Large Multifamily (5+)	17,376	18%
TOTAL	97,965	100%

Table 2
PY 2008 WAP Clients in Single Family Homes by Climate Zone

Climate Zone	PY 2008 Units	Percent of PY 2008 Units
Very Cold Climate	14,323	25%
Cold Climate	23,935	42%
Moderate Climate	12,280	21%
Hot/Humid Climate	4,474	8%
Hot/Dry Climate	2,506	4%
TOTAL	57,518	100%

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

- The median household income was $13,223. However, almost 10 percent of WAP clients had income of $6,000 or less and more than 10 percent of WAP clients had income of $25,000 or more.

- The average WAP household had 2.5 members, but one in four households was an elderly person living alone.

- Two thirds of the WAP households were white non-Hispanic, one fourth were black non-Hispanic, and about 10 percent were other racial/ethnic groups.

WAP client housing units also are diverse. Nationally, the average WAP client home is a one story detached home with 1,272 square feet of living space. However, while over 90 percent of the homes in the hot climate zones are single story homes, more than half of those in the cold climate zones have two or more stories. One third of WAP client homes were built before 1940, but one-fourth 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 2008

Characteristic	Statistics for Single Family Homes		
Year Built	Pre 1940 = 32%	1940-1969 = 43%	1970 or Later = 25%
Space Heating Fuel	Gas = 60%	Electric = 14%	Delivered = 26%
Heating System	Central = 81%	Room = 15%	Other = 4%
Supplemental Heat	Electric = 9%	Wood = 8%	Other = 1%
Air Conditioning	Central = 39%	Window/Wall = 31%	None = 30%
Water Heating Fuel	Natural Gas = 55%	Electric = 35%	Other = 10%

The WAP program conducts extensive testing of client's homes, both to identify cost-effective energy saving opportunities and to ensure that the client's 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.

- Infiltration Rates – Blower door tests conducted prior to weatherization show that the average client home had an air leakage rate of 3,298 CFM 50. That is about three times the required ventilation needs for the average WAP client, computed using the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 62.2 standard and taking into account square footage and number of household members. Over one-fourth of clients had air leakage rates of 4,500 CFM 50 or more; these homes would be very drafty and air sealing could be expected to make the home much more efficient and comfortable. However, about 10 percent of homes were tested to be at 1,600 CFM 50 or less; for these homes, air sealing would not be the primary focus of weatherization.

- Furnace Efficiency – Pre-weatherization furnace testing found that the average WAP client home had a Steady State Efficiency (SSE) rating of 80 percent, and that one half of the furnaces had an SSE between 77 percent and 84 percent. Those levels are consistent with what would be expected from older homes where the furnace has not recently been replaced. About 10 percent of the homes have a furnace with an SSE less than 70 percent; furnace replacement might be cost-effective for these homes. About 10 percent of the homes have a furnace with an SSE of 90 percent or greater, indicating that a new furnace already has been installed in the home.

After this 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 a significant impact on the homes in which they are installed. Table 4 shows the rate at which the major measures were installed during PY 2008 and the share of the clients receiving the measure where the maximum energy savings impact was expected. For example, most homes received attic insulation (70 percent). However, the maximum savings impact would be observed only in homes where no attic insulation existed prior to weatherization (34 percent of the homes that received attic insulation). For other homes that received attic insulation, the savings would vary depending on the amount of insulation that was added to bring the home up to the targeted insulation R-value. With respect to equipment, the highest savings would be expected when the equipment replacement can be justified as an energy measure (i.e., a home where inefficient equipment is replaced with equipment that has a much higher efficiency rating). There may be no energy savings if equipment is replaced because of health and safety problems. Table 4 shows that about 22 percent of households had a furnace replacement and that in about one-half of those homes, the replacement, was

justified as an energy efficiency measure and could be expected to deliver the maximum energy savings to the home.

Table 4
Major Measure Installation Rates for Single Family Homes Served by WAP in PY 2008

Measure	Installation Rate	Percent with Highest Expected Energy Impact Measure
Bypass Air Sealing	79%	w/Blower Door=86%
Attic Insulation	70%	None Existing=34%
Wall Insulation	29%	Dense Pack=72%
Furnace Replacement	22%	Energy Measure=54%
Water Heater Replacement	9%	Energy Measure=33%
Refrigerator	13%	Energy Measure=92%

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 2008. Net program savings was estimated by comparing the savings for treatment group homes to the savings for comparison group homes.[1] Table 5 shows that the gross gas savings for gas heated homes in PY 2008 was 195 therms[2] per home per year. However, during the same period, the comparison group (PY 2009 clients) reduced their usage by 14 therms per home per year without receiving any treatments. Therefore, net savings due to the program are estimated to be 181 therms (17.8%) per home per year.

Table 5
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Gas Savings (therms*/year)

Group/Breakout	# Homes	Use Pre-WAP	Use Post-WAP	Gross Savings	Net Savings	% of Pre
Treatment Group	3,498	1,020	825	195 (±12)	181 (±13)	17.8% (±1.2%)
Comparison	3,118	974	960	14 (±3)		

*100,000 British Thermal Units

[1] 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.
[2] 100,000 British Thermal Units

Table 4 shows that the major energy efficiency measures were installed at different rates; not every home received all measures. The analysis of natural gas impacts found that one explanatory factor for different levels of gas savings was the number of major measures installed in the home. 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 4.13).
- Homes with higher levels of spending on weatherization measures (See Table 4.16).

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 2.4 times the amount of energy saved by homes that only had one major measure installed. The table also shows that the average pre-weatherization usage was higher for homes that received more major measures.

Table 6
PY 2008 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	342	866	59 (±16)	6.8 (±1.8)
Any One Major Measure	983	989	118 (±9)	12.0 (±0.9)
Any Two Major Measures	973	1,035	181 (±14)	17.5 (±1.3)
Any Three Major Measures	619	1,146	286 (±19)	25.0 (±1.7)
All Four Major Measures	192	1,220	414 (±28)	33.9 (±2.3)

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 2.1 major measures and had average savings of 271 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 133 therms. The higher usage homes saved twice as much energy with slightly more installed measures.

Table 7
PY 2008 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	3,498	1,020	181 (±13)	17.8% (±1.2%)
<750 th/yr.	1.4	858	571	67 (±9)	11.8% (±1.5%)
750-1000	1.7	963	875	133 (±10)	15.2% (±1.2%)
1000-1250	1.9	726	1,120	206 (±12)	18.4% (±1.1%)
1250-1500	2.1	472	1,367	271 (±27)	19.8% (±2.0%)
>=1500 th/yr.	2.0	479	1,879	414 (±49)	22.1% (±2.6%)

Note – Comparison group, not shown, was also stratified by usage.

The analysis found that there were no statistically significant differences in energy savings associated with some potential explanatory factors, including:

- Whether the work was performed by in-house crews or contractors (See Table 4.16).
- Whether a priority list or a calculation procedure was used (See Table 4.16).

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 (HDD) (Table 8). The average gas savings in the Cold Zone was higher than the average gas savings for the Very Cold Zone. One possible reason for this finding 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. Similarly, average savings in the Hot/Humid Zone were not statistically different from savings in the Moderate Zone despite having fewer heating degree days and lower pre-weatherization gas usage. This suggests that the determinants of program performance are complex and are not always consistent with what might be expected from *a priori* projections.

Table 8
PY 2008 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	3,498	1,020	181 (±13)	17.8% (±1.2%)
Very Cold	2.1	1,139	1,068	190 (±27)	17.8% (±2.5%)
Cold	1.6	1,909	1,125	209 (±13)	18.5% (±1.2%)
Moderate	1.6	311	868	140 (±47)	16.1% (±5.4%)
Hot-Humid	1.9	83	684	134 (±49)	19.6% (±7.2%)
Hot-Dry	0.2	56	490	26 (± 42)	5.3% (±8.6%)

Note – Comparison group, not shown, was also 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 2008 was 735 kWh and the net savings was estimated to be 680 kWh (7.1%).

Table 9
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Electric Savings for Natural Gas Main Heat by End Use

Usage Component	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
Treatment Group	2,991	9,528	8,792	735 (±102)	680 (±140)	7.1% (±1.5%)
Comparison	2,204	9,401	9,344	56 (±67)		

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 was estimated by comparing pre-weatherization usage (weather-normalized) to the post-weatherization usage (weather-normalized) for homes treated during PY 2008. Net program savings was 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 2008 was 1,995 kWh. During the same period, the comparison group reduced usage by 192 kWh without receiving any treatments; net savings due to the program are estimated to be 1,804 kWh (9.0%).

Table 10
PY 2008 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	306	19,994	1,995 (±381)	1804 (±458)	9.0%(±2.3)
Comparison	248	21,503	192 (±400)		

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 that 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

[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.

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 2008 WAP Energy Impacts for Single Family Site-Built Homes
Net Electric Savings for Electric Main Heat (kWh/yr)
by Number of Major Measures

# Major Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
No Major Measures	63	19,229	410 (±593)	2.1% (±3.1%)
One Major Measure	133	20,052	1,750 (±449)	8.7% (±2.2%)
Two Major Measures	66	19,006	1,840 (±824)	9.7% (±4.3%)
Three or Four Major Measures	18	23,515	5,322 (±1,602)	22.6% (±6.8%)
All Electric Heat Units	306	19,944	1,804 (±458)	9.0% (±2.3%)

Table 12 shows that higher savings were observed for homes with higher usage. Homes that used 20,000 or more kWh prior to weatherization had average savings that were 42 percent higher than homes with pre-weatherization usage of less than 20,000 kWh.[4]

Table 12
PY 2008 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	# Homes	Electric Use Pre-WAP	Net Savings	% of Pre
<20,000 kWh/yr.	164	14,637	1,621 (+/-467)	11.1% (+/- 3.2%)
>=20,000 kWh/yr.	142	27,774	2,317 (+/-781)	8.3% (+/-2.8%)

Comparison group, not shown, also stratified by pre-WAP electric use.

Table 7 shows that, for homes with natural gas main heating fuel, higher usage homes save more energy and a higher percent of pre-weatherization usage. Table 12 shows that, for homes with electric main heating fuel, higher usage homes save more energy, but do not save a greater percentage of pre-weatherization usage. One possible explanation for that difference is that some of the electric main heat homes with high usage might have high baseload usage, rather than high heating and cooling usage. Since the WAP program focuses mainly on reducing home heating and cooling usage, there would be a lower percentage impact for those homes. (Note: Table 4.3 shows that about 80 percent of pre-weatherization natural gas usage is for home heating. Table 5.3 shows that only about 50 percent of pre-weatherization electric usage is for home heating and home cooling.)

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:

[4] Note: The difference is not statistically significant at the 90% confidence level.

- 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 2008.

Table 13 shows the estimated energy savings for delivered fuel homes for PY 2008. These homes represent about 25 percent of the population of single family site-built homes treated in PY 2008. The average energy savings of 17.8 Mean Million British Thermal Units (MMBtu) for fuel oil main heat homes is consistent with the average energy savings of 18.1 MMBtu for natural gas main heat homes (Table 5). Homes heated with propane and other fuels had lower average savings than 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 2008 WAP Energy Impacts for Single Family Site-Built Homes
Net Savings for Delivered Fuel Main Heat

Main Heating Fuel	Heating Fuel Savings (MMBtu*/yr)	Electric Savings (kWh/yr)
Fuel Oil	17.8	511
Propane	15.8	691
Other	14.1	630
All Delivered Fuels	**16.7**	**587**

* Mean Million British Thermal Units

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 is 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 non-energy benefits to total program costs.

This report presents information on energy savings for PY 2008. In this report, the energy cost savings and cost-effectiveness are presented from three different perspectives.

- Impact on PY 2008 Clients – The first scenario documents how the program impacted PY 2008 clients. It shows the clients' first year energy cost savings based on actual energy prices in 2008 and the estimated net present value of their energy cost savings based on actual energy prices for 2008 through 2012, projected energy prices beginning in 2013, and the discount rates in effect in 2008.

- PY 2013 Analysis Perspective – The second scenario is the most relevant to analysts 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 Analysis 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 2008 Client Perspective is the most useful for documenting what the program accomplished while the PY 2013 Analysis 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 2008 Client Perspective and Tables 16 and 17 reflect the assumptions under the PY 2013 Analysis Perspective.

Table 14 shows the estimated average annual energy costs and first year cost savings for PY 2008 clients by main heating fuel type. On average, WAP clients had pre-weatherization energy bills of $2,279 and energy savings of $283 (12.4%). 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 2008 WAP Energy Impacts for Single Family Site-Built Homes
Energy Costs and Cost Savings by Main Heating Fuel
(2008 Dollars)

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$996	$952	$1,948	$178	$61	$239	12.3%
Electricity	-	$1,796	$1796	-	$187	$187	10.4%
Fuel Oil	$2,402	$1,106	$3,510	$396	$65	$461	13.1%
Propane	$2,457	$996	$3,453	$407	$69	$476	13.9%
Other	$850	$917	$1,767	$141	$61	$201	11.4%
All Clients	**$1,155**	**$1,124**	**$2,279**	**$198**	**$84**	**$283**	**12.4%**

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 1.47 for the overall program and is greater than 1.0 for all main heating fuel types. However, because of the much higher cost savings for homes heated with fuel oil or propane, the SIR is much higher for those heating fuel types.

Table 15
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel
(2008 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Heating Fuel	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**
Natural Gas	$2,738	$573	$3,311	$2,768	$543	1.20
Electricity	-	$2,802	$2,803	$2,587	$216	1.08
Fuel Oil	$7,466	$589	$8,055	$3,441	$4,614	2.34
Propane	$5,884	$656	$6,543	$2,940	$3,603	2.23
Other	$2,892	$538	$3,430	$2,739	$691	1.25
All Clients	**$3,225**	**$971**	**$4,196**	**$2,846**	**$1,350**	**1.47**

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 $2,209 and first year energy savings of $264 (11.9%). When compared to the PY 2008 energy cost savings, Table 16 shows that the projected energy cost savings for a program implemented in PY 2013 are lower than the energy cost savings experienced by clients served in 2008 because the prices of natural gas and propane are lower in 2013 than they were in 2008.

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

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$799	$1,102	$1,811	$142	$65	$208	11.5%
Electricity	-	$1,852	$1,852	-	$192	$192	10.3%
Fuel Oil	$2,606	$1,156	$3,762	$430	$68	$497	13.2%
Propane	$1,968	$1,062	$3,030	$326	$74	$399	13.2%
Other	$925	$967	$1,892	$153	$64	$217	11.5%
All Clients	**$1,027**	**$1,182**	**$2,209**	**$175**	**$88**	**$264**	**11.9%**

Other heating fuels include wood, kerosene, and coal.

However, Table 17 shows that, despite the lower first year projected energy savings for PY 2013 WAP clients, the net present value of those energy cost savings are higher because the specified discount rate for Fiscal Year (FY) 2013 is lower than the specified discount rate for FY 2008; 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 1.72 for the overall program, somewhat higher than the SIR of 1.47 experienced by the clients served by the PY 2008 program. Despite lower projected energy costs, investments in weatherization have a higher economic value because of the lower discount rate.

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)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Heating Fuel	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**
Natural Gas	$3,514	$684	$4,197	$3,012	$1,185	1.39
Electricity	-	$3,457	$3,457	$2,815	$642	1.23
Fuel Oil	$9,973	$689	$10,662	$3,744	$6,918	2.85
Propane	$7,223	$787	$8,010	$3.199	$4,812	2.50
Other	$3,588	$634	$4,222	$2,980	$1,242	1.42
All Clients	**$4,161**	**$1,176**	**$5,337**	**$3,096**	**$2,240**	**1.72**

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 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, but the estimated cost-effectiveness of installed measures was about the same for homes that received one major measure and for homes that received four major measures. (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. non-DOE Funds – Homes that were treated with both DOE and non-DOE funds had higher energy savings than homes that were treated with DOE funds alone and thereby had a great impact on client energy bills. However, homes that used only DOE funds had higher cost-effectiveness ratios. (See Table 7.6) With additional funds, WAP agencies can spend more per home and increase the number of measures installed. However, even though the additional measures have a SIR of 1.0 or greater, the average cost-effectiveness ratio is expected to decline because the SIR for the additional measure is lower than the average SIR for the measures that have already been installed.

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 U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) during Program Years (PY) 2007, 2008, and 2009. The main focus of this study is on PY 2008. The analysis uses data from a number of sources to characterize the population of single family homes 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 includes:

- Energy Impacts for Single Family Homes
- Energy Impacts for Mobile Homes
- Energy Impacts for Small Multifamily Buildings
- Energy Impacts for Large Multifamily Buildings
- Non-energy 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 non-energy impacts.

1.1 NATIONAL WEATHERIZATION ASSISTANCE PROGRAM EVALUATION OVERVIEW

WAP 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 2007. DOE furnished funding to ORNL in 2009 for a national evaluation for PYs 2007 and 2008, with a particular emphasis on PY 2008. 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:

- Impact Assessment – Characterization of the weatherization network and the households that are income-eligible for WAP, measurement and monetization of the energy and non-energy 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.

- Special Technical Studies – Examination of the performance of the program with respect to technical issues such as air sealing, duct sealing, furnace efficiency, and refrigerators.

- 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 2007, 2008, and 2009.

- 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 client's home 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.

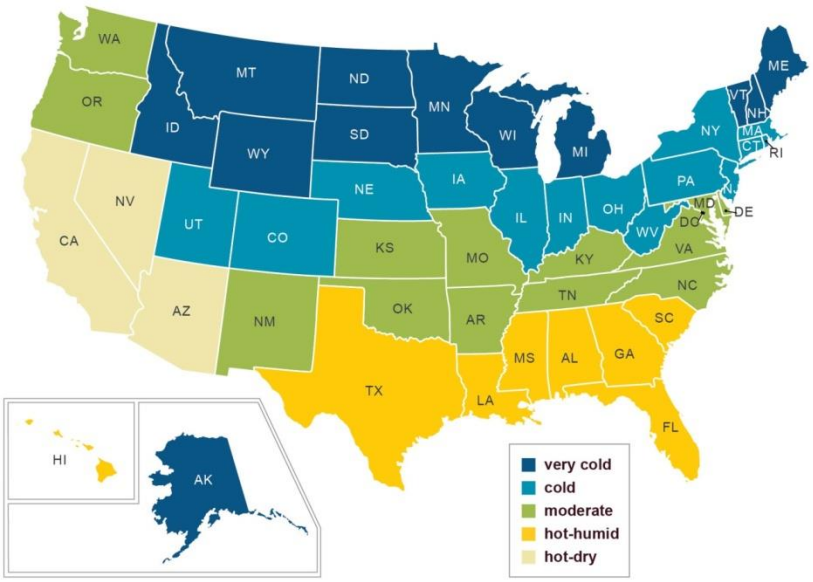

Figure 1.1 Climate Zone Map for the PY 2008 Evaluation

1.3 ORGANIZATION OF THE SINGLE FAMILY ENERGY IMPACT REPORT

The report consists of seven sections, including:

- Section 1 – Introduction: Furnishes an overview of the Weatherization Assistance Program Evaluation, the WAP Impact Evaluation, and the evaluation of single family homes.

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

- Section 3 – Program Participation, Production, and Costs: 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 – Impacts for Homes Heated with Natural Gas: Furnishes estimates of the natural gas and electric impacts for homes with natural gas main heat.

- Section 5 – Impacts for Homes Heated with Electricity: Furnishes estimates of the electric impacts for homes with electric main heat.

- Section 6 – Impacts for Homes Heated with Delivered Fuels: Reports on how sub-meter 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 – Energy Investments, Cost Savings, 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 and Nonenergy Impact Reports.

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 2007, 2008, and 2009. The main focus of the study is on PY 2008. 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 Sub-meter Studies
- U.S. Energy Information Administration (EIA) Energy Price Data and Projections
- U.S. National Climatic Data Center (NCDC) Weather Data

This section of the report describes the data collection procedures and outcomes for grantees, subgrantees, and electric and gas utilities.

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 2007, 2008, and 2009. 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 ORNL Evaluation Team selected a sample of 400 agencies with probability proportionate to size. The measure of size was planned program funding for PY 2008. The sampling procedure involved the following steps:

- Grantee Allocation – Each grantee was allocated a share of the sample of 400 subgrantees based on its share of PY 2008 program funding.

- Subgrantee Sample – For each grantee, a set of subgrantees was sampled with probability proportionate to size based on PY 2008 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.

2.1.2 Client Sampling Procedures

The APPRISE Evaluation Team contacted each of the sampled agencies to get information on clients served in PYs 2007, 2008, and 2009. The client sampling procedures involved the following steps:

- Client List – Each subgrantee furnished a list of clients for PYs 2007, 2008, and 2009.

- 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 one-third of clients in the utility main heat stratum and one-fourth of the

clients in the delivered fuel main heat stratum; for each subgrantee a minimum of 7 clients was selected for each fuel group for each year.[5]

2.1.3 Subgrantee and Client Sampling Statistics and Response Rates

The ORNL Evaluation Team selected a census of 51 grantees and a sample of 400 subgrantees. The following statistics describe the sample and the response rates:

- Grantees
  - Population – 51 grantees received WAP funding in PY 2008.
  - Census – All 51 grantees were included in the sample.
  - Response – All 51 grantees responded to information requests (100%).
- Subgrantees
  - Population
    - 905 subgrantees were listed in grantee plans for PY 2008.
    - 879 subgrantees actually received WAP funding in PY 2008.
  - Sample
    - 400 of 905 subgrantees were sampled.
    - 395 of 879 funded subgrantees were sampled.
  - Response – 379 of 395 funded subgrantees furnished client lists (96%).

The Evaluation Team selected a sample of 22,134 PY 2008 clients from the 379 funded subgrantees that furnished a list of clients. 11,328 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.

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 that heated with either natural gas or electricity. The following statistics describe the response rate to this data request:

- Sample – 395 funded subgrantees were asked to furnish a list of clients.
- Client List Response – 379 of 395 funded subgrantees furnished client lists (96%).
- Utility Data Response – 368 of 395 funded subgrantees furnished utility data for sampled clients (93%).

[5] The initial specifications called for sampling 25 percent of treated units. That is the number of units that was needed to furnish statistically robust estimates of the households and housing units served by the program and the measures installed by the WAP program. The sampling rate was increased for homes heated with natural gas and electricity to account for the attrition in available usage data; the evaluation needed to start with a larger number of homes so that the sample size after attrition would be sufficient to furnish statistically reliable results of energy usage impacts.

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

- Sample – The Evaluation Team selected a sample of 9,071 PY 2008 clients who lived in a single family home heated with natural gas or electricity from the 379 funded subgrantees that furnished client lists.

- Responding Subgrantees – The 368 subgrantees that responded to the utility data request had 8,902 of these 9,071 sampled clients (98%).

- Main Heating Supplier – The 368 subgrantees that responded furnished the heating energy supplier information for 7,943 of their 8,902 single family home clients (89%). That represents 88% of all sampled clients.

- Electric Data Supplier - The 368 subgrantees that responded furnished electric supplier information for 7,471 of their 8,902 single family home clients (84%). That represents 82% 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 2008 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 – 395 funded subgrantees were asked to furnish a list of clients.

- Client List Response – 379 of 395 funded subgrantees furnished a list of clients (96%).

- Service Delivery Data Response – 365 of 395 funded subgrantees furnished client service delivery data (92%).

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

- Sample – The Evaluation Team selected a sample of 10,924 PY 2008 clients who lived in single family homes from the 379 funded subgrantees that furnished client lists.

- Responding Subgrantees – The 365 subgrantees that responded to the client service delivery data request had 10,713 of the 10,924 sampled clients (98%).

- Client Data – The 365 subgrantees that responded furnished service delivery data for 10,340 of their 10,713 single family home clients (97%). That represents 95% 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 that 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 1/1/2006 through 12/31/2010. The following statistics describe the response rates:

- Natural Gas or Electric Main Heating Fuel
    - Companies – 580 natural gas and electric companies were identified for one or more sampled PY 2008 single family home clients.
    - Company Response – 428 of the 580 companies furnished data for one or more of the sampled clients (74%).
    - Client Response – Data were received for 6,026 of the 7,943 PY 2008 single family clients for whom a supplier was listed (76%). That is 66% of the 9,071 sampled single family home clients that heat with either natural gas or electricity.
- Electric Usage for Natural Gas Main Heat Clients
    - Companies – 428 electric companies were identified as the electric supplier for one or more PY 2008 single family home clients who heat with natural gas.
    - Company Response – 310 of the 428 electric companies furnished data for one or more of the sampled clients (72%).
    - Client Response - Data were received for 5,020 of the 6,444 PY 2008 single family clients for whom an electric supplier was listed (78%). That is 64% of the 7,809 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

The evaluation furnishes information that can be used to characterize all housing units served by the WAP in PY 2008. This report focuses on characterizing single family site-built homes.

3.1 METHODOLOGY

For PY 2008, 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 2008.

The primary data source for this section of the report was furnished by subgrantees for a sample of clients. In total, 365 subgrantees furnished detailed information for 19,496 clients who were served by the WAP in PY 2008, including 10,340 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 2008 Sampled Clients by Climate Zone

Climate Zone	PY 2008 Sampled Clients	Percent of PY 2008 Sample
Very Cold Climate	5,340	27%
Cold Climate	10,539	54%
Moderate Climate	2,464	13%
Hot/Humid Climate	623	3%
Hot/Dry Climate	530	3%
TOTAL	19,496	100%

Table 3.2
PY 2008 Sampled Clients by Housing Unit Type

Housing Unit Type	PY 2008 Sampled Clients	Percent of PY 2008 Sample
Single Family Site-Built	10,340	53%
Single Family Mobile Home	2,826	15%
Small Multifamily (2-4)	1,798	9%
Large Multifamily (5+)	4,532	23%
TOTAL	19,496	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 68 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 59 percent of the total units weatherized in PY 2008.

Table 3.3
PY 2008 Weighted Clients by Climate Zone

Climate Zone	PY 2008 Weighted Count of Clients	Percent of PY 2008 Clients
Very Cold Climate	24,749	25%
Cold Climate	42,233	43%
Moderate Climate	18,794	19%
Hot/Humid Climate	6,390	7%
Hot/Dry Climate	5,799	6%
TOTAL	97,965	100%

Table 3.4
PY 2008 Weighted Clients by Housing Unit Type

Housing Unit Type	PY 2008 Weighted Count of Clients	Percent of PY 2008 Clients
Single Family Site-Built	57,518	59%
Single Family Mobile Home	17,754	18%
Small Multifamily (2-4)	5,317	5%
Large Multifamily (5+)	17,376	18%
TOTAL	97,965	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 Hot/Humid 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 2008 Weighted Clients by Climate Zone and Housing Unit Type

Climate Zone	Single Family	Mobile Home	Small Multifamily	Large Multifamily	All Housing Unit Types
Very Cold Climate	58%	19%	9%	14%	100%
Cold Climate	57%	14%	6%	24%	100%
Moderate Climate	65%	27%	1%	7%	100%
Hot/Humid Climate	70%	17%	6%	7%	100%
Hot/Dry Climate	43%	19%	1%	36%	100%
TOTAL	59%	18%	5%	18%	100%

Table 3.6 shows the number and percent of single family homes by Climate Zone. About two-thirds of the 57,518 treated single family homes were in the Very Cold and Cold Climate Zones.

Table 3.6
PY 2008 WAP Weighted Clients in Single Family Homes by Climate Zone

Climate Zone	PY 2008 Units	Percent of PY 2008 Units
Very Cold Climate	14,323	25%
Cold Climate	23,935	42%
Moderate Climate	12,280	21%
Hot/Humid Climate	4,474	8%
Hot/Dry Climate	2,506	4%
TOTAL	57,518	100%

3.2 HOUSEHOLD CHARACTERISTICS

Table 3.7 furnishes national and Climate Zone statistics on the household characteristics for PY 2008 clients in single family homes. Overall, the single family homes served by the WAP are primarily homeowners with incomes at or near the poverty level and have a vulnerable individual living 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; almost three-fourths 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 Very Cold 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 owner-occupied.

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.

Table 3.7
PY 2008 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	13,224	14,376	14,886	11,400	9,324	15,264
Median % of Poverty	98%	99%	109%	87%	78%	102%
% < 100% of Poverty	52%	51%	43%	61%	71%	48%
Vulnerability Status						
% w/Elderly Individual	49%	36%	48%	58%	67%	47%
% w/Disabled Individual	39%	34%	35%	49%	44%	50%
% w/Children	31%	39%	31%	23%	22%	38%
Household Status						
% Homeowner	87%	86%	86%	92%	96%	66%
Mean Household Size	2.5	2.7	2.5	2.2	2.1	3.0
% Single Parent	20%	17%	21%	20%	27%	15%
% Single Elderly	28%	21%	27%	34%	40%	22%
Race/Ethnicity						
% White non-Hispanic	66%	74%	75%	61%	33%	33%
% Black non-Hispanic	24%	14%	17%	31%	56%	6%
% Hispanic	7%	5%	6%	5%	9%	55%
% Asian	1%	1%	1%	1%	1%	3%
% Native American	3%	7%	1%	2%	<1%	3%
% Other	<1%	<1%	<1%	<1%	2%	0%

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

- Income - In most Climate Zones, almost all of the households have incomes at or below $30,000 per year. In the Hot/Humid Climate Zones, almost 90 percent of households have incomes at or below $20,000 per year.

- Poverty – A small percentage of the households have incomes above 150 percent of poverty. Some grantees use 60 percent of state median income as the income standard.

Table 3.8
PY 2008 Clients in Single Family Homes
Distribution of Income and Poverty by Climate Zone

Variable	Percent of Population				
	10%	25%	Median	75%	90%
Income					
Very Cold Zone	$6,469	$9,576	$14,376	$21,275	$29,963
Cold Zone	$6,983	$10,200	$14,886	$21,444	$30,237
Moderate Zone	$6,888	$8,088	$11,400	$16,140	$22,776
Hot/Humid Zone	$1,080	$7,056	$9,324	$13,878	$20,434
Hot/Dry Zone	$5,100	$9,900	$15,264	$21,024	$28,611
ALL ZONES	$6,213	$8,756	$13,224	$19,740	$27,972
Percent of Poverty					
Very Cold Zone	41%	70%	99%	129%	152%
Cold Zone	43%	76%	109%	139%	172%
Moderate Zone	43%	72%	87%	115%	141%
Hot/Humid Zone	9%	47%	78%	104%	128%
Hot/Dry Zone	20%	67%	102%	140%	169%
ALL ZONES	38%	72%	98%	129%	157%

Table 3.9 shows how ownership status varies by demographic group. Households with an elderly member were most likely to be owner-occupied. However, over 80 percent of all demographic groups were homeowners.

Table 3.9
PY 2008 Clients in Single Family Homes
Home Ownership by Demographic Group

Demographic Group	% Owners	% Renters
Elderly Households	93%	6%
Disabled Households	87%	12%
Households with Children	83%	16%
Single Parent Households	84%	16%
Single Elderly Households	93%	7%

3.3 HOUSING UNIT CHARACTERISTICS

Table 3.10 furnishes national and Climate Zone statistics on the housing unit characteristics for PY 2008 clients in single family homes. The overall finding is that single family homes treated by the WAP are most likely to be small detached homes. The majority are single story.

Table 3.10
PY 2008 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	1,272	1,357	1,340	1,164	1,236	1,360
Mean Heated Space	1,418	1492	1,502	1,231	1,293	1,342
% One Story	61%	49%	46%	84%	98%	94%
% Detached	94%	98%	89%	98%	94%	97%
Housing Vintage						
% Pre-1940	32%	38%	39%	22%	8%	7%
% 1940-1969	43%	35%	44%	46%	50%	37%
% 1970 or Later	26%	27%	17%	32%	42%	56%
Pre WX Status						
Mean Furnace SSE	81%	81%	80%	79%	82%	75%
Mean CFM 50	3,638	2,993	3,707	4,059	4,650	2,050
Mean HDD* 65	5,398	7,460	5,791	4,058	1,954	2,790
Mean CDD** 65	1,042	538	823	1,338	2,462	1,998

* Heating Degree Days
** Cooling Degree Days

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, almost all of the homes are one story.

- Housing Unit Age – The majority of housing units in the Very Cold and Cold Climate Zones were built prior to 1970, while the majority of housing units in the other Climate Zones were built 1940 or later. More than one-third were built after 1970.

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

Table 3.11 shows the distribution of homes with respect to pre-weatherization indicators. In most Climate Zones more than 50 percent of the homes had significant potential for reduction of air leakage and improvements in energy efficiency. Even in the Hot/Dry Climate Zone, at least 25 percent of the homes needed reduction in air leakage rates.

Table 3.11
PY 2008 Clients in Single Family Homes
Distribution of Pre WX Status by Climate Zone

Variable	Percent of Population				
	10%	25%	Median	75%	90%
CFM 50					
Very Cold Zone	1,358	1,900	2,714	3,800	4,950
Cold Zone	1,727	2,408	3,372	4,654	5,957
Moderate Zone	1,782	2,640	3,750	4,930	6,750
Hot/Humid Zone	2,200	2,960	4,150	5,820	7,999
Hot/Dry Zone	1,227	1,354	1,834	2,700	3,000
ALL ZONES	1,604	2,260	3,298	4,550	5,998
SSE					
Very Cold Zone	71%	77%	81%	87%	93%
Cold Zone	72%	77%	80%	84%	90%
Moderate Zone	70%	74%	80%	83%	87%
Hot/Humid Zone	70%	80%	80%	86%	90%
Hot/Dry Zone	62%	65%	76%	86%	87%
ALL ZONES	70%	77%	80%	84%	91%

Table 3.12 furnishes national and climate zone statistics on the heating and cooling systems for PY 2008 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 in all regions. In the Moderate and Hot Zones, more electric heat is used. Fuel oil is used in the colder Climate Zones, while propane is used more consistently across zones.

- Main Heating Equipment – About 90 percent of the households served in the Very Cold and Cold Zones had central heating systems, while over one-third of the clients in the Moderate and Hot 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.

The energy use patterns and energy efficiency opportunities vary considerably by Climate Zone.

Table 3.12
PY 2008 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	60%	63%	70%	41%	44%	66%
% Electric	14%	6%	6%	29%	39%	20%
% Fuel Oil	14%	16%	17%	10%	1%	3%
% Propane	9%	12%	4%	13%	16%	11%
% Other	3%	3%	3%	6%	<1%	1%
Heating System Type						
% Central Forced Air	67%	77%	71%	58%	48%	55%
% Boiler (hydronic/steam)	12%	11%	21%	2%	1%	0%
% Wall/Room Heater	11%	7%	3%	22%	31%	22%
% Electric Baseboard	4%	3%	3%	5%	2%	9%
% Heat Pump	2%	<1%	<1%	6%	3%	10%
% Portable Space Heater	2%	1%	1%	3%	7%	<1%
% Cooking Stove	<1%	<1%	<1%	<1%	0%	0%
% No Heating Source	3%	1%	2%	4%	9%	3%
Supplemental Heat						
% Electric	9%	8%	8%	12%	16%	1%
% Wood	8%	9%	5%	13%	0%	3%
% Kerosene	1%	<1	1%	3%	2%	0%
Air Conditioning Type						
% Central AC	39%	26%	29%	53%	51%	46%
% Window/Wall	29%	12%	36%	30%	42%	12%
% Evaporative Cooler	4%	<1 %	4%	2%	0%	27%
% None	30%	62%	32%	16%	8%	20%
Water Heating Fuel						
% Natural Gas	55%	55%	68%	34%	39%	65%
% Electric	35%	33%	21%	59%	50%	23%
% Fuel Oil	4%	3%	7%	<1%	<1%	0%
% Propane	6%	8%	3%	6%	11%	11%

3.4 WAP ENERGY DIAGNOSTICS

Table 3.13 shows the overall diagnostic approach used by subgrantees for the sample of homes treated in PY 2008. At the national level, about 40 percent of client homes were assessed using an audit tool and 60 percent were treated using a priority list.

Table 3.13
PY 2008 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						
% Weatherization Assistant	21%	49%	6%	26%	13%	0%
% TIPS[6]	5%	0%	11%	0%	0%	0%
% Other Audit	15%	16%	18%	8%	20%	0%
% Priority List	56%	34%	61%	62%	63%	100%
% Other	3%	1%	4%	5%	4%	0%

Table 3.14 shows the specific air leakage and heat loss diagnostics completed by subgrantees for the homes treated in PY 2008. The findings include:

- Pressure Testing – Subgrantees reported that almost 90 percent of client homes received a blower door test. Zonal pressure tests were reported for about three in ten homes and room-to-room pressure balancing was reported in about two in ten homes.

- Duct Testing – For about one in four homes that had ducts, some form of duct leakage testing was conducted. Pressure pan tests were most common. However, in some Climate Zones, almost one home in ten was tested using a duct blaster.

- IR Scanning – IR cameras were used for about one in five client homes. In the Cold Climate Zone, it was reported that one in three homes had an IR scan.

[6] Targeted Investment Protocol System

Table 3.14
PY 2008 Clients in Single Family Homes
Air Leakage and Insulation Diagnostics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Pressure Testing						
% Blower Door	87%	93%	88%	87%	87%	46%
% Zonal Pressure	29%	35%	27%	30%	17%	20%
% Room-to-Room Balance	17%	10%	21%	17%	19%	20%
Duct Testing (% for homes with ducts)						
% Any Duct Test	25%	6%	24%	47%	31%	39%
% Pressure Pan	22%	4%	20%	44%	32%	30%
% Duct Blaster	4%	2%	2%	7%	8%	9%
% Blower Door Subtraction	6%	2%	7%	8%	8%	4%
Infrared Scanning	19%	11%	33%	10%	5%	0%

Table 3.15 shows the specific equipment testing completed by subgrantees for the homes treated in PY 2008. Combustion equipment can be tested both for efficiency and for safety, while electric equipment can be tested for operating efficiency.

- Furnaces – Overall testing was conducted in about one-half of homes nationally. However, testing was much more common in the Very Cold and Cold Climate Zones.

- Water Heaters – About one in three water heaters had flue gas analysis; the highest rate was in the Cold Climate Zone, where almost one-half of homes were tested. In the Hot Climate Zones, only about one in ten homes was tested. Water flow rates were tested for about one in ten homes nationally, with the highest testing rate reported in the Hot/Dry Climate Zone.

- Air Conditioners – Air conditioner testing was completed in a very small share of the homes, even in the Hot Climate Zones.

- Refrigerators – About four in ten refrigerators were metered nationwide. The highest rate was in the Cold Climate Zone, where about one-half of refrigerators were metered.

Table 3.15
PY 2008 Clients in Single Family Homes
Equipment Diagnostics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Furnace Testing (% for Homes Applicable)						
% Flue Gas Analysis	59%	63%	80%	35%	23%	36%
% Temperature Rise	31%	27%	50%	19%	5%	1%
% Thermostat Anticipator	10%	10%	14%	6%	5%	1%
Water Heater Testing (% for Homes Applicable)						
% Flue Gas Analysis	49%	47%	68%	29%	25%	33%
% Hot Water Temperature	39%	31%	51%	37%	23%	11%
% Showerhead Flow Rate	12%	5%	15%	15%	6%	21%
% Faucet Flow Rate	9%	2%	10%	11%	7%	21%
Air Conditioner Testing (% For Homes Applicable)						
% Refrigerant Charge	2%	<1%	1%	3%	7%	0%
% Air Handler Rate	5%	3%	5%	6%	5%	6%
Refrigerator Usage Metering	38%	30%	52%	27%	36%	20%

3.5 WAP INSTALLED MEASURES

Tables 3.16, 3.17, and 3.18 furnish information on the rates at which different types of measures were installed in PY 2008. Table 3.16 shows the rate at which air sealing and shell measures were installed in PY 2008.

- Air Sealing – Subgrantees reported that air sealing was completed in over 90 percent of homes; bypass sealing using a blower door was reported for almost 70 percent of homes.

- Attic Insulation – Attic insulation was reported for 70 percent of homes, with at least 26 percent installed where none previously existed. The Hot/Humid Climate Zone showed the highest incidence of treated homes receiving attic insulation where none previously existed.

- Wall Insulation – About 30 percent of homes had wall insulation installed. The rate was close to 40 percent in the Very Cold Climate Zone, but only about 20 percent in the Moderate and Hot/Humid Climate Zones. No wall insulation was reported by agencies in the Hot/Dry Climate Zone.

- Other Insulation – Other types of insulation were installed in a significant number of homes. [Note: Since foundation type was not available, the incidence for eligible households could not be computed.]

Air sealing and attic insulation are common and important measures installed in homes. Wall insulation and other insulation types are less common. Higher installation rates are observed in the colder climate zones.

Table 3.16
PY 2008 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						
Bypass Sealing w/ Blower Door	68%	73%	71%	66%	66%	16%
Bypass Sealing w/o Blower Door	11%	10%	11%	7%	14%	37%
Caulking w/o Bypass Sealing	13%	12%	10%	17%	15%	21%
Any Bypass Sealing Or Caulking	92%	95%	92%	91%	95%	74%
Attic Insulation						
% Installed (None Existing)	26%	25%	24%	29%	37%	3%
% Installed (Over Existing)	38%	51%	35%	34%	38%	17%
% Installed (Unknown)	6%	2%	12%	4%	1%	<1%
% Installed (All Types)	70%	78%	71%	67%	77%	21%
Wall Insulation						
% Installed (Regular)	8%	11%	8%	7%	10%	0%
% Installed (Dense Pack)	21%	28%	28%	10%	7%	0%
% Installed (All Types)	29%	39%	35%	17%	18%	0%
Other Insulation						
% Floor Insulation	15%	12%	15%	25%	5%	8%
% Rim/Band Joist Insulation	17%	27%	24%	2%	<1%	0%
% Foundation Insulation	4%	7%	6%	1%	0%	0%

Table 3.17 shows the rate at which heating and water heating equipment measures were installed in PY 2008.

Table 3.17
PY 2008 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						
New Furnace (ECM*)	12%	20%	10%	7%	8%	18%
New Furnace (non ECM)	10%	9%	13%	7%	12%	3%
Heating System Tune-Up	18%	25%	23%	11%	5%	0%
Other Heating System Repairs	4%	3%	4%	4%	1%	9%
Programmable Thermostat	2%	1%	2%	1%	3%	3%
Any Heating System Measure	48%	61%	54%	32%	31%	34%
Heating Ducts (% Of Systems With Ducts)						
Duct Sealing	42%	38%	45%	43%	27%	43%
Duct Insulation	3%	3%	4%	3%	6%	0%
Water Heating Equipment						
New Water Heater (ECM)	3%	5%	2%	1%	3%	5%
New Water Heater (nonECM)	6%	10%	6%	2%	3%	3%
Water Heater Repair	8%	9%	11%	5%	2%	4%
Water Measures						
Tank Wrap	26%	18%	23%	37%	42%	6%
Pipe Wrap	44%	45%	45%	49%	35%	4%
Temperature Reduction	9%	8%	10%	11%	10%	1%
Showerhead	22%	21%	19%	23%	26%	49%
Faucet Aerator	22%	27%	18%	19%	21%	47%

* Energy conservation measure (ECM)

The key findings from Table 3.17 include:

- Heating Equipment – Heating equipment replacement was reported for about 22 percent of client homes, with about one-half being an energy conservation measure (ECM) and the other half being primarily for health and safety. Overall, close to one-half of the homes had some heating system work completed. Equipment replacement rates were higher in the colder climate zones and lower in the warmer zones.

- Ducts – Duct sealing was reported in about 40 percent of homes. Duct sealing rates were consistent across climate zones, but were low in the Hot/Humid Climate Zone.

- Water Heating Equipment – A small share of homes had water heater equipment measures; nationally only about 10 percent of equipment was replaced, most often for health and safety reasons. Another 10 percent of water heaters were repaired.

- Other Water Measures – The most common water measure was pipe wrap, delivered to about four in ten homes. In addition, about 20 percent of homes had water heater wraps, low-flow showerheads, and faucet aerators installed.

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. It was more common to replace the equipment because it was not operating safety, or was not working at all. Sealing ducts and installing other water heating measures were more commonly reported measures.

Table 3.18 shows the rate at which door and window measures were installed in PY 2008. The statistics show that about four in ten homes had some form of window measure and about four in ten homes had some form of door measure. About 10 percent of clients had one or more windows replaced for energy efficiency reasons. About 10 percent of clients also had a door replaced for energy efficiency reasons.

Table 3.18
PY 2008 Clients in Single Family Homes
Door and Window Measures by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Windows						
New Window (ECM)	11%	7%	11%	13%	11%	16%
New Window (non ECM)	6%	6%	7%	3%	4%	3%
Storm Window	3%	4%	2%	5%	<1%	1%
Window Glazing	8%	7%	8%	8%	15%	4%
Other Window Repair	9%	6%	7%	13%	19%	10%
Any Window Measure	37%	30%	36%	43%	50%	36%
Doors						
New Door (ECM)	11%	8%	10%	12%	15%	12%
New Door (non ECM)	7%	7%	7%	8%	8%	5%
Storm Door	<1%	<1%	<1%	1%	1%	0%
Door Repair	9%	4%	6%	13%	18%	11%
Other Door Measure	13%	11%	15%	12%	12%	6%
Any Door Measure	40%	30%	40%	46%	55%	34%

Table 3.19 shows the rate at which air conditioning and electric baseload equipment measures were installed in PY 2008.

- Air Conditioning – Nationally only a few clients received air conditioning measures. Installation rates were higher in the hot climate zones; 30 percent of clients in the Hot/Humid Zone and 20 percent of the clients in the Hot/Dry Zone had AC equipment measures, and close to 10 percent in each zone had new AC equipment installed.

- Duct Sealing – Over all climate zones, about 40 percent of homes with cooling system ducts had duct sealing, with a lower rate in the Hot/Humid Climate Zone.

- Other Electric Measures – About 60 percent of clients received some form of energy efficient lighting and about 15 percent received new refrigerators or freezers. Installation rates for refrigerators are slightly lower in the Moderate and Hot/Humid Climate Zones.

These statistics show that the WAP made some investments in air conditioning and electric baseload measures, but at lower rates than for weatherization measures.

Table 3.19
PY 2008 Clients in Single Family Homes
Air Conditioning and Electric Baseload Equipment Measures by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Air Conditioning (% w/ AC Units)						
New Air Conditioner (ECM)	1%	<1%	<1%	<1%	8%	9%
New Air Conditioner (non ECM)	<1%	0%	<1%	<1%	1%	<1%
Air Conditioner Repair	1%	<1%	<1%	1%	3%	7%
Air Conditioner Tune-Up	2%	0%	<1%	3%	13%	0%
Other Air Conditioner Measure	2%	<1%	2%	1%	5%	5%
Any Air Conditioning Measure	5%	1%	2%	5%	30%	21%
Cooling Ducts (% with Ducts)						
Duct Sealing	40%	46%	45%	40%	25%	49%
Duct Insulation	3%	4%	3%	3%	6%	0%
White Roof Coating	<1%	<1%	<1%	<1%	1%	0%
Other Electric Measures						
Lighting (Inside or Outside)	63%	68%	62%	57%	61%	70%
Refrigerator (ECM)	12%	19%	12%	6%	5%	15%
Refrigerator (non ECM)	1%	2%	1%	<1%	2%	<1%
Freezer	2%	6%	1%	0%	0%	0%
Other Baseload Measures	4%	7%	4%	1%	<1%	6%

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 savings levels among the different Climate Zones.
- Technical Approach – Assessment of differential savings by energy audit procedure, type of advanced building diagnostics used, and crew vs. contractor work.
- 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 was performed to estimate the energy savings attributable to individual program measures and to extrapolate the savings from the gas analysis sample to the full program population of gas heated homes as well as homes heated by delivered fuels.

A report drafted by ORNL entitled *Weatherization Works*[7] includes a summary of energy impacts for all building types as well as information on cost-effectiveness and nonenergy impacts.

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[8] 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.

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 2009 were used as a comparison group for the PY 2008 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

[7] Tonn et al. 2014. Weatherization Works – Summary of Findings from the Retrospective Evaluation of the U.S. Department of Energy's Weatherization Assistance Program. ORNL/TM-2014/338, Oak Ridge National Laboratory, Oak Ridge, Tennessee. National Laboratory, Oak Ridge, TN.
[8] See "PRISM: An Introduction," Margaret Fels, Energy and Buildings 9, #1-2, pp. 5-18 (1986).

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.

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[9] 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 sometime occur using the standard house-level approach.

4.1.2 Sample Attrition

A total of 7,547 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 more than 60% of the sampled homes. The usage data provided were not sufficient for developing savings estimates for 13.5% of the gas analysis homes and 18.7% of the electric analysis homes. 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 about 5% of the sampled cases (about 10% of the cases that had sufficient data). Many of these cases had less than a full year of data in either the pre or post periods. An additional 1.7% of sampled cases in the gas analysis had gas usage too low to be considered gas heated and occupied during both periods (and one case had usage too high to be considered single family). Just 0.2% of electric cases were classified as having usage either too low to be occupied or too high to be single family. Less than 1% of the sampled homes were removed from the analysis because they were declared

[9] 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.

savings outliers[10]. The table also shows that there were homes added to the sampled units due to the availability of data for more homes from one state that was pursuing a state-level evaluation.

Table 4.1
PY 2008 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	7,547	100%	7,547	100%
No Usage Data From Utility	2,831	37.5%	2,987	39.6%
Insufficient Data	1,018	13.5%	1,414	18.7%
Poor Model Fit	360	4.8%	354	4.7%
Usage Infeasible: Vacant, Unheated, Not SF	127	1.7%	18	0.2%
Savings Outlier	26	0.3%	49	0.7%
Usable Cases	3,185	42.2%	2725	36.1%
Additional Usable Cases (not sampled)	313		266	
Total Usable Analysis Sample	3,498		2,991	

The same screening criteria were also applied to the comparison group analysis, and the attrition rates were generally similar with the exception of the comparison group having about twice as many cases declared as outliers (though still less than 4% of otherwise-usable cases). The greater frequency of outliers in the comparison group was expected given that 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.

[10] 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 4.2
Characteristics of Single Family Site-Built Homes

Characteristic	All Homes	Gas Heated Homes		
		All Gas Heated	Gas Analysis Sample	Electric Analysis Sample
Climate				
Very Cold	25%	26%	26%	25%
Cold	42%	48%	53%	52%
Moderate	21%	14%	11%	13%
Hot-Humid	8%	6%	5%	4%
Hot-Dry	4%	5%	5%	6%
Demographics				
Median Income	$13,224	$13,684	$13,980	$13,802
Homeowner	82%	82%	89%	90%
Elderly	42%	41%	48%	47%
# Occupants	2.5	2.6	2.6	2.6
Housing Characteristics				
Heated Area	1421	1433	1504	1505
Median Age	67	67	67	67
HDD 65	5438	5580	5805	5759
CDD 65	1026	994	942	937
Central heating	86%	89%	92%	90%
Central A/C	36%	38%	43%	44%
Wx Diagnostics				
Weatherization Assistant Audit	22%	22%	25%	24%
Building Leakage test	88%	87%	90%	90%
Duct leakage test	19%	18%	16%	16%
Major Measures				
Heater replacement	21%	26%	28%	28%
Attic Insulation	69%	70%	74%	71%
Wall Insulation	29%	33%	34%	31%
Air Sealing >1000 CFM50	42%	41%	40%	37%
Refrigerator Replaced	13%	15%	17%	17%

Note – Results weighted by sample design selection probabilities.

Because of the attrition, the gas usage analysis sample has more homes in the cold and very cold climate zones, more homeowners and homes with elderly occupants, slightly larger homes, and homes that received more heating system replacements and attic insulation than the full population. The electric analysis sample is more likely to have a refrigerator replacement than the population at large. These differences in climate and measure installation rates can be expected to lead to higher savings in the analysis sample than in the larger population. This issue is addressed in developing program population impact estimates in Section 4.10.

4.3 ENERGY SAVINGS OVERALL AND BY END USE

Table 4.3 summarizes natural gas impacts and shows a break out of savings by weather-normalization component – heating[11] vs. baseload (non-heating) gas consumption. The overall gas savings are estimated at 181 therms[12] per year, equal to 17.8% of pre-program gas usage. Space heating accounted for 79% of the gas usage and achieved 87% of the total gas savings. The heating savings averaged 19.4% of pre-program heating use. There was also an 11.5% reduction in the baseload portion of gas usage (e.g., water heating and cooking).

Table 4.3
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Gas Savings Total and by End Use (therms*/yr)

Group/Breakout	# Homes	Gas Use Pre-WAP	Gas Use Post-WAP	Gross Savings	Net Savings	% of Pre
Total Use	3,498	1,020	825	195 (±12)	181 (±13)	17.8% (±1.2%)
Comparison	3,118	974	960	14 (±3)		
Heating Use	3,498	806	634	172 (±10)	157 (±11)	19.4% (±1.3%)
Comparison	3,118	772	757	15 (±4)		
Baseload Use	3,498	214	191	23 (±4)	25 (±4)	11.5% (±2.1%)
Comparison	3,118	202	203	-1 (±3)		

*100,000 British Thermal Units

The distribution of participants' pre-program total gas use is shown in Figure 4.1. The median annual gas use for participants was 980 therms and half of all homes use between 755 and 1,280 therms. Ten percent of homes used less than 593 therms and ten percent used more than 1,566 therms. The comparison group distribution (not shown) was very similar.

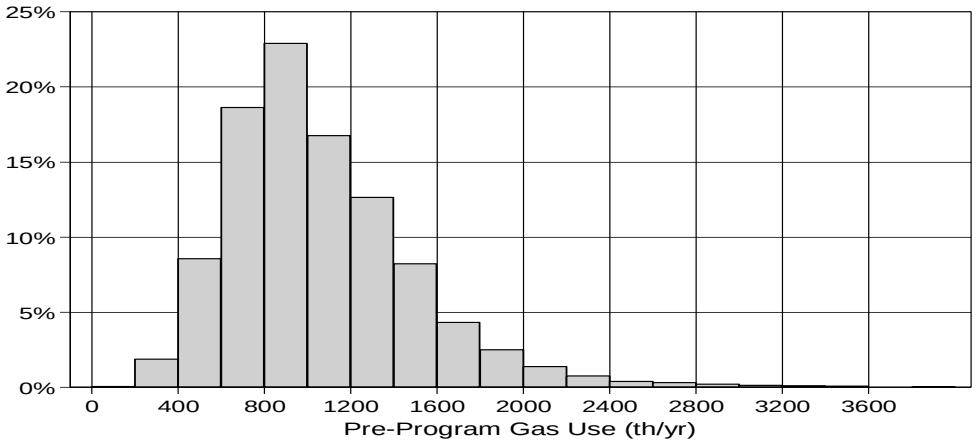

Figure 4.1: Distribution of Pre-Program Gas Use for Single Family Participants

[11] 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 Non-heating 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.
[12] 100,000 British Thermal Units

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 shows that almost 25 percent of households had a weather-normalized change in gas usage of between -2.5% and +2.5%. For about 20 percent of households, the change was less than -12.5% or greater than +12.5%. Some of the sources of these changes include: increases or decreases in the number of household members (e.g., child graduates and moves out; elderly parent gets ill and 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 are normal changes that affect households at all income levels and in all areas. Table 4.3 shows that, with all of those potential changes, the average weather-normalized gas usage for Comparison Group households changed by about 14 therms (1.5%). 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 16.5%, showing that the Participant Group households reduced their gas usage by substantially more than the Comparison Group households. Second, the graph for the Participant Group is more spread out; a little over 10 percent of households had their usage change by +/- 2.5% percent from the median change compared to almost 25 percent in that bin for the Comparison Group households. This shows that the variability in the change in gas usage is greater for the Participant Group households than for Comparison Group households.

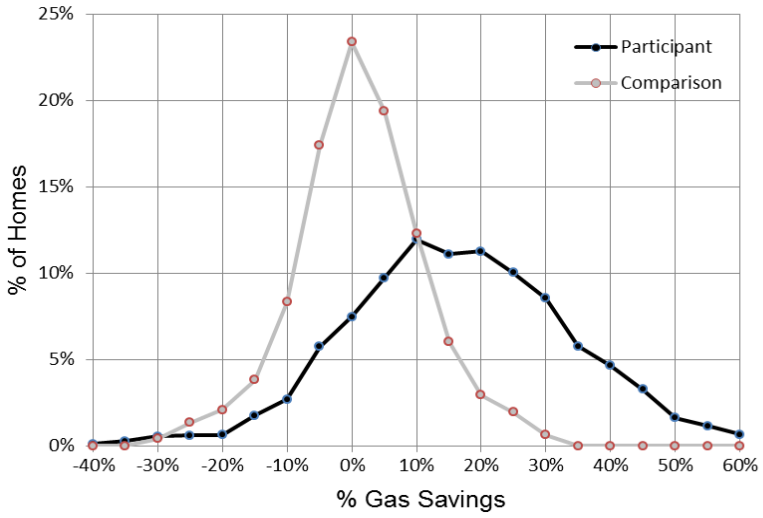

Figure 4.2: Distribution of Percent Gas Use Reduction – Participants and Comparison Group

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

- Weather-normalized usage for Treatment Group households fell by 19.1 percent and by 1.5 percent for Comparison Group households; the net impact of weatherization was to shift the gas savings graph to the right by about 17.5 percent.

- Treated homes each received a different set of measures. (See Tables 3.16 through 3.19). 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 Treatment 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 Treatment 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% or more due to non-program 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.

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. Approximately three quarters of the electric use and savings are classified as baseload (i.e., non-seasonal).

Table 4.4
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Electric Savings for Natural Gas Main Heat by End Use

Usage Component	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
Total Use	2,991	9,528	8,792	735 (±102)	680 (±140)	7.1% (±1.5%)
Comparison	2,204	9,401	9,344	56 (±67)		
Heating/Winter Use	2,991	1,037	904	134 (±66)	90 (±77)	8.7% (±7.4%)
Comparison	2,204	918	874	44 (±35)		
Cooling/Summer Use	2,991	1,264	1,192	71 (±39)	80 (±54)	6.3% (±4.3%)
Comparison	2,204	1,481	1,489	-9 (±37)		
Baseload Use	2,991	7,227	6,696	531 (±75)	510 (±107)	7.1% (±1.5%)
Comparison	2,204	7,002	6,981	21 (±61)		

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. However, about 15% of these gas heated homes had apparent 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% of the homes and exceeded 4,000 kWh in 5% of the homes. Net electric heating component savings in these homes averaged 9% (245 kWh) for homes with estimated heating use between 2,000 and 4,000 kWh and 23% (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 annual cooling/summer use averaged 1,264 kWh, indicating modest use of air conditioning on average in gas-heated WAP homes – especially because seasonality in refrigerator energy use, fans, and other seasonal loads could account for much of this value. The cooling/summer load averaged twice as large in homes reported to have central air conditioning as those without – 1,925 kWh vs. 930 kWh – and the cooling/summer savings averaged 7% for both groups.

The distribution of participants' pre-program total electric use is shown in Figure 4.3. The median annual electric use for participants was 8,099 kWh with half of all homes using between 5,469 and 11,527 kWh.

Ten percent of homes used less than 3,864 kWh and ten percent used more than 15,535 kWh. The comparison group distribution was very similar.

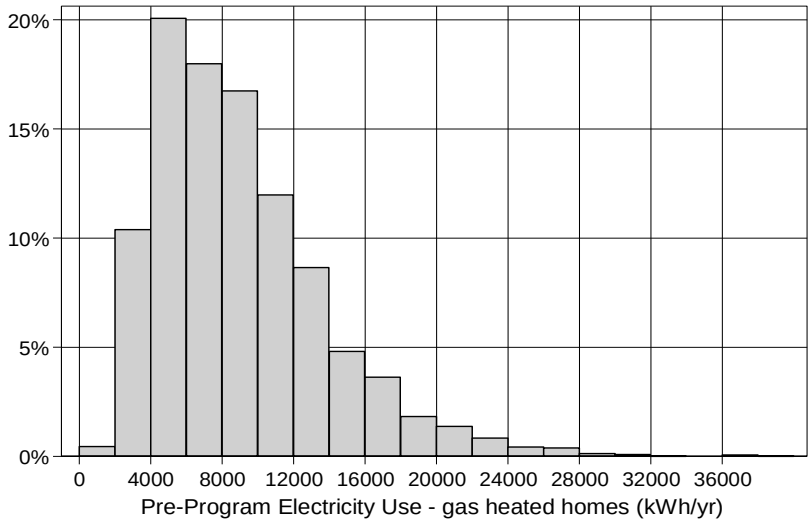

Figure 4.3: Distribution of Pre-Program Electric Use for Gas-Heated Single Family Participants

The distribution of percent electric savings for gas-heated participants and the comparison group 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 15 percent of households had a weather-normalized change in electric usage between -2.5% and +2.5%. For about 20 percent of the households, the change was less than -22.5% or greater than +22.5%. Some of the sources of these changes include: increases or decreases in the number of household members (e.g., child graduates and moves out; elderly parent gets ill and 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 are normal changes that affect households at all income levels and in all areas. Table 4.4 shows that, with all of those potential changes, the average weather-normalized usage for Comparison Group households changed by about 56 kWh per year (0.6%).

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 substantially more than the Comparison Group households. Second, the graph for the Participant Group is more spread out; a little over 10 percent of households had their usage change by +/- 2.5% percent from the median change compared to 15 percent in that bin for the Comparison Group households. This shows that the variability in the change in energy usage is greater for the Participant Group households than for Comparison Group households.

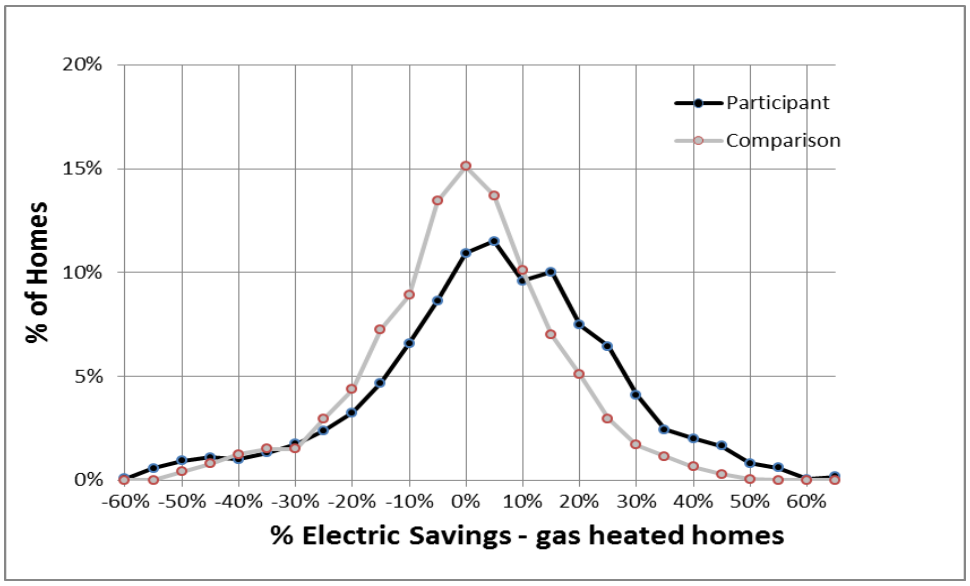

Figure 4.4: Distribution of Percent Electric Use Reduction – Gas-Heated Participants and Comparison Group

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

- Weather-normalized electric usage for Treatment Group households fell by 7.7 percent and by 0.6 percent for Comparison Group households; the net impact of weatherization was to shift the electric savings graph to the right by about 7.1 percent.

- Treated homes each received a different set of measures. (See Tables 3.16 through 3.19). 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 Treatment 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 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, any observed increase in electric usage for Treatment Group homes is smaller than the increase would have been without weatherization.

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 saving less than the 25th percentile of savings (<47 therms)

- High savers = Participants saving more than the 75th percentile of savings (>292 therms), and

- Mid-savers = Participants with 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. 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-Dry Climate Zone.

Table 4.5
PY 2008 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	27%	26%	27%
Cold	45%	53%	62%
Moderate	12%	13%	7%
Hot-Humid	5%	6%	3%
Hot-Dry	11%	4%	1%
Demographics			
Median Income	$14,136	$13,424	$14,812
Homeowner	91%	88%	88%
Elderly	50%	46%	44%
# Occupants	2.5	2.6	2.6
Housing Characteristics			
Heated Area	1536	1464	1546
Median Age	67	67	87
HDD65	5499	5791	6133
CDD65	1052	949	819
Central heating	90%	92%	95%
Central AC	49%	44%	34%
Wx Diagnostics			
Weatherization Assistant Audit	22%	26%	26%
Building Leakage Test	86%	91%	92%
Duct Leakage Test	19%	16%	15%
Major Measures			
Heater Replacement	17%	26%	44%
Attic Insulation	55%	78%	83%
Wall Insulation	18%	31%	54%
Air Sealing >1000 CFM50	30%	36%	59%
Refrigerator Replaced	17%	16%	20%

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[13]. Table 4.6 summarizes the gas savings results with participants grouped by the major measures they received in fifteen combinations.

Table 4.6
PY 2008 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	342	866	59 (±16)	6.8 (±1.8)
One Major Measure				
Heater Replacement	105	954	134 (±26)	14.1 (±2.7)
Attic Insulation	675	961	117 (±8)	12.2 (±0.8)
Wall Insulation	67	977	107 (±11)	10.9 (±1.1)
Seal: >1000 CFM50	136	1,137	117 (±38)	10.3 (±3.4)
Any One Major Measure	983	989	118 (±9)	12.0 (±0.9)
Two Major Measures				
Heater & Attic	263	1,082	205 (±14)	19.0 (±1.3)
Heater & Wall	22	968	208 (±74)	21.5 (±7.7)
Heater & Seal	40	1,351	245 (±51)	18.2 (±3.8)
Attic & Wall	309	930	172 (±12)	18.4 (±1.3)
Attic & Seal	318	1,036	159 (±28)	15.4 (±2.7)
Wall & Seal	21	1,186	223 (±74)	18.8 (±6.3)
Any Two Major Measures	973	1,035	181 (±14)	17.5 (±1.3)
Three Major Measures				
Heater & Attic & Seal	134	1,098	258 (±38)	23.5 (±3.4)
Heater & Attic & Wall	116	1,116	344 (±54)	30.8 (±4.8)
Heater & Wall & Seal	22	1,319	331 (±129)	25.1 (±9.8)
Attic & Wall & Seal	347	1,161	276 (±20)	23.7 (±1.7)
Any Three Major Measures	619	1,146	286 (±19)	25.0 (±1.7)
All Four Major Measures	192	1,220	414 (±28)	33.9 (±2.3)

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

[13] Major air sealing was defined as a leakage reduction measured by blower door testing of at least 1000 CFM50.

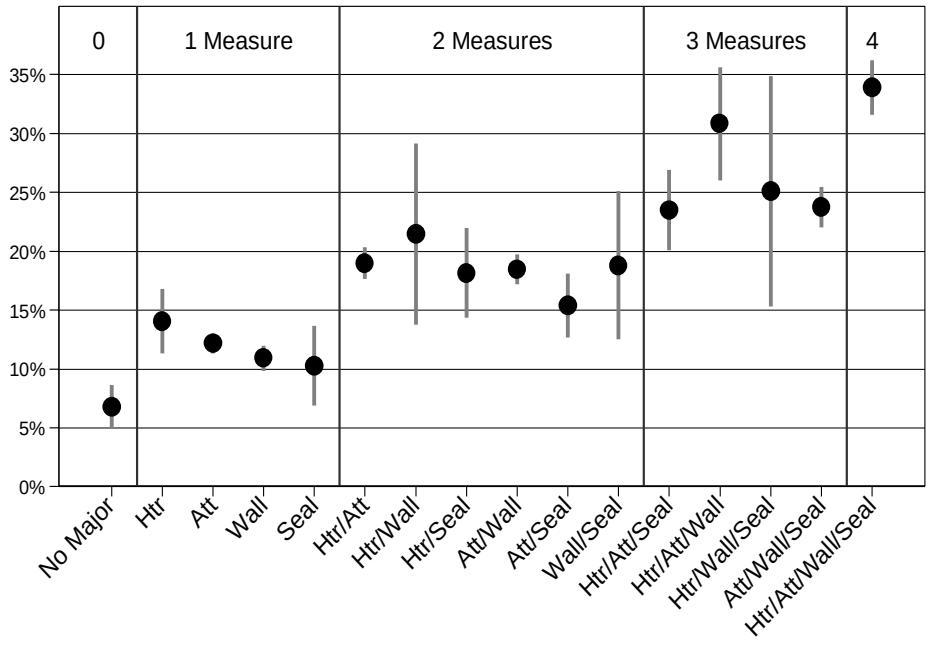

Figure 4.5: Percent Gas Savings by Measures Installed

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 11% of treated homes that received none of the major measures saved 59 therms, equal to 6.8% of their low pre-WAP gas use. 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 other homes. These homes also may have received a variety of other measures as applicable 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 homes that received only one major measure averaged 118 therms of savings equal to 12% of usage. Heating system replacements appeared to provide more savings than the other measures, although the differences between measures were not statistically significant.

- Multiple Measures – Homes that received more measures generally had high pre-weatherization usage, achieved higher levels of savings, and had a higher percentage of savings. Savings averaged 25% among the program homes that received 3 major measures and averaged 33.9% in the 6% of homes that received all four measures.

Table 4.7 summarizes the electric savings associated with two key electric baseload measures – refrigerator replacements and lighting retrofits. Both measures are associated with higher electric savings. Homes that had refrigerator replacements had the highest energy savings.

Table 4.7
PY 2008 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	Electric Use Pre-WAP	Net Savings	% of Pre
No Lighting or Refrigerator	1,066	9,316	454 (±111)	4.9%(±1.2)
Lighting, but No Refrigerator	1,126	9,574	677 (±192)	7.1%(±2.0)
Refrigerator (either Lighting)	489	9,586	1,262 (±192)	13.2%(±2.0)

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 2008 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/yr)	# Major Measures	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	1.7	3,498	1,020	181 (±13)	17.8% (±1.2%)
<750 th/yr.	1.4	858	571	67 (±9)	11.8% (±1.5%)
750 - <1000	1.7	963	875	133 (±10)	15.2% (±1.2%)
1000 - <1250	1.9	726	1,120	206 (±12)	18.4% (±1.1%)
1250 - <1500	2.1	472	1,367	271 (±27)	19.8% (±2.0%)
>=1500 th/yr.	2.0	479	1,879	414 (±49)	22.1% (±2.6%)

Note – Comparison group, not shown, was also stratified by usage.

Gas savings increase dramatically with pre-weatherization usage: therm savings are six times larger for the highest users than for the lowest users and percent savings nearly double over this range. The number of major measures installed per home does not increase as dramatically as the savings do 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. High electric use can be the result of many end uses other than lighting or refrigeration; therefore pre-retrofit usage has a weaker relationship with refrigerator replacements which drive much of the savings in baseload electric use. 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 2008 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	Electric Use Pre-WAP	Net Savings	% of Pre
All Clients	18%	2,991	9,528	680 (±140)	7.1% (±1.5%)
<6,000 kWh/yr.	18%	925	4,420	151 (±70)	3.4% (±1.6%)
6 - <8,000	19%	538	7,060	517 (±114)	7.3% (±1.6%)
8 - <10,000	20%	501	8,922	397 (±170)	4.5% (±1.9%)
10 - <12,000	15%	358	11,008	528 (±282)	4.8% (±2.6%)
12 - <14,000	16%	259	13,024	1,131 (±682)	8.7% (±5.2%)
>=14,000 kWh/yr.	19%	410	18,631	2,227 (±579)	12.0% (±3.1%)

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. Since the PY 08 WAP served many more homes in colder climates than in milder climates, the analysis sample was concentrated in the Cold and Very Cold Zones; and very few homes were from the Hot-Humid or Hot-Dry Zones. The small samples in hot climates limit our ability to provide precise results for these areas. Table 4.10 summarizes gas impacts for homes with natural gas main heat by climate zone. The climate zones with the higher 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
PY 2008 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	3,498	1,020	181 (±13)	17.8% (±1.2%)
Very Cold	2.1	1,139	1,068	190 (±27)	17.8% (±2.5%)
Cold	1.6	1,909	1,125	209 (±13)	18.5% (±1.2%)
Moderate	1.6	311	868	140 (±47)	16.1% (±5.4%)
Hot-Humid	1.9	83	684	134 (±49)	19.6% (±7.2%)
Hot-Dry	0.2	56	490	26 (± 42)	5.3% (±8.6%)

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 Cold Climate Zone were 21% leakier on average than homes in the Very Cold Climate Zone. 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 a generally strong relationship between EUI and climate zone—homes in colder climates have lower EUIs. The homes in the Hot-Dry Climate Zone were the tightest of all Climate Zones. This apparent anomaly may be explained by the typical construction practices in hot dry climates of slab-on-grade foundations and stucco/masonry walls that lead to tight homes.[14]

Table 4.11
PY 2008 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	1,511	5,763	13.8
Very Cold	2,954	1,530	7,283	10.9
Cold	3,569	1,564	5,964	13.3
Moderate	4,324	1,319	4,193	17.3
Hot-Humid	5,739	1,371	2,291	23.6
Hot-Dry	1,901	1,385	2,360	20.0

Table 4.12 summarizes gas use and savings into finer categories by heating degree days (HDD). Gas use and savings increased as the number of heating degree day 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 2008 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	3,498	1,020	191 (±13)	17.8%(±1.2)
<3000 HDD65	154	614	80 (±31)	13.0% (±5.1%)
3,000 - <4000	92	702	93 (±44)	13.3% (±6.3%)
4,000 - <5000	204	986	157 (±33)	15.9% (±3.4%)
5,000 - <6000	844	1,008	199 (±18)	19.8% (±1.8%)
6,000 - <7000	1,332	1,207	229 (±24)	18.9% (±1.9%)
>=7,000 HDD65	872	1,036	162 (±14)	15.7% (±1.4%)

Note – Comparison group, not shown, was also stratified by HDD65.

[14] The 2009 Residential Energy Consumption Survey (RECS) shows that 52 percent of homes in the West Census Region have a slab foundation, while only 23 percent of homes in the Northeast Census Region have that foundation type. The survey also showed that 55 percent of homes in the West Census Region have a stucco, brick, or stone exterior compared to 36 percent of homes in the Northeast Census Region.

Table 4.13 shows the gross and net electric impacts for gas-heated homes by Climate Zone. The highest electric use and savings appear to be in the Hot/Humid Climate Zone but the sample size is small so the higher savings are not statistically significant. The Climate Zones with the higher electric use appear to have higher electric savings, but these differences are generally not statistically significant. Another factor that appears to affect savings is the refrigerator replacement rate. Refrigerator replacement rates varied from 0 percent of homes (15 states) to about 50 percent of homes.

Table 4.13
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Electric Savings for Natural Gas Main Heat by Climate Zone (kWh/year)

Climate	Refrigerator Replacement %	# Homes	Electric Use Pre-WAP	Net Savings	% of Pre
All Clients	18%	2,991	9,528	680 (±140)	7.1%(±1.5)
Very Cold	24%	984	9,133	697 (±185)	7.6%(±2.0)
Cold	19%	1,617	8,895	666 (±128)	7.5%(±1.4)
Moderate	4%	284	11,901	823 (±659)	6.9%(±5.5)
Hot-Humid	9%	49	13,481	925 (±877)	6.9%(±6.5)
Hot-Dry	9%	57	7,488	251 (±281)	3.4% (±3.8)

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

4.8 ANALYSIS OF OTHER FACTORS

Table 4.14 summarizes gas impacts based on whether the building shell retrofits were performed by contractors or by in-house crews, and also by whether the measures were selected using a priority list or software-based calculation. There were no statistically significant differences in savings for either of these comparisons.

Table 4.14
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Gas Savings for Natural Gas Main Heat by Work Approaches (therms/year)

Work Method	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
Building Shell Work By				
Contractor	945	1,041	179 (±21)	17.2% (±2.0)
Agency Crew	1,383	994	194 (±15)	19.5% (±1.5)
Audit Approach				
Priority List	1,343	979	192 (±21)	19.6% (±2.2%)
Software / Calculation	1,699	1,086	178 (±13)	16.4% (±1.2%)

Some WAP grantees serve homes using use DOE funds only, some combine DOE and Low-Income Home Energy Assistance Program (LIHEAP) funds to deliver services, and others use multiple funding sources. Table 4.15 compares savings for different job funding sources and also includes average spending on ECMs.

The first comparison is based on whether the work was performed with just DOE funds or whether there were also non-DOE funds involved. Jobs that used DOE funds only spent an average of $1,745 on ECMs. Jobs that received non-DOE funds saved a little more than those that had DOE funds only (29 therms/yr), but they spent considerably more per unit on ECMs ($4,102).

The second part of Table 4.15 is based on the relative amount of funds leveraged by the sub-grantee that did the work, not necessarily the spending on the specific job. Programs where DOE was the dominant funding source saved about 178 therms per year, but only spent $1,958 per unit. Programs where the total amount of non-federal funds was greater than the total amount of federal funds saved more energy (213 therms per year), but spending on ECMs averaged $4,558 per unit, more than twice the amount spent on ECMs.

Table 4.15
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Net Gas Savings for Natural Gas Main Heat by Funding Sources

Funding Sources	# Homes	ECM Measure $/home	Gas Use Pre-WAP	Net Savings	% of Pre
Job Funding Sources					
Only DOE Funds	1309	$1,745	997	169 (±19)	17.0% (±1.9%)
DOE & Non-DOE Funds	1796	$4,102	1063	198 (±16)	18.6% (±1.5%)
Sub-grantee Wx Funding Sources					
DOE WAP-dominated	219	$1,958	1062	178 (±23)	16.8% (±2.2%)
WAP+LIHEAP-dominated	502	$2,391	903	148 (±20)	16.4% (±2.2%)
WAP+LIHEAP Majority, Some Other	1195	$3,168	981	175 (±20)	17.9% (±2.0%)
Majority Other, WAP+LIHEAP Minority	1354	$4,558	1145	213 (±26)	18.6% (±2.3%)

Table 4.16 summarizes gas savings by the amount of spending on efficiency measures for each job. This cost break-out was only available for about half of the cases in the analysis. The savings were considerably smaller than average for jobs where less than $1000 was spent on efficiency measures and considerably larger than average when efficiency measure spending exceeded $4000. But savings were fairly similar across spending levels for jobs between these extremes while spending grew rapidly.

Table 4.16
PY 2008 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
<$1,000	268	$587	873	88 (±16)	10.1% (±1.8%)
$1,000 - <$2,000	395	$1,492	995	143 (±18)	14.4% (±1.8%)
$2,000 - <$3,000	349	$2,460	1058	138 (±25)	13.0% (±2.3%)
$3,000 - <$4,000	292	$3,485	1105	162 (±14)	14.7% (±1.2%)
>=$4,000	542	$6,580	1104	264 (±25)	23.9% (±2.3%)

Table 4.17 shows a breakout of gas savings by whether or not total job costs exceeded $8000. The $8000 figure was selected to represent approximately the 10% highest-cost jobs overall and were primarily performed in states with substantial leveraging funds available. On average, high-cost jobs saved nearly twice as much gas as lower cost jobs, but the efficiency measure costs were more than three times as large.

Table 4.17
PY 2008 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 <$8000	2625	$2,708	1024	168 (±12)	16.4% (±1.2%)
Total Job Cost>=$8000	290	$8,475	1154	320 (±42)	27.7% (±3.7%)

4.9 PROGRAM YEAR 2007 AND PROGRAM YEAR 2009 ENERGY SAVINGS

Program Year 2008 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 were also collected for homes that participated in PY 2007 and 2009.

The PY 2007 data were collected with the goal of assessing impacts for that year. However, the amount of time elapsed between participation and data collection lowered expectations for successful data collection from utilities and caused the primary focus to be PY 2008. The PY 2009 data were collected primarily for creating the comparison group for the PY 2008 analysis but PY 2009 impacts could be assessed by using PY 2007 and PY 2008 participants as a "post/post" comparison group based on the principles of difference-in-difference estimation.

Table 4.18 summarizes the gas savings results for PY 2007 and PY 2009. For comparison, the PY 2008 gas savings averaged 181 therms net (195 therms gross), equal to 17.8% of the 1,020 therms of pre-program annual gas use. The PY 2007 savings were a little lower than PY 2008 savings, but the difference was not statistically significant.

Table 4.18
PY 2007 and PY 2009 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Gas Savings (therms/yr)

Program Year	# Homes	Gas Use Pre-WAP	Gas Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2007	2,842	990	817	173 (±11)	160 (±11)	16.1% (±1.1%)
Comparison	5,442	998	984	14 (±4)		
PY 2009	2,750	998	813	185 (±11)	173 (±10)	17.4% (±1.0%)
Comparison	4,210	848	836	12 (±4)		

Table 4.19 summarizes the electric savings results for gas-heated homes in PY 2007 and PY 2009. For comparison, the PY 2008 savings were 680 kWh/year net (735 kWh/yr gross), equal to 7.1% of the 9,528 kWh/yr pre-program electric use. The PY 2007 savings were slightly lower than PY 2008, and the PY 2009 savings were a little higher than PY 2008 but neither difference was statistically significant. Still,

the pattern of savings increasing over the three years would be consistent with expectations given the growing frequency of lighting and refrigeration measures being included in the program over time.

Table 4.19
PY 2007 and PY 2009 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Electric Savings for Natural Gas Main Heat

Program Year	# Homes	Electric Use Pre-WAP	Electric Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2007	2,271	9,296	8,682	614 (±130)	617 (±143)	6.6% (±1.5%)
Comparison	4,307	9,415	9,417	-3 (±42)		
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)		

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

The break-outs of savings presented throughout this section have summarized program impacts for various groups of interest. But such break-outs 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 was 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 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 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. Once the major measures of wall

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

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 from window replacement). Program measures not included in the final model included:

- All hot water related measures – showerheads, aerators, tank wraps, pipe insulation, temperature turn down, water heater replacement
- Foundation wall insulation
- Rim/band joist insulation
- Duct insulation (savings of 13 therms but very wide confidence interval)
- Window measures: replacement, storm windows, window repairs, etc.
- Heating system repairs and tune-ups
- Very rare measures: white roofs, skirting, ceiling fans
- Audit method: Priority List vs. calculation-based – no effect

The exclusion of a measure from the model does not necessarily indicate that the measure provides no savings but only that there was 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 which may save less from the other major measures than the average home, 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 4.20.

Table 4.20
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Gas Savings (therms/yr) by Measure for Natural Gas Main Heat

Measure	% of Homes	Savings per installation	Contribution to Overall Savings	% of Total Savings
Air Sealing	100%	50	50	28%
Attic Insulation	70%	62	43	24%
Wall Insulation	33%	80	27	15%
Heater Replacement	26%	101	26	15%
Duct Sealing	35%	19	7	4%
Setback Thermostat	13%	22	3	2%
Floor Insulation	12%	14	2	1%
Ventilation	13%	-20	-3	-1%
Other / Unattributed	100%	24	24	14%
Total			178	100%

The measures in the table are ordered by their overall contribution to program gas savings. Air sealing work is estimated to have provided the largest fraction of program savings – an average of 50 therms per home equal to 28% of the overall program gas savings. Heating system replacement is estimated to have provided the largest gas savings per installation at 101 therms, but only contributed 26 therms to overall program savings because replacements were only performed in 26% of homes. Overall, the four major measures of air sealing, heating system replacement, attic insulation, and wall insulation are estimated to account for more than 80% of the observed gas savings. Ventilation improvements, such as the installation of an exhaust fan in a tighter home, were estimated to increase gas use by 20 therms on average. Overall, the gas explanatory factors model estimates that the program produced average annual natural gas savings of 178 therms – essentially identical to the 181 therms net savings of the billing analysis sample.

An explanatory factors model was also developed to estimate electric savings in gas-heated homes. The results of this analysis are summarized in Table 4.21.

Table 4.21
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Electric Savings (kWh/yr) by Measure for Natural Gas Main Heat

Measure	% of Homes	Savings per installation	Contribution to Overall Savings	% of Total Savings
Lighting	60%	251	151	25%
Refrigerator Replacement	15%	567	84	14%
Air Conditioner Replacement	1%	2057	14	2%
Freezer Replacement	2%	355	7	1%
Other / Unattributed	100%	358	358	58%
Total			614	100%

Lighting retrofits are estimated to have saved 251 kWh per home for the 60% of homes that received that measure. Refrigerator replacements are estimated to have saved 567 kWh for the 15% of homes receiving replacements. Air conditioner replacement was very rare but was estimated to produce large savings when performed. Freezer replacements were not an allowable measure under WAP but some sub-grantees used utility funds to perform these replacements. The majority of electric savings in gas-heated homes is not attributed to any of the specific electric measures, but may be due to 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 614 kWh – about 10% less than the 680 kWh estimated from the billing analysis sample. This reduction is primarily due to differences in measure installation rates between the sample and the population.

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 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 limited the extent of further analysis and exploration.

5.1.1 Sample Attrition

There were 1,111 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 56% of the sampled homes. The usage data provided were not sufficient for developing savings estimates for 19% 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 about 3% of the sampled cases. An additional 6% of sampled cases in the analysis had electric usage too low to be considered electrically heated and occupied during both periods. Less than 1% of the sampled homes were removed from the analysis because they were declared savings outliers[16]. The table also shows that there were homes added to the sampled units due to the availability of data for more homes from one state that was pursuing a state-level evaluation.

[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 2008 WAP Single Family Site-Built Homes
Electric Usage Sample Attrition – Electric Main Heat

	Electric Analysis	
Sample Group / Attrition Cause	**Homes**	**% of Sample**
Sampled	1,111	100%
No Usage Data From Utility	492	44%
Insufficient Data	214	19%
Poor Model Fit	32	3%
Usage Infeasible: Vacant, Unheated, Not SF	72	6%
Savings Outlier	9	1%
Usable Cases	292	26%
Additional Usable Cases (not sampled)	14	
Total Usable Analysis Sample	306	

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 Zones. Participants who lived in electric-heated homes tended to have lower incomes than 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 a heating system replacement, wall insulation or a refrigerator replacement than other homes, but received attic insulation and air leakage reductions at a comparable rate to other homes.

The analysis sample attrition has created a group with more homes from the Cold and Very Cold Climate Zones, homes with fewer elderly occupants, slightly smaller homes, and homes that received fewer heating system replacements and more attic insulation than the full electric- heat population. These differences in climate and measure installation rates can be expected to lead to different savings in the analysis sample than in the larger population.

Table 5.2
Characteristics of Single Family Site-Built Homes

Characteristic		All Homes	Electric Heat Population	Electric Heat Analysis Sample
Climate				
	Very Cold	25%	9%	11%
	Cold	42%	20%	30%
	Moderate	21%	49%	48%
	Hot-Humid	8%	17%	9%
	Hot-Dry	4%	4%	2%
Demographics				
	Median Income	$13,224	$11,520	$12,420
	Homeowner	82%	83%	83%
	Elderly	42%	36%	26%
	# Occupants	2.5	2.4	2.3
Housing Characteristics				
	Heated Area	1,421	1,317	1,299
	Median Age	67	47	57
	HDD65	5,438	4,128	4,506
	CDD65	1,026	1,447	1,223
	Central Heating	86%	81%	89%
	Central A/C	36%	56%	56%
Wx Diagnostics				
	Weatherization Assistant Audit	22%	19%	15%
	Building Leakage Test	88%	90%	92%
	Duct Leakage Test	19%	32%	28%
Major Measures				
	Heater Replacement	21%	12%	8%
	Attic Insulation	69%	67%	71%
	Wall Insulation	29%	14%	16%
	Air Sealing >1000 Cfm50	42%	45%	41%
	Refrigerator Replaced	13%	8%	7%

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 1,804 kWh, equal to 9.0% of total pre-program usage. These percent savings are much lower than the 17.8% 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 averaged 17.6% which compares favorably with the 19.4% heating savings found in gas-heated homes, especially considering the much lower installation rates of wall insulation and heating system replacements for homes with electric heat. The baseload component savings estimate is considerably lower than the 510 kWh baseload savings found in gas-heated homes. Part of this difference may be explained by the low rate of refrigerator replacements in homes with electric heat – 7% of the electric heat analysis sample compared to 18% of the gas heat sample – and part may be related to the wide uncertainty due to the small sample size.

Table 5.3
PY 2008 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	Electric Use Pre-WAP	Gross Savings	Net Savings	% of Pre
Total Use	306	19,994	1,995 (±381)	1804 (±458)	9.0%(±2.3)
Comparison	248	21,503	192 (±400)		
Heating/Winter Use	306	8,531	1,867 (±295)	1502 (±416)	17.6%(±4.9)
Comparison	248	8,327	365 (±309)		
Cooling/Summer Use	306	1,402	68 (±173)	201 (±239)	14.3%(±17.1)
Comparison	248	1,291	-133 (±163)		
Baseload Use	306	10,011	60 (±251)	101 (±464)	1.0%(±4.6%)
Comparison	248	11,884	-41 (±346)		

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 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.

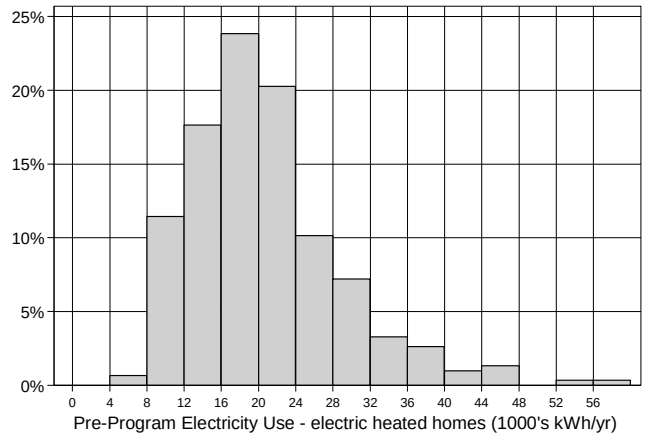

Figure 5.1: Distribution of Pre-Program Electric Use for Electric Heat Single Family Participants

The distribution of percent savings for electric-heat participants and comparison group 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 centered on 0% and shows that about 18 percent of households had a weather-normalized change in electric usage between -2.5% and +2.5%. For about 15 percent of the households, the change was less than -17.5% or greater than +17.5%. Some of the sources of these changes include: increases or decreases in the number of household members (e.g., child graduates and moves out; elderly parent gets ill and 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 are normal changes that affect households at all income levels and in all areas. Table 4.4 shows that, with all of those potential changes, the average weather-normalized usage for Comparison Group households changed by about 192 kWh per year (0.9%).

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 10.0%, showing that the Participant Group households reduced their energy consumption by substantially more than the Comparison Group households. Second, the graph for the Participant Group is more spread out; about 14 percent of households had their usage change by +/- 2.5% percent from the median change compared to 18 percent in that bin for the Comparison Group households. This shows that the variability in the change in energy usage is greater for the Participant Group households than for Comparison Group households.

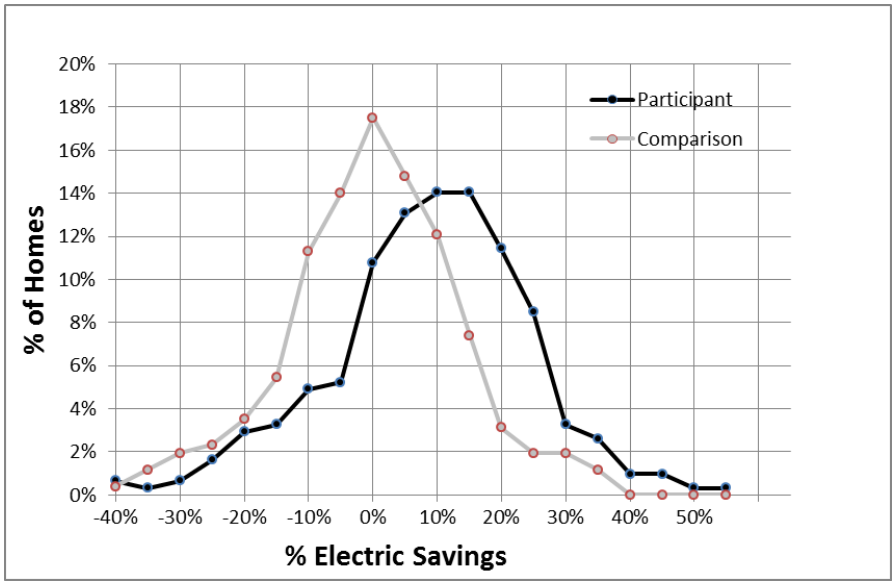

Figure 5.2: Distribution of Percent Electric Savings – Electric Heat Participants and Comparison Group

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% or more due to non-program 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 for gas heated homes: air sealing, attic insulation, wall insulation, and heating equipment replacement. Because the sample size is small, only the total number of major measures is examined, not the individual combinations.

Table 5.4
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Net Electric Savings for Electric Main Heat (kWh/yr)
by Number of Major Measures

# Major Measures	# Homes	Electric Use Pre-WAP	Net Savings	% of Pre
No Major Measures	63	19,229	410 (±593)	2.1% (±3.1%)
One Major Measure	133	20,052	1,750 (±449)	8.7% (±2.2%)
Two Major Measures	66	19,006	1,840 (±824)	9.7% (±4.3%)
Three or Four Major Measures	18	23,515	5,322 (±1,602)	22.6% (±6.8%)
All Electric Heat Units	306	19,944	1,804 (±458)	9.0% (±2.3%)

Homes that received no major measures achieved little savings while those that received one or two major measures saved about 9% of pre-retrofit use. Although relatively few homes received three or four major measures, the savings in these homes were much larger.

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. Due to the small number of cases in the analysis, the sample was split at 20,000 kWh per year into low and high users. The results are shown in Table 5.5. The annual kWh savings are higher for homes with higher usage, but the average percent savings is lower for the high-use homes. The relationship is not as strong as that found for gas usage, perhaps because of the variety of electric end-uses in homes. The average number of major measures was about the same in both usage categories (1.4).

Table 5.5
PY 2008 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	# Homes	Electric Use Pre-WAP	Net Savings	% of Pre
<20,000 kWh/yr.	164	14,637	1,621 (+/-467)	11.1% (+/- 3.2%)
>=20,000 kWh/yr.	142	27,774	2,317 (+/-781)	8.3% (+/-2.8%)

Comparison group, not shown, also stratified by pre-WAP electric use.

5.6 CLIMATE ZONE IMPACTS

Because of the small number of electric-heat homes in the sample and the very small number of homes from the hot climates (27 homes in Hot-Humid and only six in Hot-Dry), 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. Homes in warmer areas appear to achieve higher savings compared to homes in colder climates. An analysis by end use component found that this difference can be accounted for by cooling/summer savings in the warmer climate. However, the confidence intervals are wide and the comparison group adjustments were in opposite directions.

Table 5.6
PY 2008 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	Electric Use Pre-WAP	Net Savings	% of Pre
Warm (<3500 HDD65)	77	17,667	2,609 (±717)	14.8% (±4.1%)
Cold (>=3500 HDD65)	229	21,030	1,498 (±552)	7.1% (±2.6%)

Comparison group, not shown, also stratified by HDD65.

5.7 PROGRAM YEAR 2007 AND PROGRAM YEAR 2009 ELECTRICITY SAVINGS

Table 5.7 summarizes the electric savings results for electric-heated homes that participated in PY 2007 and PY 2009. For comparison, the PY 2008 savings were 1,804 kWh/yr net (1,995 kWh/yr gross), equal to 9.0% of the 19,994 kWh/yr pre-program electric use. The PY 2007 and PY 2009 savings were both considerably larger than the PY 2008 results, but these differences were not statistically significant (the small samples led to wide confidence intervals). Still, these higher savings results in the years before and after PY 2008 imply that the true PY 2008 savings may be closer to the higher end of the confidence interval rather than to the lower end.

Table 5.7
PY 2007 and PY 2009 WAP Energy Impacts for Single Family Site-Built Homes
Gross and Net Electric Savings for Electric Main Heat

Program Year	# Homes	Electric Use Pre-WAP	Electric Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2007	193	21,911	19,340	2,571 (±657)	2,360 (±842)	10.8% (±3.8%)
Comparison	371	21,402	21,191	211 (±409)		
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)		

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 and limited the value of the specific measure impact estimates, but the approach was still considered worth using to develop national estimates based on measures. The results of this analysis are summarized in Table 5.8.

Table 5.8
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Electric Savings (kWh/yr) by Measure for Electric Main Heat

Measure	% of Homes	Savings per installation	Contribution to Overall Savings	% of Total Savings
Air Sealing	100%	863	863	43%
Attic Insulation	67%	773	514	26%
Wall Insulation	14%	1490	215	11%
Air Conditioner Replacement	4%	2473	98	5%
Refrigerator Replacement	8%	1131	89	4%
Other / Unattributed	100%	206	206	10%
Total			1984	100%

Air sealing and attic insulation are estimated to account for more than two-thirds of the savings. National program electric savings in homes with electric heat are estimated to be 1,984 kWh/yr, about 10% larger than the 1,804 kWh found from the billing analysis sample. This difference implies that the analysis sample was biased toward homes with fewer major measures or located in areas with lower savings.

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 non-program 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 comprised 52 treated homes and 35 comparison-group homes in seven states.

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 2008 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%

* Mean Million British Thermal Units (MMBtu).
Net MMBTU savings calculated as Treatment MMBTU savings – Control % savings * Treatment Pre Use. Net % savings calculated as Net Treatment MMBTU savings / Treatment Pre Use.

It should be noted that the homes in the metering study were treated by the program during the ARRA period, when the program increased the allowable spending level. Therefore the incidence of major measure installation was higher than in PY 2008. Compared to statistics for PY 2008 oil-heated homes (pre-ARRA) in the Northeast, homes in the metering study had higher average spending ($1,700 higher) and a higher installation rate for attic insulation and wall insulation.

To account for these differences and formally 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 2008 WAP Energy Impacts for Single Family Site-Built Homes
Oil Heat Metering Results vs. Expected Savings

Analysis Method	Fuel Savings - gross (MMBtu/yr)
Metering Study	22.0 (±5.0)
Projection from Gas Explanatory Factors Model	22.6 (±1.8)
Difference	-0.6 (5.3)

The table shows that the average gross savings measured in the oil-heated homes were virtually identical to the savings expected if these had been gas-heated homes in the same locations that received the same mix of measures. In other words, the results 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. Given this consistency, the gas explanatory factors model savings estimation approach was then 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 locations.

Table 6.3
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Net Savings for Delivered Fuel Main Heat

Main Heating Fuel	Heating Fuel Savings (MMBtu/yr)	Electric Savings (kWh/yr)
Fuel Oil	17.8	511
Propane	15.8	691
Other	14.1	630
All Delivered Fuels	**16.7**	**587**

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.

- Non-Energy Benefits – The evaluation collected data and referencing literature sources to estimate and monetize the non-energy 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 non-energy 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 non-energy 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 2008. In this section, the energy cost savings and cost-effectiveness are presented from three different perspectives.

- Impact on PY 2008 Clients – The first scenario documents how the program impacted PY 2008 clients. It shows the clients' first-year energy cost savings based on actual energy prices in 2008 and the estimated net present value of their energy cost savings based on actual energy prices for 2008 through 2012, projected energy prices beginning in 2013, and discount rates in effect in 2008.

- PY 2013 Analysis Perspective – The second scenario is the most relevant to analysts 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 Analysis 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 analysts at this time.

7.2 IMPACT ON PY 2008 CLIENTS

This section presents the estimated energy cost savings and cost-effectiveness for clients that were served during PY 2008. 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 2008.
- 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 2009-2012 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 2008.
- 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 2008 dollars.

Table 7.1
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Energy Costs and Cost Savings by Main Heating Fuel (2008 Dollars)

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$996	$952	$1,948	$178	$61	$239	12.3%
Electricity	-	$1,796	$1796	-	$187	$187	10.4%
Fuel Oil	$2,402	$1,106	$3,510	$396	$65	$461	13.1%
Propane	$2,457	$996	$3,453	$407	$69	$476	13.9%
Other	$850	$917	$1,767	$141	$61	$201	11.4%
All Clients	**$1,155**	**$1,124**	**$2,279**	**$198**	**$84**	**$283**	**12.4%**

Participant annual energy costs averaged $2,279 prior to WAP, and WAP reduced these costs by an average of $283, equal to a 12.4% 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 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 $4,196 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spent an average of $2,846 on efficiency measures in these homes, yielding a net benefit of $1,350 per home and an SIR of 1.47. In other words, the energy savings are worth 47% more than the cost of the efficiency measures. The significant uncertainty in future energy prices, as well as in the energy savings costs, yields a 90% confidence interval that extends from 1.19 to 1.89. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.2
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel
(2008 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	$2,738	$573	$3,311	$2,768	$543	1.20	0.95 – 1.52
Electricity	-	$2,802	$2,803	$2,587	$216	1.08	0.87 – 1.32
Fuel Oil	$7,466	$589	$8,055	$3,441	$4,614	2.34	1.77 - 3.18
Propane	$5,884	$656	$6,543	$2,940	$3,603	2.23	1.74 – 2.92
Other	$2,892	$538	$3,430	$2,739	$691	1.25	1.00 - 1.62
All Clients	**$3,225**	**$971**	**$4,196**	**$2,846**	**$1,350**	**1.47**	**1.19 - 1.89**

The SIR is greater than unity across all heating fuels, but is much larger 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 lowest average spending on efficiency measures while producing cost savings comparable to the Very Cold

Climate Zone. A significant portion of this cost difference compared to the Very Cold Climate Zone is that heating system replacements are more often classified as efficiency measures in the Very Cold Climate Zone due to differences in state program rules. The only Climate Zone that did not appear to produce cost-effective savings is the Hot-Dry Zone, but the results for that zone are based on small samples.

Table 7.3
PY 2008 WAP Energy Impacts for Single Family Site-Built Homes
Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Climate Zone
(2008 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	$3,861	$761	$4,622	$4,050	$573	1.14
Cold	$3,918	$799	$4,717	$2,262	$2,454	2.08
Moderate	$2,090	$1,320	$3,409	$2,509	$901	1.36
Hot-Humid	$1,812	$1,766	$3,578	$3,266	$312	1.10
Hot-Dry	$1,056	$682	$1,738	$2,536	-$797	0.69

One issue to consider is whether delivering more measures per home leads to greater cost-effectiveness. Previously, Table 4.6 showed 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 in a higher level of 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 two measures. The overall SIR of 1.03 is 0.17 lower than the 1.20 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 7.9 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 2008 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) (2008 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	$725	$420	$1,145	$1,476	-$331	0.78
One	$1,961	$500	$2,461	$2,384	$77	1.03
Two	$3,030	$629	$3,659	$3,375	$284	1.08
Three	$4,358	$704	$5,062	$4,987	$75	1.02
Four	$6,412	$1,117	$7,529	$7,493	$36	1.00
All Clients (N=1,846)	$3,032	$616	$3,648	$3,557	$91	1.03*

* See footnote 13 on prior page for explanation of lower SIR.

Another issue examined is whether targeting homes with higher pre-weatherization usage results in higher cost-effectiveness. Previously, 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 dramatically with pre-weatherization gas use – growing more than four-fold from the lowest to highest usage bin.

Table 7.5
PY 2008 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 (2008 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 therms/yr.	$1,083	$343	$1,425	$2,989	-$1,564	0.48
750 - <1000	$2,144	$940	$3,083	$3,163	-$80	0.97
1000 - <1250	$3,260	$425	$3,685	$3,966	-$281	0.93
1250 - <1500	$4,609	$757	$5,366	$4,383	$983	1.22
>=1500 therms/yr.	$6,897	$631	$7,528	$4,053	$3,475	1.86

Table 7.6 summarizes the cost-effectiveness of program treatments based on whether the home was treated using just DOE funds or with DOE plus other funding sources. The DOE-only jobs were much more cost-effective than jobs that received other funds. The DOE-only jobs produced 74% of the bill savings at 43% of the energy measure cost compared to jobs that received funds from other sources. Measure installation data revealed only modestly lower rates of attic and wall insulation and measured air leakage reductions for DOE-only jobs compared to jobs receiving other funds. The main differences in

measure installation rates were for heating system replacement (15% DOE-only vs. 39% DOE+) and refrigerator replacement (14% DOE-only vs. 22% DOE+).

Table 7.6
PY 2008 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 non-DOE Funds (2008 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	$2,644	$232	$2,877	$1,745	$1,132	1.65
DOE + Non-DOE Funds	$3,149	$721	$3,870	$4,102	-$232	0.94

Table 7.7 summarizes cost-effectiveness based on the amount of funds leveraged by the local agency that performed the work – not necessarily the funds spent on the specific job. It appears that cost-effectiveness and net dollar benefits per job decline as agency leveraging increases. The implications of this result and the prior table are that DOE funding captures the most cost-effective savings available and additional funds are often used on less cost-effective measures.

Table 7.7
PY 2008 WAP Impacts for Single Family Site-Built Homes with Natural Gas Main Heat
Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness
by Agency Funds Leveraging (2008 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Sub-grantee Wx Funding Sources	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**
DOE WAP-dominated	$3,710	$613	$4,323	$1,958	$2,365	2.21
WAP+LIHEAP dominated	$2,251	$459	$2,710	$2,391	$319	1.13
WAP+LIHEAP majority, some Other	$2,554	$469	$3,023	$3,168	-$145	0.95
Majority Other, WAP+LIHEAP minority	$3,447	$744	$4,191	$4,558	-$367	0.92

Table 7.8 summarizes cost-effectiveness for different levels of spending on efficiency measures. Cost-effectiveness declines as efficiency measure costs increase with the SIR going below unity for jobs where efficiency measure costs exceeded $3,000.

Table 7.8
PY 2008 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 (2008 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
<$1,000	$1,679	$448	$2,127	$587	$1,540	3.62
$1,000 - <$2,000	$2,544	$376	$2,919	$1,492	$1,427	1.96
$2,000 - <$3,000	$2,444	$579	$3,023	$2,460	$563	1.23
$3,000 - <$4,000	$2,882	$209	$3,091	$3,485	-$394	0.89
>=$4,000	$4,248	$1,071	$5,319	$6,580	-$1,261	0.81

Table 7.9 summarizes cost-effectiveness for "high-cost" jobs – defined as total job costs (not just efficiency measures) exceeding $8000—compared to all other jobs. These high-cost jobs represent approximately 10% of the homes in the analysis and reduce the overall SIR for the analysis group by 14%.

Table 7.9
PY 2008 WAP Impacts for Single Family Site-Built Homes with Natural Gas Main Heat
Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness
by Total Job Cost >$8,000 (2008 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Total Job Cost	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
Job Cost <$8000	$2,696	$525	$3,221	$2,708	$513	1.19
Job Cost>=$8000	$4,977	$1,231	$6,208	$8,475	-$2,267	0.73

7.3 PY 2013 ANALYSIS 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 Analysis Perspective and the Longer-Term Analysis Perspective (discussed in the following section) is that a different discount rate is used. On an annual basis, the White House Office of Management and Budget (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 Analysis 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 7.10 summarizes the average energy costs and annual cost savings for the first year after participation in WAP in 2013 dollars.

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

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$799	$1,102	$1,811	$142	$65	$208	11.5%
Electricity	-	$1,852	$1,852	-	$192	$192	10.3%
Fuel Oil	$2,606	$1,156	$3,762	$430	$68	$497	13.2%
Propane	$1,968	$1,062	$3,030	$326	$74	$399	13.2%
Other	$925	$967	$1,892	$153	$64	$217	11.5%
All Clients	**$1,027**	**$1,182**	**$2,209**	**$175**	**$88**	**$264**	**11.9%**

For PY 2013 participants, annual energy costs are expected to average $2,209 prior to WAP, and it is projected that WAP would reduce these costs by an average of $264, 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 homes heated by natural gas.

Table 7.11 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 the 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 $5,337 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spend an average of $3,096 on efficiency measures in these homes, yielding a net benefit of $2,240 per home and an SIR of 1.72. In other words, the projected energy savings would be worth 72% more than the cost of the efficiency measures. The significant uncertainty in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 1.35 to 2.26. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.11
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	$3,514	$684	$4,197	$3,012	$1,185	1.39	1.06 – 1.88
Electricity	-	$3,457	$3,457	$2,815	$642	1.23	0.98 – 1.51
Fuel Oil	$9,973	$689	$10,662	$3,744	$6,918	2.85	2.11 – 3.93
Propane	$7,223	$787	$8,010	$3.199	$4,812	2.50	1.91 – 3.36
Other	$3,588	$634	$4,222	$2,980	$1,242	1.42	1.11 – 1.85
All Clients	**$4,161**	**$1,176**	**$5,337**	**$3,096**	**$2,240**	**1.72**	**1.35 – 2.26**

The projected SIR is greater than unity across all heating fuels, but is much larger 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 ANALYSIS 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 Analysis Perspective and the PY 2013 Analysis Perspective is that a different discount rate is used. For more general 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 Analysis Perspective. Annual energy costs are expected to average $2,209 prior to WAP, and it is projected that WAP would reduce these costs by an average of $264, equal to an 11.9% reduction in total energy costs.

Table 7.12 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 SIR which is the 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 $4,313 worth of energy bill savings over the lifetime of the measures (discounted to 2013 dollars) and spend an average of $3,096 on efficiency measures in these homes, yielding a net benefit of $1,216 per home and an SIR of 1.39. In other words, the projected energy savings would be worth 39% more than the cost of the efficiency measures. The significant uncertainty in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 1.11 to 1.79. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.12
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	$2,805	$589	$3,394	$3,012	$382	1.13	0.88 – 1.47
Electricity	-	$2,830	$2,830	$2,815	$15	1.01	0.81 – 1.21
Fuel Oil	$7,967	$595	$8,562	$3,744	$4,818	2.29	1.74 – 3.06
Propane	$5,789	$677	$6,465	$3,199	$3,266	2.02	1.58 – 2.64
Other	$2,906	$549	$3,455	$2,980	$475	1.16	0.93 – 1.47
All Clients	**$3,325**	**$987**	**$4,313**	**$3,096**	**$1,216**	**1.39**	**1.11 – 1.79**

The projected SIR is greater than unity across all heating fuels, but is much larger 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.