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National Weatherization Assistance Program Impact Evaluation – Energy Impacts for Mobile Homes

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NATIONAL WEATHERIZATION ASSISTANCE PROGRAM IMPACT EVALUATION ENERGY IMPACTS FOR MOBILE HOMES

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CONTENTS

Page

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

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
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
ORNL	Oak Ridge National Laboratory
PRISM	Princeton Scorekeeping Method
PY	Program Year
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 mobile homes treated by DOE's Weatherization Assistance Program (WAP) during Program Years (PY) 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, 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

The Energy Center of Wisconsin (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 were:

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Energy Supplier Data Collection

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

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Greg Dalhoff
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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 mobile 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 mobile 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 homes, mobile homes, small multifamily buildings, and large multifamily buildings) and summarizes overall program performance for all building types in terms of energy and non-energy benefits. The reports give policymakers detailed information on program performance for each building type.

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 mobile home energy impacts is part of the Impact Assessment.

Study Overview

The mobile home energy impact study characterized the WAP program and its measured 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 measures costs for sampled clients.

- Collection of energy usage information from energy suppliers and through direct metering in clients' homes.

- Statistical analysis of pre- and post-weatherization energy usage to develop robust estimates of the net energy impacts associated with service delivery.

- Projection of measure lifetimes and energy costs to estimate cost savings and program cost-effectiveness.

This report furnishes information on the households and housing units served by the program, documents the services delivered to those households and housing units, presents data on the change in energy consumption and energy costs experienced by WAP clients, and compares the cost of 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. PY 2008 program statistics are available from 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 20 percent of the treated units were mobile homes. Table 2 shows the distribution of treated mobile homes by Climate Zone. Sixty percent 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	17,754	18%
Small Multifamily (2-4 units)	5,317	5%
Large Multifamily (5+ units)	17,376	18%
TOTAL	97,965	100%

Table 2
PY 2008 WAP Clients in Mobile Homes by Climate Zone

Climate Zone	PY 2008 Units	Percent of PY 2008 Units
Very Cold Climate	4,739	27%
Cold Climate	5,805	33%
Moderate Climate	4,987	28%
Hot/Humid Climate	1,093	6%
Hot/Dry Climate	1,130	6%
TOTAL	17,754	100%

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

- The median household income was $11,472. But, almost 10 percent of WAP clients had income of $5,000 or less and more than 10 percent of WAP clients had income of $20,000 or more.
- The average WAP clients had 2.7 household members, but one in five households was an elderly person living alone.
- Over 80 percent of the clients were white non-Hispanic households, about 10 percent were black non-Hispanic households, and about 10 percent were other racial/ethnic groups.

WAP client mobile homes are not as diverse as site-built homes. Nationally, the average WAP client mobile home has 960 square feet of living space with very little variation by Climate Zone. Almost 90 percent of WAP client mobile homes were built after 1970.

Table 3 shows how WAP client mobile homes varied with respect to a number of important housing unit characteristics. The main heating fuel for WAP client mobile homes was almost equally divided among natural gas, electricity, and delivered fuels. But, almost two-thirds used electricity for water heating. About 70 percent of mobile home clients had air conditioning, while 30 percent did not. Some WAP clients use electric and/or wood supplemental heat.

Table 3
Characteristics of Mobile Homes Served by WAP in PY 2008

Characteristic			
Year Built	Pre-1940 = <1%	1940-1969 = 11%	1970 or Later = 89%
Space Heating Fuel	Gas = 35%	Electric = 35%	Delivered = 30%
Heating System	Central = 90%	Room = 8%	Other = 2%
Supplemental Heat	Electric = 8%	Wood = 7%	Other = 2%
Air Conditioning	Central = 36%	Window/Wall = 34%	None = 30%
Water Heating Fuel	Natural Gas = 25%	Electric = 64%	Other = 10%

The WAP program conducts extensive testing of clients' homes, both to identify cost-effective energy saving opportunities and to ensure that the client's 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 2,613 CFM50[1]. That is about three times the required ventilation needs computed using American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 62.2 standard for the average WAP mobile home client taking into account square footage and the number of household members. Over one-fourth of clients had air leakage rates of 3,500 CFM50 or more; these homes would be very drafty and air sealing could be expected to make the home much more efficient and comfortable. But, about 10 percent of homes were tested to be at 1,500 CFM50 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 an SSE rating of 80 percent, and that one-half of the furnaces had an SSE between 76 percent and 82 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 85 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. For site-built homes, the analysis focused on four major measures; air sealing, attic insulation, wall insulation, and furnace replacement. These four measures are responsible for most of the space heating and space cooling energy savings in site-built homes. However, there are important differences between site-built homes and mobile homes that result in different measures being installed in mobile homes.

- Air Sealing - For both site-built homes and mobile homes bypass air sealing can have a major impact on energy consumption.

- Furnace Replacement – For both site-built homes and mobile homes furnace replacement can have a major impact on energy consumption.

[1] Cubic Feet per Minute @ 50 Pascals

- Insulation - Attic insulation and wall insulation can be cost-effective measures for mobile homes. Since insulation procedures for mobile home are different than those for site-built homes, these measures are done less often in mobile homes than in site-built homes. Because of the configuration of mobile homes, floor insulation is done more often in mobile homes.

- Duct Sealing – For many site-built homes, heating and cooling ducts are inside the thermal envelope; duct sealing in site-built homes might improve the performance of the distribution system but might not reduce energy consumption. Since mobile home ducts are more likely to be outside the thermal envelope duct sealing can have a major impact on energy usage.

Table 4 shows the rate at which the measures were installed in mobile homes during PY 2008 and the share of the clients receiving this measure where the maximum energy savings were expected. For example, the maximum savings impact from furnace replacements only would be observed in homes where the replacement was a cost-effective energy conservation measure (i.e., where inefficient equipment was replaced with equipment with a higher efficiency rating). There may be no energy savings if the equipment was replaced because of health and safety problems. Table 4 shows that about 26 percent of homes had a furnace replacement, but less than one-half of those were considered to be a cost-effective energy conservation measure.

The most common mobile home measures were bypass air sealing, duct sealing, windows (including storm windows), floor insulation, and furnace replacement. Only 21 percent of mobile homes had attic insulation (compared to 70 percent for site-built homes) and only 4 percent got wall insulation (compared to 29 percent for site-built homes). However, mobile homes were more likely to get duct sealing (52 percent for mobile homes compared to 42 percent for site-built homes) and furnace replacement (26 percent for mobile homes compared to 22 percent for site-built homes).

Table 4
Measure Installation Rates for Mobile Homes Served by WAP in PY 2008

Measure	Installation Rate	Highest Expected Energy Impact
Bypass Air Sealing	75%	w/Blower Door=87%
Attic Insulation	21%	None Existing=23%
Wall Insulation	4%	Dense Pack=50%
Other Insulation	46%	Floor Insulation=93%
Furnace Replacement	26%	Energy Measure=46%
Duct Sealing	52%	Outside Envelope=100%
Windows	40%	Energy Measure=75%
Water Heater Replacement	11%	Energy Measure=36%
Refrigerator	16%	Energy Measure=94%

Gas and Electric Savings in Gas Heated Homes

The evaluation directly measured gas and electric usage for treatment group and comparison group homes that use natural gas 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 were estimated by comparing the savings for treatment group homes to the savings for comparison group homes.[2] Table 5 shows that the gross gas savings for gas heated homes in PY 2008 were 109 therms[3] per home per year. However, during the same period, the comparison group (PY 2009 clients) reduced their usage by 12 therms per home per year without receiving any treatments. So, net savings due to the program are estimated to be 97 therms (12.6%) per home per year.

Table 5
PY 2008 WAP Energy Impacts for Mobile Homes
Gross and Net Gas Savings (therms*/year)

Group/Breakout	# Homes	Use PreWAP	Use PostWAP	Gross Savings	Net Savings	% of Pre
Treatment Group	616	768	659	109 (±11)	97 (±13)	12.63% (±1.7%)
Comparison	504	781	769	12 (±6)		

*****100,000 British Thermal Units

Energy savings varied significantly among the mobile homes weatherized by the program. An explanatory factors analysis found that several factors were associated with higher energy savings, including:

- Homes that got more major measures (Table 6).
- Homes with higher pre-weatherization gas usage (Table 7).
- Homes with higher levels of spending on weatherization measures (See Table 4.14).

Table 6 shows that the amount of natural gas saved increases substantially as the number of major measures installed in the home increased; homes that had three major measures saved more than three times the amount of energy saved by homes that only had one major measure installed. The tables also show that the average pre-weatherization usage was higher for homes that received more measures.

[2] 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.
[3] 100,000 British Thermal Units

Table 6[4]
PY 2008 WAP Energy Impacts for Mobile 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	59	709	34 (±39)	4.8% (±5.5)
Any One Major Measure	119	714	55 (±17)	7.7% (±2.4)
Any Two Major Measures	124	762	105 (±12)	13.8% (±1.6)
Any Three Major Measures	67	832	182 (±43)	21.9% (±5.2)
Four or More Major Measures	44	905	185 (±31)	20.4% (±3.5)

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. For example, homes with pre-weatherization usage of 1,000 to <1,250 therms per year received an average of 2.2 major measures and had average savings of 192 therms, while homes with pre-weatherization usage of 750 to <1,000 therms received an average of 1.8 major measures and had average savings of 93 therms. The higher-usage homes saved twice as many therms of natural gas despite getting only slightly more installed measures.

Table 7
PY 2008 WAP Energy Impacts for Mobile 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
<750 th/yr.	1.7	263	551	54 (±15)	9.8% (±2.7%)
750-<1,000	1.8	211	862	93 (±20)	10.8% (±2.4%)
1,000-<1,250	2.2	99	1,114	192 (±29)	17.2% (±2.6%)
1,250+ th/yr.	2.3	43	1,463	299 (±72)	20.4% (±4.9%)

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

The analysis also 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 4.12).
- Whether a priority list or a calculation procedure was used for selecting measures (see Table 4.12).

Savings for gas heated homes varied across Climate Zones, with higher savings in the Very Cold and Cold Climate Zones (Table 8). For those zones, average annual usage was over 800 therms and average savings were about 110 therms. Relatively few cases were available for the Moderate, Hot/Humid, and Hot/Dry Climate Zones. Average usage and savings were low for those Climate Zones.

[4] For this analysis, major measures include heating system replacement, floor insulation, attic insulation, duct sealing, and major air sealing (i.e., leakage reduction of at least 1,000 CFM50).

Table 8
PY 2008 WAP Energy Impacts for Mobile 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
Very Cold	2.1	372	858	119 (±21)	13.9% (±2.4%)
Cold	1.6	205	814	107 (±16)	13.1% (±2.0%)
Moderate/Hot	1.2	39	536	40 (± 33)	7.5% (±6.2%)

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

Weatherization of gas heated homes also can result in savings of electricity. Air sealing and insulation can reduce the use of a furnace fan in the winter and the 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 were 571 kWh and the net savings were 472 kWh (5.6%).

Table 9
PY 2008 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Natural Gas Main Heat by End Use

Analysis Group	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
Treatment Group	493	8,494	7,924	570 (±197)	472 (±222)	5.6% (±2.6%)
Comparison	326	8,338	8,240	98 (±138)		

Electric Savings in Mobile Homes with Electric Main Heat

The evaluation directly measured electric usage for treatment group and comparison group mobile homes that use electric main heating fuel. Gross program savings were estimated by comparing pre-weatherization usage (weather-normalized) to the post-weatherization usage (weather-normalized) for homes treated during PY 2008. Net program savings were estimated by comparing the savings for treatment group homes to the savings for comparison group homes.[5] Table 10 shows that the gross savings for electric heat homes in PY 2008 was 2,114 kWh. During the same period, the comparison group reduced usage by 567 kWh without receiving any treatments; net savings due to the program are estimated to be 1,547 kWh (7.5%).

Table 10
PY 2008 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Electric Main Heat (kWh/year)

Analysis Group	# Homes	Elec Use Pre-WAP	Gross Savings	Net Savings	% of Pre
Treatment	276	20,609	2,114 (±356)	1,547 (±510)	7.5%(±2.5)
Comparison	188	20,946	567 (±328)		

[5] 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.

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

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

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

Table 11
PY 2008 WAP Energy Impacts for Mobile 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	31	22,293	-30 (±753)	-0.1% (±3.4%)
One Major Measure	80	19,319	766 (±519)	4.0% (±2.7%)
Two Major Measures	86	20,804	2,444 (±746)	11.7% (±3.6%)
Three or More Major Measures	61	21,210	1,779 (±768)	8.4% (±3.6%)

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 more than twice the average savings for homes with pre-weatherization usage of less than 20,000 kWh.

Table 12
PY 2008 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Electric Main Heat by Pre-Weatherization Electric Usage

Pre-WAP Use	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
<20,000 kWh/yr.	122	15,002	988 (+/-455)	6.6% (+/- 3.0%)
>=20,000 kWh/yr.	154	25,709	2,040 (+/-790)	7.9% (+/-3.1%)

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

Energy Savings in Homes that Heat with a Delivered Fuel

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

- Direct Metering of Homes – Energy use was directly metered for a sample of 120 site-built 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 for mobile homes were used to project energy savings for the population of delivered fuel mobile homes treated in PY 2008.

Table 13 shows the estimated energy savings for delivered fuel homes for PY 2008. These homes represent about 30 percent of the population of mobile homes treated in PY 2008. The average energy savings of 11.2 Mean Million British Thermal Units (MMBtu) for delivered fuel main heat homes is consistent with the average energy savings of 9.7 MMBtu for natural gas main heat homes (Table 5).

Table 13
PY 2008 WAP Energy Impacts for Mobile Homes
Net Savings for Delivered Fuel Main Heat

Main Heating Fuel	Heating Fuel Savings (MMBtu*/yr)	Electric Savings (kWh/yr)
Fuel Oil	11.5	321
Propane	10.7	370
Other	12.1	321
All Delivered Fuels	**11.2**	**342**

* 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 cost for each sampled housing unit.

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

The analysis in this report is restricted to a comparison of the energy benefits to the service delivery costs for energy measures and incidental home repairs. The overarching impact report will compare energy and 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 analysis 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 $2,042 and energy savings of $167 (8.2%). The cost savings for fuel oil and propane heated homes is expected to be more than twice 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 Mobile 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	$784	$872	$1,656	$96	$34	$130	7.9%
Electricity	-	$1,989	$1,989	-	$134	$134	6.7%
Fuel Oil	$1,912	$1,256	$3,168	$242	$38	$280	8.8%
Propane	$2,157	$924	$3,081	$270	$36	$306	9.9%
Other	$855	$1,021	$1,876	$106	$28	$134	7.1%
All Clients	$956	$1,086	$2,042	$119	$48	$167	8.2%

Note: Other heating fuels include wood, kerosene, and coal.

Table 15 furnishes a projection of the energy cost-effectiveness of the program for mobile 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 0.89 for the overall program. The SIR is less than 1.0 for homes heated with natural gas or electricity. It is greater than 1.0 for homes heated with fuel oil or propane because of the much higher energy cost savings for those homes.

Table 15
PY 2008 WAP Energy Impacts for Mobile 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**	**SIR**
Natural Gas	$1,450	$314	$1,764	$2,506	-$742	0.70
Electricity	-	$1,989	$1,989	$3,218	-$1,229	0.62
Fuel Oil	$4,558	$372	$4,930	$2,532	$2,398	1.95
Propane	$3,940	$324	$4,264	$2,589	$1,675	1.65
Other	$2,522	$262	$2,784	$2,879	-$95	0.97
All Clients	$1,644	$775	$2,419	$2,721	-$302	0.89

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 $2,021 and first year energy savings of $157 (7.8%). 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 slightly 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 Mobile 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	$632	$952	$1,584	$77	$37	$115	7.2%
Electricity	-	$2,159	$2,159	-	$145	$145	6.7%
Fuel Oil	$2,066	$1,321	$3,387	$261	$40	$301	8.9%
Propane	$1,728	$1,010	$2,738	$216	$39	$255	9.3%
Other	$930	$1,095	$2,025	$115	$30	$145	7.2%
All Clients	$844	$1,177	$2,021	$105	$53	$157	7.8%

Note: 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 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 1.03 for the overall program, somewhat higher than the SIR of 0.89 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 Mobile 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**	**SIR**
Natural Gas	$1,865	$376	$2,240	$2,727	-$486	0.82
Electricity	-	$2,450	$2,450	$3,501	-$1,051	0.70
Fuel Oil	$6,063	$441	$6,504	$2,755	$3,749	2.36
Propane	$4,807	$386	$5,193	$2,817	$2,376	1.84
Other	$3,128	$309	$3,437	$3,132	$305	1.10
All Clients	$2,107	$946	$3,053	$2,961	$92	1.03

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 lowest average energy savings, but it had the highest SIR because it had the lowest average energy measures costs. (See Table 7.3)
- Major Measures – Homes that received more major measures saved more energy, and the estimated cost-effectiveness increased as the number of installed measures increased. (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 therefore 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.

1.0 INTRODUCTION

The purpose of this report is to disseminate the findings from an analysis of the energy savings, cost savings, and cost-effectiveness for mobile 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 mobile 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 Mobile Homes
- Energy Impacts for Single Family Homes
- Energy Impacts for Small Multifamily Buildings
- Energy Impacts for Large Multifamily Buildings
- Energy and Non-energy Impacts of the Weatherization Assistance Program

To the extent possible, WAP 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) 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 PY 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 mobile home energy impacts is part of the program Impact Assessment.

1.2 MOBILE HOME ENERGY IMPACT STUDY OVERVIEW

The mobile home 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.

- 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 homes before and after the installation of weatherization measures.

- Energy Data Analysis - Statistical procedures were used to develop normalized estimates of the difference in usage 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.

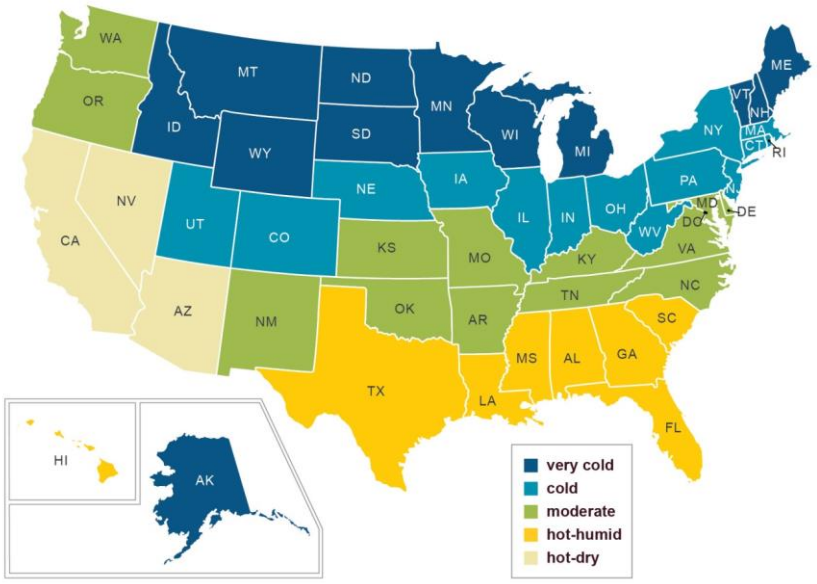

Figure 1.1: Climate Zone Map for the PY 2008 Evaluation

1.3 ORGANIZATION OF THE MOBILE HOME ENERGY IMPACT REPORT

The report consists of seven sections, including:

- Section 1 – Introduction: Furnishes an overview of the WAP Evaluation, the WAP Impact Evaluation, and the evaluation of mobile homes.

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

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

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

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

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

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

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

2.0 OVERVIEW OF DATA COLLECTION METHODOLOGY

The purpose of the mobile home energy impact study is to measure the energy savings, cost savings, and cost-effectiveness for mobile homes treated by WAP during PY 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 Submeter Studies
- U.S. Energy Information Administration (EIA) Energy Price Data and Projections
- National Climatic Data Center (NCDC) Weather Data

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.[6]

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; 2,957 of those clients lived in mobile 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 who 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%).

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

- Sample – The Evaluation Team selected a sample of 2,023 PY 2008 clients who lived in a mobile home heated with natural gas or electricity from the 379 funded subgrantees that furnished client lists.

[6] 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.

- Responding Subgrantees – The 368 subgrantees that responded to the utility data request had 1,988 of these 2,023 sampled clients (98%).

- Main Heating Supplier – The 368 subgrantees that responded furnished the heating energy supplier information for 1,739 of their 1,988 mobile home clients (87%). That represents 86 percent of all sampled clients.

- Electric Data Supplier - The 368 subgrantees that responded furnished electric supplier information for 1,603 of their 1,988 mobile home clients (81%). That represents 79 percent of all sampled mobile 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 2,954 PY 2008 clients who lived in mobile 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 2,907 of the 2,957 sampled clients (98%).

- Client Data – The 365 subgrantees that responded furnished service delivery data for 2,826 of their 2,907 mobile home clients (97%). That represents 96 percent of all sampled mobile home clients.

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

2.3 NATURAL GAS AND ELECTRIC USAGE DATA COLLECTION

For all sampled clients who heated with either natural gas or electricity, the evaluation team requested data from the company that supplied the client's main heating fuel. The supplier was asked to furnish monthly data for the period 1/1/2006 through 12/31/2010. The following statistics describe the response rates:

- Natural Gas or Electric Main Heating Fuel
    - Companies – 321 natural gas and electric companies were identified for one or more sampled PY 2008 mobile home clients.
    - Company Response – 243 of the 321 companies furnished data for one or more of the sampled clients (76%).
    - Client Response – Data were received for 1,221 of the 1,739 PY 2008 mobile home clients for whom a supplier was listed (70%). That is 60 percent of the 2,023 sampled mobile home clients who heat with either natural gas or electricity.
- Electric Usage for Natural Gas Main Heat Clients
    - Companies – 180 electric companies were identified as the electric supplier for one or more PY 2008 mobile home clients who heat with natural gas.
    - Company Response – 124 of the 180 electric companies furnished data for one or more of the sampled clients (69%).
    - Client Response - Data were received for 674 of the 925 PY 2008 mobile home clients for whom an electric supplier was listed (73%). That is 56 percent of the 1,204 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.

3.0 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 mobile 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 2,826 mobile 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 units)	1,798	9%
Large Multifamily (5+ units)	4,532	23%
TOTAL	19,496	100%

The sample of clients supplied by WAP subgrantees was weighted to account for client-level sampling rates and to adjust for survey non response. The weighting procedures included the following steps:

- Base Weight – Each sampled client was assigned a base weight that 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.

Applying the adjusted case weights allows one to estimate the total number of clients served by Climate Zone and Housing Unit Types. 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 mobile homes were 18 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 units)	5,317	5%
Large Multifamily (5+ units)	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 Moderate Climate Zone had the largest percent of mobile homes served and the Hot/Dry Climate Zone had the largest percent 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%	23%	100%
Moderate Climate	65%	27%	1%	7%	100%
Hot/Humid Climate	70%	17%	6%	7%	100%
Hot/Dry Climate	43%	19%	1%	37%	100%
TOTAL	59%	18%	5%	18%	100%

Table 3.6 shows the number and percent of mobile homes by Climate Zone. Almost all of the 17,754 treated mobile homes were in the Very Cold, Cold, and Moderate Climate Zones.

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

Climate Zone	PY 2008 Units	Percent of PY 2008 Units
Very Cold Climate	4,739	27%
Cold Climate	5,805	33%
Moderate Climate	4,987	28%
Hot/Humid Climate	1,093	6%
Hot/Dry Climate	1,130	6%
TOTAL	17,754	100%

3.2 HOUSEHOLD CHARACTERISTICS

Table 3.7 furnishes national and Climate zone statistics on the household characteristics for PY 2008 clients in mobile homes. The overall finding is that the mobile homes served by the WAP are primarily homeowners with incomes below the poverty level who have a vulnerable individual in the home.

Table 3.7
PY 2008 Clients in Mobile 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	$11,472	$12,548	$12,207	$10,512	$9,504	$14,350
Median % of Poverty	87%	88%	89%	81%	76%	105%
% < 100% of Poverty	61%	62%	56%	69%	74%	40%
Vulnerability Status						
% w/Elderly Individual	40%	32%	40%	44%	50%	43%
% w/Disabled Individual	49%	45%	47%	57%	48%	52%
% w/Children	31%	37%	27%	30%	34%	24%
Household Status						
% Homeowner	91%	90%	91%	92%	93%	93%
Mean Household Size	2.7	4.0	2.2	2.3	2.2	2.2
% Single Parent	19%	16%	19%	21%	22%	12%
% Single Elderly	22%	20%	24%	23%	27%	22%
Race/Ethnicity						
% White non-Hispanic	82%	84%	96%	74%	55%	85%
% Black non-Hispanic	9%	1%	1%	16%	41%	1%
% Hispanic	6%	7%	2%	9%	0%	14%
% Asian	<1%	0%	0%	1%	2%	0%
% Native American	3%	8%	1%	1%	2%	0%
% Other	0%	0%	0%	0%	0%	0%

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 – Households in the Hot/Humid Climate Zone have the highest percent of households with an elderly member; households in the Very Cold Climate Zone have the highest percent of households with a child.

- Race/Ethnicity – White non-Hispanic households are the majority of mobile home clients in all Climate Zones. The Hot/Humid Climate Zone has the highest incidence of Black non-Hispanic clients and the Hot/Dry Climate Zone has the highest incidence of Hispanic clients in mobile homes.

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 Moderate and Hot/Humid Climate Zones, 90 percent of households have incomes at or below $21,000 per year.

- Poverty – In most Climate Zones, more than half of the mobile home clients had incomes below the poverty line. Only a small percent of the clients had incomes above 150 percent of poverty.

Table 3.8
PY 2008 Clients in Mobile Homes
Distribution of Income and Poverty Climate Zone

	Percent of Population				
Variable	**10%**	**25%**	**Median**	**75%**	**90%**
Income					
Very Cold Zone	$3,586	$7,842	$12,548	$17,680	$23,346
Cold Zone	$5,532	$7,805	$12,207	$17,616	$23,952
Moderate Zone	$4,608	$7,953	$10,512	$15,600	$20,232
Hot/Humid Zone	$0*	$7,137	$9,504	$14,664	$20,893
Hot/Dry Zone	$8,293	$10,440	$14,350	$20,398	$28,244
ALL ZONES	$4,608	$7,894	$11,472	$16,887	$23,016
Percent of Poverty					
Very Cold Zone	23%	61%	88%	120%	143%
Cold Zone	31%	67%	89%	127%	154%
Moderate Zone	33%	58%	81%	107%	135%
Hot/Humid Zone	21%	56%	76%	100%	123%
Hot/Dry Zone	68%	88%	105%	140%	168%
ALL ZONES	29%	63%	87%	118%	146%

Table 3.9 shows how ownership status varies by demographic group. Households with an elderly member were most likely to be homeowners. However, close to 90 percent of all demographic groups were homeowners.

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

Demographic Group	**% Owners**	**% Renters**
Elderly Households	93%	7%
Disabled Households	92%	8%
Households with Children	88%	12%
Single Parent Households	89%	11%
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 mobile homes. The overall finding is that mobile homes treated by the WAP are most likely to be small and were constructed after 1970. There is relatively little variation among these homes across Climate Zones, with the exception that homes in the Very Cold Zone tend to be better sealed (mean CFM50[7] = 2,540) while those in the Hot/Humid Zone tend to be leakier (mean CFM50 = 3,775).

Table 3.10
PY 2008 Clients in Mobile Homes
Housing Unit Characteristics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Housing Unit Configuration						
Median Heated Space	960	980	938	980	1,064	980
Mean Heated Space	1,058	1,026	1,090	1,042	1,094	1,056
Housing Vintage						
% pre-1940	<1%	<1%	1%	0%	0%	0%
% 1940-1969	11%	13%	11%	8%	8%	14%
% 1970 or later	89%	87%	88%	92%	92%	86%
PreWX Status						
Mean Furnace SSE	78%	77%	80%	81%	*	*
Mean CFM50	2,906	2,540	2,890	3,094	3,775	2,852
Mean HDD65**	5,352	7,326	5,725	4,191	2,006	3,415
Mean CDD65[+]	994	528	817	1,168	2,289	1,855

*Insufficient data to report.
** Heating Degree Day
[+] Cooling Degree Days

Table 3.11 shows the distribution of homes with respect to important pre-weatherization indicators. It appears that in most Climate Zones, more than 50 percent of the homes have significant potential for air leakage reduction to improve energy efficiency.

[7] Cubic Feet per Minute @ 50 Pascals

Table 3.11
PY 2008 Clients in Mobile Homes
Distribution of PreWX Status by Climate Zone

Variable	Percent of Population 10%	25%	Median	75%	90%
CFM50					
Very Cold Zone	1,375	1,780	2,300	3,038	3,982
Cold Zone	1,575	1,969	2,617	3,469	4,500
Moderate Zone	1,490	1,940	2,800	3,800	5,062
Hot/Humid Zone	1,966	2,600	3,250	4,487	6,182
Hot/Dry Zone	1,500	1,825	2,539	3,445	5,000
ALL ZONES	1,500	1,906	2,613	3,500	4,732
SSE					
Very Cold Zone	60%	72%	79%	82%	85%
Cold Zone	74%	77%	80%	82%	85%
Moderate Zone	70%	79%	81%	84%	86%
Hot/Humid Zone*	-	-	-	-	-
Hot/Dry Zone*	-	-	-	-	-
ALL ZONES	69%	76%	80%	82%	85%

*Insufficient data to report.

Table 3.12 furnishes national and Climate Zone statistics on the heating and cooling systems for PY 2008 clients in mobile homes. The overall findings are that WAP client homes are evenly split among gas heat, electric heat, and heat with a delivered fuel. Most have a central heating system, air conditioning, and an electric water heater. The detailed Climate Zone statistics show that the dominant energy use patterns for households served by the WAP vary across the country. Important findings include:

- Heating Fuel – In the colder Climate Zones, natural gas is the main heat in about half of the homes, while electric heat is most common in the Moderate and Hot/Humid Zones.
- Main Heating Equipment – In all Climate Zones, most households had a central heating system (CFA or Heat Pump).
- Supplemental Heat – The use of supplemental heat is consistent across Climate Zones. One exception is wood supplemental heat is not used in the Hot/Humid Climate Zone.
- 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 – Electricity was the most common main water heating fuel in all Climate Zones except for the Hot/Dry Zone.

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

Table 3.12
PY 2008 Clients in Mobile 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	35%	53%	45%	10%	14%	42%
% Electric	35%	13%	20%	70%	75%	18%
% Fuel Oil	10%	11%	17%	4%	0%	4%
% Propane	18%	21%	17%	13%	11%	37%
% Other	2%	2%	1%	3%	0%	0%
Heating System Type						
% Central Forced Air	86%	92%	93%	75%	75%	78%
% Boiler (hydronic/steam)	<1%	<1%	1%	0%	0%	0%
% Wall/Room Heater	7%	6%	2%	10%	15%	12%
% Electric Baseboard	1%	1%	1%	1%	0%	1%
% Heat Pump	3%	<1%	1%	7%	2%	7%
% Portable Space Heater	2%	<1%	1%	3%	3%	2%
% Cooking Stove	<1%	0%	0%	<1%	0%	0%
% No Heating Source	2%	1%	1%	4%	6%	1%
Supplemental Heat						
% Electric	8%	10%	7%	5%	12%	9%
% Wood	7%	8%	6%	8%	0%	5%
% Kerosene	2%	1%	2%	2%	4%	0%
Air Conditioning Type						
% Central AC	37%	19%	31%	54%	59%	21%
% Window/Wall	26%	23%	36%	21%	35%	11%
% Evaporative Cooler	9%	7%	4%	3%	0%	59%
% None	30%	51%	31%	25%	8%	13%
Water Heating Fuel						
% Natural Gas	25%	39%	28%	8%	11%	40%
% Electric	64%	48%	64%	85%	84%	26%
% Fuel Oil	<1%	<1%	1%	0%	0%	0%
% Propane	10%	13%	7%	6%	5%	34%

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 42 percent of client homes were assessed using an audit tool and 56 percent were treated using a priority list.

Table 3.13
PY 2008 Clients in Mobile 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	22%	42%	5%	31%	3%	0%
% TIPS[8]	5%	0%	15%	0%	0%	0%
% Other Audit	15%	29%	9%	10%	16%	0%
% Priority List	56%	27%	68%	55%	79%	100%
% Other	3%	2%	3%	4%	2%	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 over 90 percent of client homes received a blower door test. Zonal pressure tests were reported for about two in ten homes and room-to-room pressure balancing were reported in about one-fourth of homes.

- Duct Testing – For about 40 percent of 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 in ten homes was tested using duct blasters.

- Infrared (IR) Scanning – IR cameras were used for about one in ten client homes.

Most client homes receive diagnostics that go beyond what the auditor can directly observe.

[8] Targeted Investment Protocol System

Table 3.14
PY 2008 Clients in Mobile 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	93%	95%	97%	95%	93%	60%
% Zonal Pressure	21%	10%	26%	26%	15%	26%
% Room-to-Room Balance	24%	18%	31%	19%	33%	24%
Duct Testing (% for homes with ducts)						
% Any Duct Test	44%	35%	37%	55%	56%	64%
% Pressure Pan	39%	31%	33%	54%	54%	29%
% Duct Blaster	8%	2%	5%	13%	8%	18%
% Blower Door Subtraction	9%	4%	9%	6%	11%	35%
Infrared Scanning	10%	6%	15%	9%	11%	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 safety, while electric equipment can be tested for operating efficiency.

- Furnaces – Overall testing was conducted in about 40 percent of homes nationally. But testing was much more common in the Very Cold and Cold Climate Zones.

- Water Heaters – About one in four water heaters had flue gas analysis; the highest rate was in the Hot/Dry Climate Zone where almost one-half of homes were tested. In the Hot/Humid Climate Zone, only about one in ten 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 over one-half of refrigerators were metered.

There is substantial variation in the number and types of diagnostic tests that are conducted; the variation by Climate Zone is significant.

Table 3.15
PY 2008 Clients in Mobile 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	40%	44%	59%	19%	14%	39%
% Temperature Rise	27%	24%	47%	18%	2%	7%
% Thermostat Anticipator	14%	18%	21%	7%	2%	2%
Water Heater Testing (% for homes applicable)						
% Flue Gas Analysis	26%	29%	34%	14%	10%	47%
% Hot Water Temperature	40%	42%	45%	41%	25%	17%
% Showerhead Flow Rate	14%	12%	15%	15%	6%	28%
% Faucet Flow Rate	8%	6%	7%	7%	6%	26%
Air Conditioner Testing (% for homes applicable)						
% Refrigerant Charge	2%	<1%	<1%	8%	0%	0%
% Air Handler Rate	5%	3%	5%	7%	4%	10%
Refrigerator Usage Metering	39%	34%	56%	33%	24%	14%

3.5 WAP INSTALLED MEASURES

Table 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 doing air sealing in over 90 percent of homes; bypass sealing using a blower door was reported for about two-thirds of homes.
- Attic Insulation – Attic insulation was reported for 20 percent of homes. The attic insulation installation rate was about 70 percent for site-built homes.
- Wall Insulation – Only a small percent (4 percent) of homes had wall insulation installed. The wall insulation installation rate was about 29 percent for site-built homes.
- Other Insulation – Floor insulation was installed in over 40 percent of homes.

Air sealing and floor insulation are common and important measures installed in mobile homes. Attic insulation was added to a small number of homes.

Table 3.16
PY 2008 Clients in Mobile 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	65%	63%	68%	73%	77%	17%
Bypass Sealing w/o Blower Door	10%	7%	10%	7%	8%	34%
Caulking w/o Bypass Sealing	16%	23%	15%	12%	10%	16%
Any Bypass Sealing or Caulking	91%	92%	93%	92%	97%	69%
Attic Insulation						
% Installed (none existing)	5%	5%	4%	6%	9%	0%
% Installed (over existing)	15%	18%	10%	18%	28%	<1%
% Installed (unknown)	1%	1%	1%	2%	2%	0%
% Installed (all types)	21%	25%	15%	26%	40%	<1%
Wall Insulation						
% Installed (regular)	2%	2%	3%	<1%	1%	0%
% Installed (dense pack)	2%	4%	2%	<1%	0%	0%
% Installed (all types)	4%	5%	6%	1%	1%	0%
Other Insulation						
% Floor Insulation	43%	49%	48%	44%	27%	4%
% Rim/band Joist Insulation	1%	1%	1%	1%	0%	0%
% Foundation Insulation	2%	1%	4%	<1%	0%	0%

Table 3.17 shows the rate at which equipment measures were installed in PY 2008. The key findings include:

- Heating Equipment – Heating equipment replacement was reported for about 26 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, one-half of the homes had some heating system work completed. Equipment replacement rates were higher in the Very Cold, Cold, and Hot/Dry Climate Zones.

- Ducts – Duct sealing was reported in one-half of homes. Duct sealing rates were consistent across Climate Zones.

- Water Heating Equipment – A small share of homes had water heating equipment measures; nationally only about 10 percent of equipment was replaced and most were for health and safety reasons. Another 6 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 one-fourth of homes had water heater wraps, low-flow showerheads, and faucet aerators installed.

Equipment measures are less common than are 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 wasn't operating safely or wasn't working at all. Sealing ducts and installing other water heating measures were more commonly reported measures.

Table 3.17
PY 2008 Clients in Mobile 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%	19%	11%	5%	10%	25%
New Furnace (non-ECM)	14%	13%	18%	9%	3%	23%
Heating System Tune-up	19%	25%	25%	14%	7%	0%
Other Heating System Repairs	4%	4%	5%	3%	4%	1%
Programmable Thermostat	2%	1%	2%	1%	6%	0%
Any Heating System Measure	52%	65%	63%	33%	32%	52%
Heating Ducts (% of systems with ducts)						
Duct Sealing	52%	51%	54%	54%	49%	46%
Duct Insulation	3%	2%	4%	4%	0%	0%
Water Heating Equipment						
New Water Heater (ECM)	4%	6%	2%	1%	9%	9%
New Water Heater (non-ECM)	7%	11%	8%	4%	3%	6%
Water Heater Repair	6%	5%	8%	5%	2%	2%
Water Measures						
Tank Wrap	26%	13%	28%	35%	53%	7%
Pipe Wrap	39%	37%	36%	48%	62%	5%
Temperature Reduction	13%	9%	14%	17%	16%	0%
Showerhead	28%	24%	27%	28%	31%	46%
Faucet Aerator	23%	24%	20%	21%	27%	32%

Table 3.18 shows the rate at which door and window measures were installed in PY 2008. The statistics show that 52 percent of homes had some form of window measures and 54 percent of homes had some form of door measure. About 23 percent of clients had one or more windows replaced for energy efficiency reasons and 26 percent of clients had a door replaced for energy efficiency reasons.

Table 3.18
PY 2008 Clients in Mobile 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)	23%	27%	26%	21%	9%	9%
New Window (non-ECM)	10%	12%	10%	8%	12%	9%
Storm Window	7%	12%	8%	3%	1%	9%
Window Glazing	5%	3%	3%	7%	15%	4%
Other Window Repair	7%	5%	4%	8%	14%	17%
Any Window Measure	52%	59%	51%	47%	51%	47%
Doors						
New Door (ECM)	26%	30%	28%	25%	11%	14%
New Door (non-ECM)	16%	15%	9%	22%	29%	17%
Storm Door	<1%	0%	1%	<1%	0%	0%
Door Repair	5%	4%	2%	6%	17%	5%
Other Door Measure	6%	7%	5%	7%	6%	11%
Any Door Measure	54%	56%	46%	60%	64%	46%

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; 29 percent of clients in the Hot/Humid Zone and 39 percent of the clients in the Hot/Dry Zone had AC equipment measures, and over 10 percent in each of these zones had new AC equipment installed.

- Duct Sealing – Over all Climate Zones, about 60 percent of homes with cooling system ducts had duct sealing with slightly lower rates in the Hot/Humid and Hot/Dry Climate Zones.

- Other Electric Measures – About 65 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 program 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 Mobile 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%	0%	<1%	<1%	9%	9%
New Air Conditioner (non-ECM)	1%	<1%	<1%	1%	4%	4%
Air Conditioner Repair	1%	<1%	<1%	1%	4%	1%
Air Conditioner Tune-up	2%	0%	0%	5%	9%	0%
Other Air Conditioner Measure	3%	<1%	2%	1%	2%	26%
Any Air Conditioning Measure	8%	1%	4%	7%	29%	39%
Cooling Ducts (% with ducts)						
Duct Sealing	59%	59%	66%	64%	42%	36%
Duct Insulation	2%	2%	3%	3%	0%	0%
White Roof Coating	10%	5%	6%	17%	27%	0%
Other Electric Measures						
Lighting (inside or outside)	65%	72%	68%	60%	63%	45%
Refrigerator (ECM)	15%	19%	17%	10%	6%	15%
Refrigerator (non-ECM)	1%	1%	1%	1%	0%	0%
Freezer	<1%	1%	<1%	0%	0%	0%
Other Baseload Measures	3%	1%	2%	<1%	0%	25%

4.0 ENERGY IMPACTS FOR MOBILE HOMES WITH GAS MAIN HEAT

The WAP evaluation directly measured gas and electric usage for treated mobile 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 levels for levels of spending on efficiency measures, total job costs, job funding sources, and agency funding sources.

These analyses help to show how program services and impacts vary by population subgroup. A further statistical analysis of explanatory factors related to observed energy savings were performed to estimate the energy savings attributable to individual program measures and to extrapolate the savings from the gas analysis sample to the full program population of gas heated mobile homes as well as homes heated by delivered fuels.

A report drafted by ORNL entitled *Weatherization Works*[9] includes a summary of energy impacts for all housing 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[10] and produces estimates of weather-adjusted annual energy consumption for each home based on monthly usage data and daily outdoor temperatures using a variable degree day base regression analysis.

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 – mobile 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 removing 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.

[9] 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.

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

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[11] to estimate net savings. As the name implies, this approach involves pooling all of the monthly billing data together across all homes into a single statistical model to explain monthly variations in energy use as a function of weather (degree day variables) and program interventions. The analysis included several alternative modeling specifications.
2. The second approach employed a variation on the pooled model that aggregates the energy use and weather data for each home and then statistically analyzes this aggregate data set to estimate program impacts. This method was developed at ORNL and is referred to as the ORNL aggregate model.

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

4.1.2 Sample Attrition

A total of 1,245 gas heated mobile 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 about half of the sampled homes. The usage data provided were not sufficient for developing savings estimates for 13 percent of the gas analysis homes and 19 percent 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 percent of the sampled cases (about 10 percent 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 2 percent of sampled cases in the gas analysis had gas usage too low to be considered gas heated and occupied during both periods. Just 0.2 percent of electric cases were classified as having usage either too low to be occupied or too high to be mobile homes. Less than 1 percent of the sampled homes were removed from the analysis because they were declared savings outliers[12]. 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.

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

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

Table 4.1
PY 2008 WAP Mobile 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	1,245	100%	1,245	100%
No Usage Data from Utility	567	46%	610	49%
Insufficient Data	164	13%	240	19%
Poor Model Fit	59	5%	46	4%
Usage Infeasible: Vacant, Unheated, not SF	29	2%	3	0%
Savings Outlier	4	0%	9	1%
Usable Cases	422	34%	337	27%
Additional Usable Cases (not sampled)	194		156	
Total Usable Analysis Sample	616		493	

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 more cases declared as outliers (though still less than 4 percent of otherwise-usable cases). The greater frequency of outliers in the comparison group was expected given that outliers were defined based 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 data on climate, demographics, housing stock, and program measures for site-built homes, all mobiles homes, and mobile homes with gas heat. The last two columns summarize these same characteristics for the gas and electric usage analysis samples. The table shows that, compared to site-built homes, treated mobile homes are smaller and newer, and their occupants have lower incomes but are more likely to be homeowners. Mobile homes have a similar geographic distribution to site-built homes with a modest skew toward the Moderate Zone and away from the Cold Zone. Mobile homes are also much more likely to receive a duct leakage test and duct sealing work and are a little more likely to receive a heating system replacement compared to site-built homes, but they are much less likely to receive attic and especially wall insulation.

The table also shows that mobile homes with gas heat are much less common in the moderate and hot Climate Zones and are a little older than mobile homes heated by other fuels. The gas and electric analysis samples are generally quite similar to the gas heated mobile home population on all listed characteristics.

Table 4.2
PY 2008 WAP Energy Impacts for Mobile Homes
Characteristics of Mobile Homes

Characteristic	All Site Built Homes	All Mobile Homes	Gas Heated Mobile Homes		
			All Gas Heated	Gas Analysis Sample	Electric Analysis Sample
Climate					
Very Cold	25%	27%	31%	34%	26%
Cold	42%	34%	45%	42%	47%
Moderate	21%	27%	14%	15%	12%
Hot/Humid	8%	6%	3%	0%	3%
Hot/Dry	4%	6%	8%	8%	12%
Demographics					
Median Income	$13,224	$11,472	$12,060	$11,752	$12,472
Homeowner	82%	90%	91%	89%	93%
Elderly	42%	44%	45%	45%	49%
# Occupants	2.5	2.2	2.1	2.0	2.1
Housing Characteristics					
Heated Area	1,421	1,009	989	958	1,045
Median Age	67	37	47	47	47
HDD 65	5,438	5,381	5,787	6,053	5,699
CDD 65	1,026	986	889	826	908
Central Heating	86%	89%	95%	97%	93%
Central A/C	36%	35%	30%	30%	31%
Wx Diagnostics					
Weatherization Assistant Audit	22%	22%	24%	30%	21%
Building Leakage Test	88%	92%	91%	93%	94%
Duct Leakage Test	19%	43%	35%	31%	46%
Major Measures					
Heater Replacement	21%	27%	30%	30%	28%
Attic Insulation	69%	19%	15%	16%	20%
Wall Insulation	29%	3%	3%	4%	3%
Air Sealing >1,000 CFM50	42%	36%	31%	32%	29%
Duct Sealing	31%	50%	51%	52%	58%
Refrigerator Replaced	13%	16%	18%	19%	18%

Note: Results weighted by sample design selection probabilities.

4.3 ENERGY SAVINGS OVERALL AND BY END USE

Table 4.3 summarizes natural gas impacts and shows a breakout of savings by weather-normalization component – heating[13] vs. baseload (non-heating) consumption. The gas savings are estimated at 97 therms[14] per year, equal to 12.6 percent of pre-program gas usage. Space heating was 79 percent of the gas usage and 74 percent of the gas savings. These savings are considerably less than the 181 therms (17.7 percent of 1,020 therm pre-program usage) for site-built homes. In comparison to site-built homes, the average mobile home was 36 percent smaller (958 vs. 1,504 ft²) and used 25 percent less natural gas. The gas savings differential was entirely in the heating portion.

Table 4.3
PY 2008 WAP Energy Impacts for Mobile 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	616	768	659	109 (±11)	97 (±13)	12.6% (±1.7%)
Comparison	504	781	769	12 (±6)		
Heating Use	616	607	518	89 (±11)	73 (±15)	12.0% (±2.4%)
Comparison	504	616	600	16 (±8)		
Baseload Use	616	161	141	20 (±7)	25 (±12)	15.5% (±7.4%)
Comparison	504	164	169	-5 (±8)		

*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 788 therms and half of all homes use between 634 and 986 therms. Ten percent of homes used less than 526 therms and ten percent used more than 1,199 therms. The comparison group distribution (not shown) was very similar.

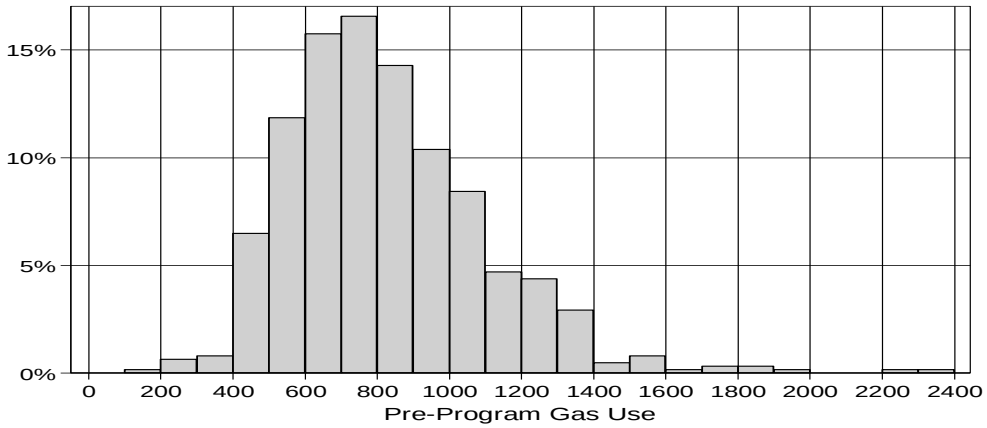

Figure 4.1: Distribution of Pre-Program Gas Use for Mobile Home Participants

[13] The space heating portion of the load actually includes some of the water heating load (and any other seasonal end uses) as gas water heating usage increases in the winter due to lower incoming cold water temperatures and other factors. See "*Seasonality of 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.
[14] 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 energy savings that was observed for households that did not receive weatherization services. The line graph for those households is centered on 0 percent and shows that over 25 percent of households had a weather-normalized gas savings of between +/- 2.5 percent. For about 20 percent of households, the savings were less than -12.5 percent or greater than +12.5 percent. Some of the sources of these savings 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 events 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 savings for comparison group households was about 12 therms (1.5 percent).

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 11.7 percent, showing that the participant group households had substantially higher gas savings then did the comparison group households. Second, the graph for the participant group is more spread out; about 15 percent of households had savings of +/- 2.5 percent from the median savings compared to almost 25 percent in that bin for the comparison group households. This shows that the variability in gas savings is greater for the participant group households than for comparison group households.

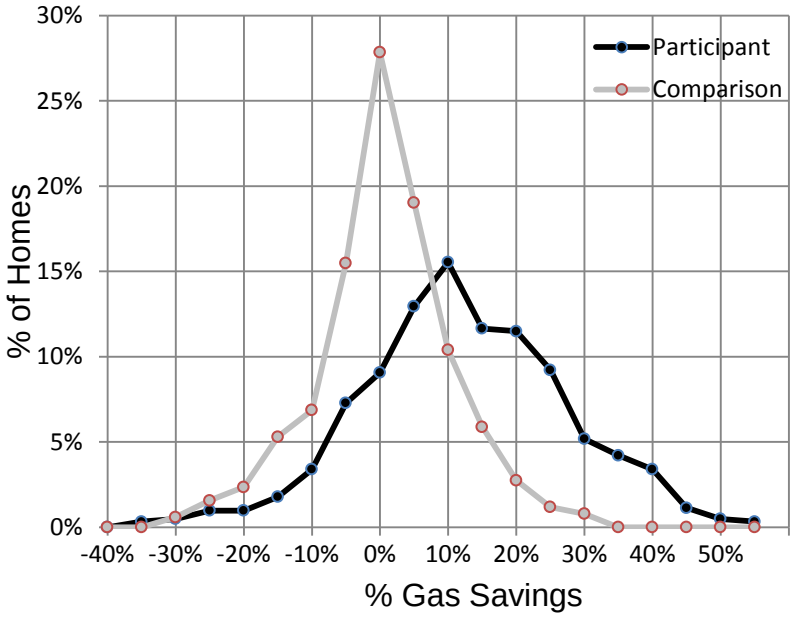

Figure 4.2: Distribution of Natural Gas Savings – Participant and Comparison Groups

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

- Weather-normalized usage for treatment group households fell by 14.2 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 12.7 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 of gas savings 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 gas savings for the comparison group may help explain this apparent anomaly. As shown in Figure 4.2 above, some comparison group homes increased usage by 20 percent or more due to 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 overall and 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 many electric end uses vary seasonally, such as refrigerators and lighting, and so a portion of their consumption is statistically allocated to the heating or cooling component. Approximately three-fourths of the electric use and savings are classified as baseload (i.e., non-seasonal).

Table 4.4
PY 2008 WAP Energy Impacts for Mobile 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	493	8,494	7,924	570 (±197)	472 (±222)	5.6% (±2.6%)
Comparison	326	8,338	8,240	98 (±138)		
Heating/Winter Use	493	848	778	70 (±82)	162 (±210)	19.1% (±24.8%)
Comparison	326	816	908	-92 (±169)		
Cooling/Summer Use	493	1,076	981	95 (±102)	30 (±132)	2.8% (±12.3%)
Comparison	326	1,051	986	65 (±89)		
Baseload Use	493	6,570	6,165	405 (±167)	280 (±275)	4.3% (±4.2%)
Comparison	326	6,471	6,346	125 (±159)		

The heating/winter electric use averaged less than 1,000 kWh annually. Much of this usage could be accounted for by a gas furnace fan and seasonality in other loads such as lighting. However, about 12 percent of gas heated homes had apparent electric heating usage large enough to indicate some use of supplemental electric heat. The estimated annual heating component was between 2,000 and 4,000 kWh in 9 percent of the homes and exceeded 4,000 kWh in 3 percent of the homes. Annual electric savings averaged 796 kWh in homes with heating use of 2,000 to 4,000 kWh and averaged 949 kWh in homes with use greater than 4,000 kWh.

The annual cooling/summer use averaged 1,076 kWh, indicating modest use of air conditioning on average in these homes since seasonality in refrigerator energy use, fans, and other seasonal loads could account for much of this value. The cooling/summer load averaged about three times as large in the 36

percent of homes reported to have central air conditioning as those without – 2,169 kWh vs. 774 kWh – but neither group had cooling savings that were statistically significant.[15]

The distribution of participants' pre-program total electric use is shown in Figure 4.3. The median annual electric use for participants was 7,012 kWh with half of all homes using between 5,147 and 10,582 kWh. Ten percent of homes used less than 3,554 kWh and ten percent used more than 14,409 kWh. The comparison group distribution was very similar.

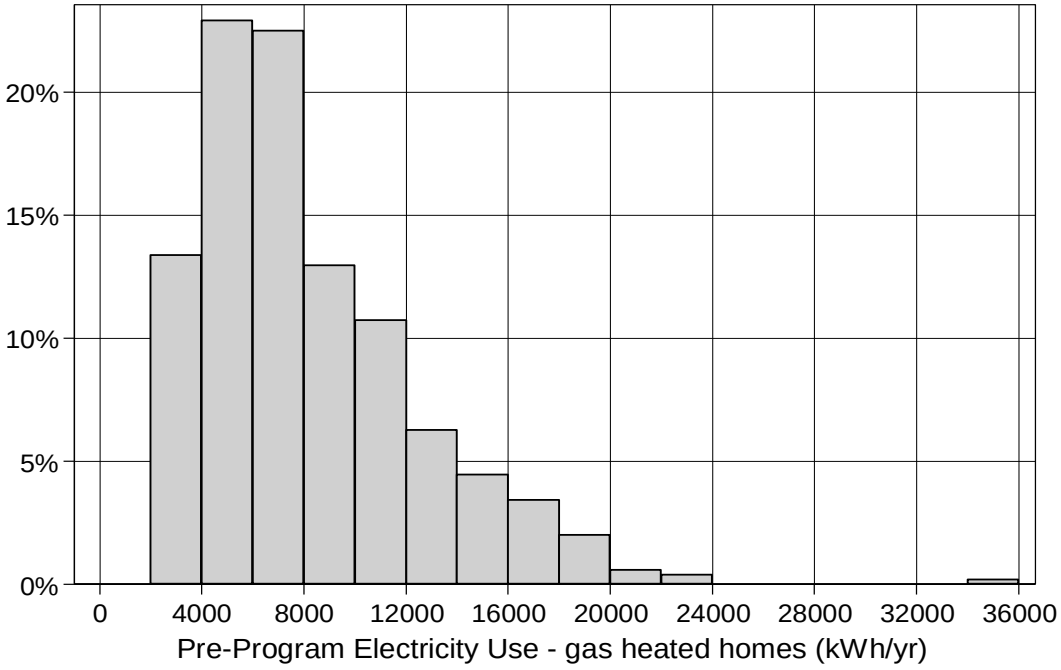

Figure 4.3: Distribution of Pre-Program Electric Use for Gas Heated Mobile Home Participants

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 year-over-year electric savings that was observed for households that did not receive weatherization services. The line for those households is centered on -5 percent and shows that about 20 percent of households had a weather-normalized electric savings +/-7.5 percent. For about 20 percent of the households, savings were less than -22.5 percent or greater than +22.5 percent. Some of the sources of these savings 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 98 kWh per year (1.2 percent).

[15] Table 4.4 shows that the electric savings for homes with natural gas main heat were statistically significant (i.e., we can reject the null hypothesis that the savings were zero). However, none of the end use estimates were statistically significant. That means that the analysis cannot reject the null hypothesis for Heating/Winter use, Cooling/Summer use, or Baseload use individually. The electric savings are likely to result from some savings for each of the three end uses. However, that cannot be determined with 95 percent confidence.

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 percent, 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 savings of +/- 2.5 percent from the median change compared to 20 percent in that bin for the comparison group households. This shows that the variability in energy savings is greater for the participant group households than for comparison group households.

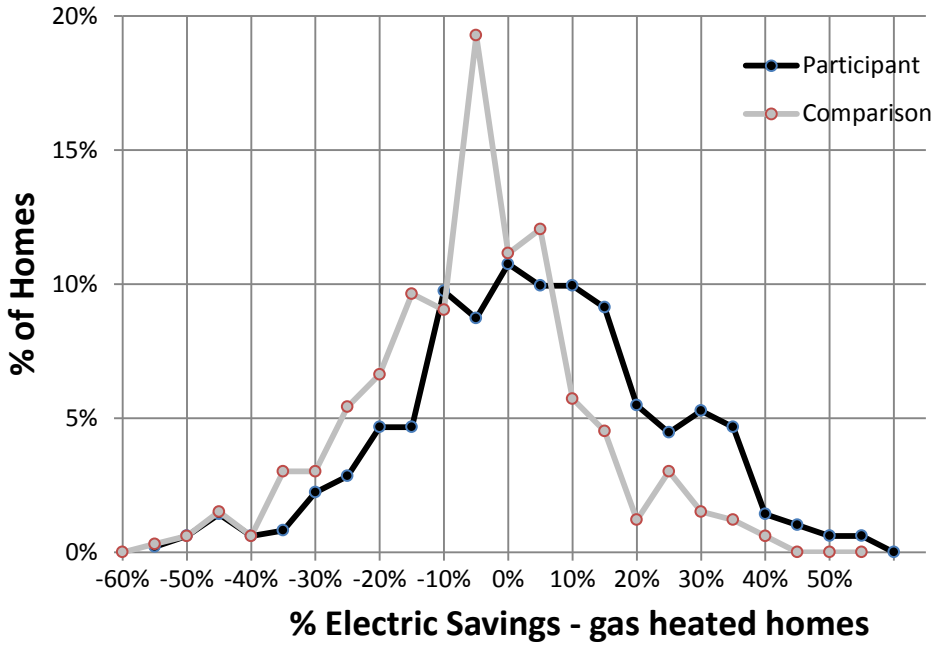

Figure 4.4: Distribution of Electric Savings – Participant and Comparison Groups (Gas Main Heat)

The distributions for electric savings are much closer together than they were for gas savings – reflecting the lower 5.5 percent average savings and the fact that many gas heated homes received few measures designed to reduce electric use (i.e., refrigerators or lighting). The median savings were 3.8 percent with half of the participants saving between -8.8 percent and +16.7 percent. A total of 42 percent of participants had an apparent increase in electric use after treatment compared to 49 percent of the comparison group.

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 by the level of gas savings. Three savings categories were created:

- Low savers were defined as participants that saved less than the 25th percentile of gas savings (<19 therms)
- High savers were defined as saving more than the 75th percentile of gas savings (>181 therms), and
- Mid-savers were defined as participants with savings between these limits.

The table shows that largest differences between high- and low-saving homes were in the pre-program gas use and in the measure installation rates. Compared to low savers, high savers used much more gas before participating and were more likely to have their heating system replaced, achieved large air leakage reductions, and received duct sealing and attic insulation. High savers were also less likely to be elderly and were more likely to have had the audit performed using the Weatherization Assistant software (MHEA). High savers were more likely to have had duct leakage tested and were more likely to live in the Very Cold Climate Zone.

Table 4.5
Characteristics of Homes with Low, Medium and High Gas Savings
Natural Gas Main Heat Mobile Homes

Characteristic	Low Saver	Mid Saver	High Saver
Gas Use and Savings (th/yr)			
Pre-Program Gas Use	668	693	1,048
Net Gas Savings	-61	84	294
Climate			
Very Cold	33%	30%	47%
Cold	50%	36%	52%
Moderate	9%	23%	2%
Hot/Humid	1%	0%	0%
Hot/Dry	7%	11%	0%
Demographics			
Median Income	$11,752	$11,880	$11,100
Homeowner	83%	93%	86%
Elderly	54%	45%	31%
# Occupants	1.9	1.9	2.2
Housing Characteristics			
Heated Area	1,028	904	1,022
Median Age	47	47	47
HDD 65	5927	5824	6789
CDD 65	951	844	648
Central Heating	95%	97%	97%
Central A/C	29%	25%	44%
Wx Diagnostics			
Weatherization Assistant Audit	17%	32%	39%
Building Leakage Test	93%	92%	93%
Duct leakage Test	19%	35%	33%
Major Measures			
Heater Replacement	17%	29%	50%
Attic Insulation	10%	13%	32%
Wall Insulation	0%	5%	4%
Air Sealing >1,000 CFM50*	19%	33%	44%
Duct Sealing	46%	47%	73%
Refrigerator Replaced	23%	14%	30%

Note: Results weighted by sample design selection probabilities.
* Cubic Feet per Minute @ 50 Pascals

4.5 ENERGY SAVINGS BY INSTALLED MEASURES

The 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 five major measures that appeared to drive a significant share of the observed gas savings in mobile homes: heating system replacement, floor insulation, attic insulation, duct sealing, and major air sealing[16]. Table 4.6 summarizes the gas savings results with participants grouped by the number of major measures they received.

Table 4.6
PY 2008 WAP Energy Impacts for Mobile Homes
Gas Savings for Homes with Natural Gas Main Heat
By Number of Major Measures (therms/year)

Group/Breakout	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
No Major Measures	59	709	34 (±39)	4.8 (±5.5)
Any One Major Measure	119	714	55 (±17)	7.7 (±2.4)
Any Two Major Measures	124	762	105 (±12)	13.8 (±1.6)
Any Three Major Measures	67	832	182 (±43)	21.9 (±5.2)
Four or Five Major Measures	44	905	185 (±31)	20.4 (±3.5)

Savings averaged 5 percent of pre-program gas usage for homes that did not receive any of the five major measures. Savings increased as the number of measures increased; mobile homes that got three or more measures saved more than 180 therms of natural gas (more than 20 percent of pre-program usage). But, most mobile homes received two or fewer major measures.

Table 4.7 summarizes the electric savings associated with two key electric baseload measures – refrigerator replacements and lighting retrofits (primarily CFLs). Both measures are associated with higher electric savings. Homes that received replacement refrigerators saved much more than homes that did not. These results are consistent with findings for site-built homes.

Table 4.7
PY 2008 WAP Energy Impacts for Mobile Homes
Net Electric Savings for Homes with Natural Gas Main Heat
By Measure Combination (kWh/year)

Measures	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
No Lighting or Refrigerator	95	8,604	238 (±275)	2.8% (±3.2)
Lighting, but No Refrigerator	158	8,599	447 (±276)	5.2% (±3.2)
Refrigerator (either Lighting)	78	8,028	1,077 (±317)	13.4% (±3.9)

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

4.6 ENERGY SAVINGS BY PRE-WEATHERIZATION USAGE LEVEL

Previous research has shown that homes with higher levels of pre-weatherization usage tend to achieve greater 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. (For this analysis, the comparison group was stratified into the same categories to provide a net savings adjustment.)

Table 4.8
PY 2008 WAP Energy Impacts for Mobile 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
<750 th/yr.	1.7	263	551	54 (±15)	9.8% (±2.7%)
750-<1000	1.8	211	862	93 (±20)	10.8% (±2.4%)
1000-<1250	2.2	99	1,114	192 (±29)	17.2% (±2.6%)
>=1250	2.3	43	1,463	299 (±72)	20.4% (±4.9%)

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

Gas savings increase dramatically with pre-weatherization usage: therm savings are about six times larger for the highest users than for the lowest users, and percent savings double over this range. Compared to site-built homes, savings are smaller among the two lower usage bins but just as large in the higher two bins. This pattern may be explained by the fact that usage of more than 1,000 therms is exceptionally high for mobile homes given their size and construction characteristics indicating that major problems are more likely in these higher usage bins.

Table 4.9 shows electric savings by pre-weatherization electric usage level for homes with gas main heat. Homes with pre-weatherization usage of less than 6,000 kWh had very low savings (44 kWh). Households with pre-weatherization usage of 6,000 kWh or more had average savings of more than 500 kWh. However, once household crossed the 6,000 kWh usage level, there did not appear to be a strong relationship between higher levels of pre-weatherization usage and higher electric savings. Homes with pre-weatherization usage of 14,000 kWh or more had average savings of 625 kWh, only about 10 percent higher than the households with pre-weatherization usage of 6,000 to less than 10,000 kWh.

Table 4.9
PY 2008 WAP Energy Impacts for Mobile Homes
Net Electric Savings for Homes with Natural Gas Main Heat
by Pre-Weatherization Electric Use (kWh/year)

Pre-WAP Usage	Refrigerator Replacement %	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
<6,000 kWh/yr.	29%	179	4,366	44 (±196)	1.0% (±4.5%)
6,000-<10,000	21%	175	7,617	561 (±173)	7.4% (±2.3%)
10,000-<14,000	21%	84	11,606	690 (±495)	5.9% (±4.3%)
>=14,000 kWh/yr.	20%	55	17,333	625 (±911)	3.6% (±5.3%)

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

Baseload electric savings are generally associated with refrigerator replacements and lighting. In the analysis sample, the lowest usage homes actually had the highest rate of refrigerator replacements in PY 2008. (Note: These differences were mainly a result of geography; certain states did not do refrigerator

replacements in PY 2008.) That is one reason why there is relatively little correlation between pre-weatherization usage and electric savings.

4.7 CLIMATE ZONE ANALYSIS

The Climate Zones were defined to provide insight into how energy use and program savings vary due to climatic differences. In general, one might expect that gas usage and savings potential would be higher in the colder Climate Zones while electric usage and savings potential would be higher in warmer climates for homes with air conditioning. The sample design and the fact that the PY 2008 WAP program served many more homes in colder climates than in milder climates led to the bulk of the analysis sample being concentrated in the Cold and Very Cold Climate Zones while very few homes were from the Hot/Humid or Hot/Dry zones. For mobile homes, this skew was even more severe – more than 90 percent of all homes in the analysis sample were in the Very Cold and Cold Climate Zones, leaving too few cases in the other three Climate Zones to develop reliable savings estimates. To address this issue, the Moderate, Hot/Dry and Hot/Humid Climate Zones were combined for the mobile home analysis and are referred to as the "Moderate/Hot" Climate Zone.

Table 4.10 summarizes gas impacts for homes with natural gas main heat by Climate Zone. Savings and pre-program gas use are both highest in the Very Cold Climate Zone. The overall net savings are reduced by the low savings in the small number of cases in the Moderate/Hot zones because 27 percent of the gas heated mobile homes were located in those zones yet just 6 percent of the sample was in those zones.

Table 4.10
PY 2008 WAP Energy Impacts for Mobile 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
Very Cold	2.1	372	858	119 (±21)	13.9% (±2.4%)
Cold	1.6	205	814	107 (±16)	13.1% (±2.0%)
Moderate/Hot	1.2	39	536	40 (±33)	7.5% (±6.2%)

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

Table 4.11 shows the gross and net electric impacts for gas heated homes by Climate Zone. Savings appear to be largest in the Moderate/Hot zones but the sample size is quite small and differences between zones are not statistically significant.

Table 4.11
PY 2008 WAP Energy Impacts for Mobile Homes
Electric Savings for Natural Gas Main Heat by Climate Zone (kWh/year)

Climate Zone	Refrigerator Replacement %	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
Very Cold	21%	261	8,539	407 (±388)	4.8% (±4.5)
Cold	29%	190	8,433	441 (±331)	5.2% (±3.9)
Moderate/Hot	3%	42	8,535	566 (±548)	6.6% (±6.4)

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

4.8 ANALYSIS OF OTHER FACTORS

Table 4.12 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 4.12
PY 2008 WAP Energy Impacts for Mobile 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	93	789	90 (±30)	11.4% (±3.8%)
Agency Crew	270	760	106 (±14)	13.9% (±1.9%)
Audit Approach				
Priority List	186	721	87 (±21)	12.1% (±2.9%)
Software / Calculation	221	807	109 (±18)	13.5% (±2.2%)

Table 4.13 compares savings for different job funding sources and also includes average spending on efficiency measures. 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 received non-DOE funds appeared to save a little more than did DOE-only jobs but this difference wasn't statistically significant. However, the jobs completed solely with DOE funds had less than half as much spent on efficiency measures.

Table 4.13
PY 2008 WAP Energy Impacts for Mobile Homes
Net Gas Savings for Natural Gas Main Heat
By Use of non-DOE Funds and by Subgrantee Wx Funding Sources (therms/year)

Funding Sources	# Homes	ECM Measure $/Home	Gas Use Pre-WAP	Net Savings	% of Pre
Job Funding Sources					
Only DOE Funds	184	$1,890	790	87 (±19)	11.0% (±2.4%)
DOE & Non-DOE Funds	229	$4,336	746	103 (±20)	13.8% (±2.7%)
Subgrantee Wx Funding Sources					
DOE WAP-dominated	28	$1,564	805	86 (±59)	10.7% (±7.3%)
WAP+LIHEAP-dominated	58	$2,526	790	115 (±35)	14.6% (±4.4%)
WAP+LIHEAP Majority, Some Other	324	$2,797	768	97 (±18)	12.6% (±2.3%)
Majority Other, WAP+LIHEAP Minority	173	$5,381	747	96 (±27)	12.9% (±3.6%)

The second part of Table 4.13 is based on the relative amount of funds leveraged by the subgrantee that did the work, not necessarily the spending on the specific job. Unlike with site-built homes, mobile home

gas savings were not larger for agencies that received substantial funding sources other than DOE or LIHEAP, in spite of the fact that these homes had much higher spending levels.

Table 4.14 summarizes gas savings by the amount of spending on efficiency measures for each job. This cost breakout was only available for about 40 percent of the cases in the analysis. The savings were about the same for the lower two categories of spending but were twice as large for homes where $4,000 or more was spent on efficiency measures. More than 70 percent of the homes in this highest spending category received heating system replacements. Pre-program gas use was about the same for all levels of spending and was actually lowest for the homes that had the highest spending.

Table 4.14
PY 2008 WAP Energy Impacts for Mobile Homes
Net Gas Savings for Natural Gas Main Heat
By Efficiency Measure Cost

Efficiency Measure Costs	# Homes	ECM Measure $/Home	Gas Use Pre-WAP	Net Savings	% of Pre
<$2,000	97	$1,159	799	82 (±31)	10.3% (±3.9%)
$2,000-<$4,000	82	$2,985	776	81 (±23)	10.4% (±3.0%)
>=$4,000	74	$6,786	758	164 (±41)	21.6% (±5.4%)

Table 4.15 shows a breakout of gas savings by whether or not total job costs exceeded $8,000. The $8,000 figure was selected to represent about the 10 percent highest-cost jobs overall and were primarily performed in states with substantial leveraging funds available. On average, high-cost jobs saved much more than other jobs but measure costs increased at an even higher rate.

Table 4.15
PY 2008 WAP Energy Impacts for Mobile Homes
Net Gas Savings for Natural Gas Main Heat By High Cost ($8,000) Job

Total Job Cost	# Homes	ECM Measure $/Home	Gas Use Pre-WAP	Net Savings	% of Pre
Total Job Cost <$8,000	357	$2,839	758	91 (±15)	12.0% (±2.0%)
Total Job Cost >=$8,000	35	$8,634	779	163 (±43)	20.9% (±5.5%)

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, also were collected for homes that participated in Program Years 2007 and 2009. The PY 2007 data were collected with the goal of assessing impacts for that year, but the amount of time that 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 4.16 summarizes the gas savings results for PY 2007 and PY 2009. For comparison, the PY 2008 gas savings averaged 97 therms net (109 therms gross), equal to 12.6 percent of the 768 therms pre-program annual gas use. The PY 2007 savings were virtually identical to the PY 2008 results and the PY 2009 results were slightly larger, but the difference was not statistically significant.

Table 4.16
PY 2007 and PY 2009 WAP Energy Impacts for Mobile Home
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	449	791	691	100 (±12)	98 (±13)	12.4% (±1.7%)
Comparison	853	754	752	2 (±7)		
PY 2009	487	784	670	114 (±20)	115 (±19)	14.7% (±2.5%)
Comparison	712	696	697	-1 (±8)		

Table 4.17 summarizes the electric savings results for gas heated homes in PY 2007 and PY 2009. For comparison, the PY 2008 savings were 472 kWh/year net (571 kWh/yr gross), equal to 5.6 percent of the 8,494 kWh/yr. pre-program electric use. The PY 2007 savings estimate is lower than that for PY 2008 (but not statistically significant) and the PY 2009 savings is much higher than PY 2008 and statistically significant. The pattern of increasing electric baseload savings over the three years is stronger but consistent with the site-built home findings and may be due to an increasing frequency of lighting and refrigeration measures being included in the program over time.

Table 4.17
PY 2007 and PY 2009 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Natural Gas Main Heat

Program Year	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2007	347	8,321	7,982	339 (±250)	311 (±266)	3.7% (±3.2%)
Comparison	647	8,321	8,293	28 (±96)		
PY 2009	344	8,250	7,246	1,004 (±311)	1,097 (±376)	13.3% (±1.3%)
Comparison	574	8,590	8,683	-93 (±102)		

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

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

In addition to providing potentially useful estimates of measure savings and other insights into factors associated with savings, the regression analyses of savings were also used to estimate the overall savings for the population of gas heated mobile homes and for homes heated by delivered fuels (oil and propane). Table 4.2 summarized characteristics of mobile homes in the analysis sample compared to those in the gas heated population and all mobile homes in the program. There were some differences in measure installation rates and other factors. The regression model developed using the billing analysis sample was used to estimate 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 as 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[17] 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. Attic insulation, heating system replacement, floor insulation, duct sealing, and air leakage reduction were found to account for the bulk of the savings. The small sample and geographic skew limited the ability of the modeling to provide the same level of reliability as the modeling done for the site-built homes. Many potential measures were dropped from the model due to weak explanatory power. The gas savings results from the explanatory factors model are summarized in Table 4.18.

Table 4.18
PY 2008 WAP Energy Impacts for Mobile 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	96%	47	44	45%
Duct Sealing	51%	39	20	20%
Heater Replacement	30%	52	15	15%
Floor Insulation	38%	32	12	12%
Attic Insulation	15%	63	9	9%
Other / Unattributed	100%	-2	-2	0%
Total			98	100%

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

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 share of program savings – an average of 44 therms per home equal to nearly half of the overall gas savings. Duct sealing is estimated to provide the second largest overall impact – providing average estimated savings of 39 therms per home for about half of all participating mobile homes. Heating system replacements is the third largest source of savings – producing 52 therms per home in 30 percent of all mobile homes. Floor insulation is the next largest savings measure, producing estimated savings of 32 therms per home in 38 percent of homes. Attic insulation was only performed in 15 percent of mobile homes and was estimated to save 63 therms in those cases.

The five major measures account for an estimated 100 therms in average savings per home – which is actually two therms more than the overall estimated net savings for the nation. Although ventilation system installations could result in some increase in gas use (as found in the site-built home analysis), the other remaining measures almost certainly provided sufficient savings to offset this. This small discrepancy is attributed to uncertainty in the estimated measure-level impacts leading to a slight over-estimation of one or more measure savings.

Overall, the gas explanatory factors model estimates that the program produced average annual natural gas savings of 98 therms – essentially identical to the 97 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 4.19.

Table 4.19
PY 2008 WAP Energy Impacts for Mobile 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	67%	280	187	55%
Refrigerator Replacement	18%	535	93	27%
Air Conditioner Replacement	1%	920	9	3%
Other / Unattributed	100%	51	51	15%
Total			340	100%

Lighting retrofits are estimated to have saved 280 kWh per home for the 67 percent of homes that received that measure. Refrigerator replacements are estimated to have saved 535 kWh for the 18 percent of homes receiving replacements. Air conditioner replacement was very rare but was estimated to produce large savings when performed. Another 51 kWh in electricity savings in gas heated mobile homes are 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 electricity savings in gas heated homes are estimated at 340 kWh – substantially less than the 472 kWh net savings from the billing analysis sample. This 132 kWh reduction in savings is due to differences between the analysis sample and the population. (The analysis sample had more measures

installed than did the average home served by the program. Therefore, the explanatory factors model estimated lower savings for the population than was observed for the analysis sample.)

5.0 ENERGY IMPACTS FOR MOBILE 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, installed measures, and 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 mobile homes with electric heat were analyzed using the same approach employed for the electric savings analysis in gas heated mobile homes – a standard pre/post treatment/comparison design using weather-normalized utility billing data. The relatively small number of homes in the electric heat analysis sample limited the extent of further analysis and exploration.

5.1.1 Sample Attrition

A total of 819 mobile homes with electric heat were 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 55 percent of the sampled homes. The usage data provided were not sufficient for developing savings estimates for 15 percent of the electric analysis homes. Most of this attrition was due to too little pre-retrofit data – the analysis required a minimum 270 days of electric data (in addition to some requirements about weather). The weather-normalization itself indicated a poor model fit in either the pre or post periods for about 2 percent of the sampled cases. An additional 6 percent of sampled cases in the analysis had electric usage too low to be considered electrically heated and occupied during both periods (and 1 case had usage too high to be considered a mobile home). Less than 1 percent of the sampled homes were removed from the analysis because they were declared savings outliers[18]. 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.

[18] 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 Mobile Homes
Electric Usage Sample Attrition – Electric Main Heat

	Electric Analysis	
Sample Group / Attrition Cause	**Homes**	**% of Sample**
Sampled	819	100%
No Usage Data from Utility	367	45%
Insufficient Data	124	15%
Poor Model Fit	15	2%
Usage Infeasible: Vacant, Unheated, not SF	48	6%
Savings Outlier	5	<1%
Usable Cases	260	32%
Additional Usable Cases (not sampled)	16	
Total Usable Analysis Sample	276	

The same screening criteria were also applied to the comparison group analysis and the group ended up with 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 mobile home sample compared to mobile 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 Zone and less likely to be in the Cold or Very Cold Zones. Participants who lived in electric heated mobile homes tended to have lower incomes than did participants with other heating fuels and their homes were more likely to have central air conditioning. The analysis sample attrition has created a group skewed slightly toward colder climates but generally similar to the larger electric heated mobile home population.

Table 5.2
PY 2008 WAP Energy Impacts for Mobile Homes
Characteristics of Mobile Homes with Electric Heat

Characteristic	All Mobile Homes	Electric heat Population	Electric Heat Analysis Sample
Climate			
Very Cold	27%	14%	19%
Cold	34%	16%	20%
Moderate	27%	51%	45%
Hot/Humid	6%	13%	11%
Hot/Dry	6%	6%	6%
Demographics			
Median Income	$11,472	$10,584	$10,044
Homeowner	90%	89%	89%
Elderly	44%	35%	43%
# Occupants	2.2	2.4	2.3
Housing Characteristics			
Heated Area	1,009	1,059	1,070
Median Age	37	37	37
HDD65	5,381	4,319	4,447
CDD65	986	1,263	1,199
Central Heating	89%	89%	92%
Central A/C	35%	54%	45%
Wx Diagnostics			
Weatherization Assistant Audit	22%	15%	12%
Building Leakage Test	92%	94%	94%
Duct Leakage Test	43%	58%	54%
Major Measures			
Heater Replacement	27%	20%	27%
Attic Insulation	19%	27%	32%
Wall Insulation	3%	3%	6%
Air Sealing >1,000 CFM50*	36%	42%	35%
Duct Sealing	50%	50%	44%
Refrigerator Replaced	16%	11%	7%

Note: Results weighted by sample design selection probabilities.
* Cubic Feet per Minute @ 50 Pascals

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. Electric savings averaged 1,547 kWh equal to 7.5 percent of total pre-program usage. The percent savings are lower than the 12.6 percent found for gas heated mobile homes but much

of this difference is due to greater number of electric end uses that are not affected by WAP measures. The savings in the heating portion of electric use averaged 12.1 percent, which is similar to the 11.9 percent heating savings found in gas heated mobile homes. The baseload component savings estimate is also similar to the 472 kWh average net savings in the gas heated analysis sample. Cooling use was small and savings averaged 9.3 percent but weren't statistically significant.

Table 5.3
PY 2008 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Electric Main Heat by End Use (kWh/year)

Usage Component	# Homes	Elec Use Pre-WAP	Gross Savings	Net Savings	% of Pre
Total Use	276	20,609	2,114 (±356)	1,547 (±510)	7.5% (±2.5)
Comparison	188	20,946	567 (±328)		
Heating/Winter Use	276	8,154	1,306 (±304)	991 (±504)	12.1% (±6.2)
Comparison	188	8,704	315 (±317)		
Cooling/Summer Use	276	1,207	238 (±145)	112 (±160)	9.3% (±13.3)
Comparison	188	1,251	126 (±182)		
Baseload Use	276	11,248	570 (±301)	444 (±469)	3.9% (±4.2%)
Comparison	188	10,991	126 (±392)		

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 21,046 kWh and half of all homes used between 16,188 and 25,209 kWh annually. Ten percent of homes used less than 12,849 kWh and ten percent used more than 29,358 kWh. The comparison group distribution was generally similar but shifted to slightly lower consumption with a median of 19,761 kWh and quartiles of 16,076 kWh and 24,586 kWh.

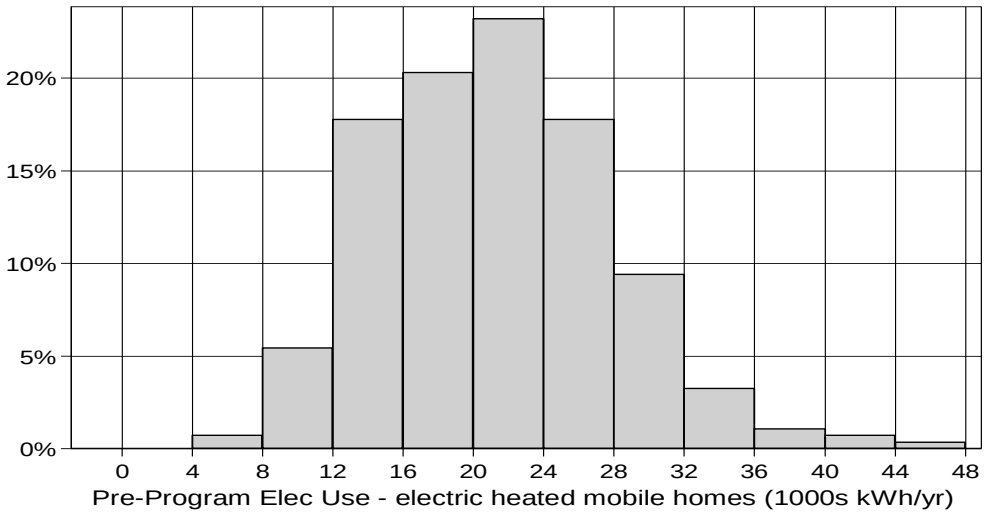

Figure 5.1: Distribution of Pre-Program Electric Use for Electric Heat Mobile Home Participants

The distribution of percent electric savings for electric heat participants and the comparison group households are shown together in Figure 5.2. The comparison group line graph shows the distribution of

the year-over-year energy savings that was observed for households that did not receive weatherization services. The line graph for those households is centered on 0% and shows that over 20 percent of households had weather-normalized electric savings between +/-2.5%. For about 30 percent of households, the savings were less than -12.5% or greater than +12.5%. Some of the sources of these savings 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 events 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 electric savings for comparison group households was about 567 kWh (2.7%).

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 7.6 percent showing that the participant group households had substantially higher electric savings then did the comparison group households. Second, the graph for the participant group is more spread out; about 15 percent of households had savings of +/- 2.5% from the median savings compared to over 20 percent in that bin for the comparison group households. This shows that the variability in electric savings is greater for the participant group households than for comparison group households.

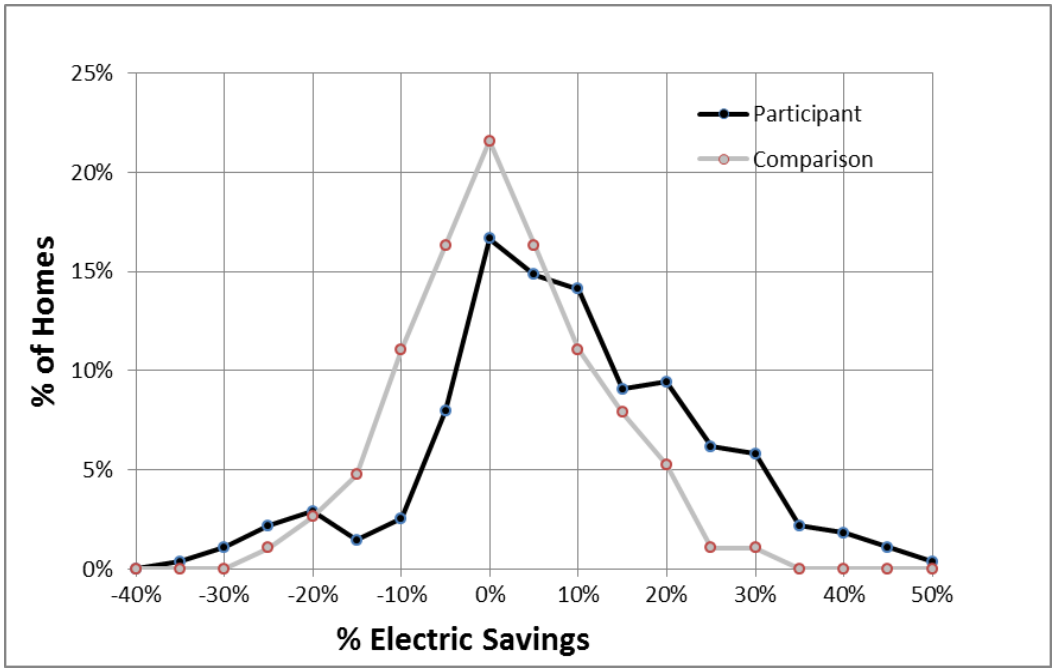

Figure 5.2: Distribution of Percent Electric Savings – Participant and Comparison Groups

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

- Weather-normalized usage for treatment group households fell by 10.2 percent and by 2.7 percent for comparison group households; the net impact of weatherization was to shift the electric savings graph to the right by about 7.5 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 of electric savings 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 electric savings for the comparison group may help explain this apparent anomaly. As shown in Figure 5.2 above, some comparison group homes increased usage by 20 percent or more due to 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, floor insulation, duct sealing, and heating equipment replacement.

Table 5.4
PY 2008 WAP Energy Impacts for Mobile 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	31	22,293	-30 (±753)	-0.1% (±3.4%)
One Major Measure	80	19,319	766 (±519)	4.0% (±2.7%)
Two Major Measures	86	20,804	2,444 (±746)	11.7% (±3.6%)
Three or More Major Measures	61	21,210	1,779 (±768)	8.4% (±3.6%)

Homes that received no major measures achieved no or little savings while those that received two major measures saved about 12 percent of pre-retrofit use. But it appears that homes that received three or more major measures had lower savings than those that received two measures. This apparent anomaly may be explained by the small sample sizes which make this difference not statistically significant.

5.5 ENERGY IMPACTS BY PRE-WEATHERIZATION USAGE LEVEL

Similar to the gas analysis, the relationship between pre-weatherization total electric use and electric savings in electrically heated homes was explored by examining net savings by level of pre-program electric usage. Due to the small number of cases in the analysis, the sample was split approximately in

half (at 20,000 kWh per year) into low users and high users. The results of this analysis are shown in Table 5.5.

Table 5.5
PY 2008 WAP Energy Impacts for Mobile Homes
Net Electric Savings for Electric Main Heat by Pre-Weatherization Electric Usage

Pre-WAP Use	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
<20,000 kWh/yr.	122	15,002	988 (+/-455)	6.6% (+/- 3.0%)
>=20,000 kWh/yr.	154	25,709	2,040 (+/-790)	7.9% (+/-3.1%)

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

The annual kWh savings are twice as large for homes with higher usage although the percent savings are only slightly larger.

5.6 CLIMATE ZONE IMPACTS

The analysis sample included just 15 electrically heated mobile homes in the Hot/Humid Climate Zone and 6 mobile homes in the Hot/Dry Climate Zone. These small samples led to combining these two Climate Zones with the Moderate Climate Zone for the analysis, which also provided for consistency with the approach taken in the mobile home gas analysis. Table 5.6 summarizes the savings results for these three Climate Zones.

Table 5.6
PY 2008 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Electric Main Heat by Climate (kWh/year)

Climate Zone	# Homes	Elec Use Pre-WAP	Net Savings	% of Pre
Very Cold	76	20,637	1,321 (±579)	6.4% (±2.8%)
Cold	58	22,647	1,821 (±1,071)	8.0% (±4.7%)
Moderate/Hot	142	20,108	1,544 (±747)	7.7% (±3.7%)

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

The differences in net savings among the three Zones were not statistically significant. An analysis by end use component found larger summer/cooling use and savings in the Hot Zones but again the small samples make this finding suggestive at best.

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 averaged 1,547 kWh net (2,114 kWh gross), equal to 7.5 percent of the 20,609 kWh pre-program annual electric use. The PY 2007 and PY 2009 savings estimates were both considerably larger than the PY 2008 results, especially in PY 2009, but the differences were not statistically significant. Still, the higher savings in PY 2007 and PY 2009 imply that the true PY 2008 savings may be higher than the point estimate. The same pattern was found in the analysis of site-built homes. A closer examination of results across years revealed that the PY 2008 sample had greater representation of lower-saving states.

Table 5.7
PY 2007 and PY 2009 WAP Energy Impacts for Mobile Homes
Gross and Net Electric Savings for Electric Main Heat

Program Year	# Homes	Elec Use Pre-WAP	Elec Use Post-WAP	Gross Savings	Net Savings	% of Pre
PY 2007	146	20,886	18,528	2,358 (±736)	2,204 (±851)	10.6% (±4.1%)
Comparison	314	20,829	20,675	154 (±274)		
PY 2009	193	21,520	18,266	3,254 (±1831)	3,138 (±1,848)	14.6% (±8.6%)
Comparison	302	19,429	19,313	116 (±265)		

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 mobile homes. The small sample size and large variance in savings across cases led to measure-specific savings estimates that were not considered sufficiently reliable to report, but the overall approach was still considered worth employing to develop national estimates of savings. This analysis estimated that the net average savings for the population of electric heat mobile homes served by the WAP were 1,567 kWh/year. That is close to the 1,547 kWh/year estimate developed from the analysis of homes for which billing data were available.

6.0 ENERGY IMPACTS FOR MOBILE HOMES WITH DELIVERED FUEL MAIN HEAT

About 22 percent of mobile homes that participated in PY 2008 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 that metering study was to test whether savings among oil-heated homes differ significantly from savings among gas heated homes. The study was conducted in site-built homes and is described in greater detail in the Single Family Site Built Homes Impact Report. The study found that savings in oil heated homes were virtually identical to the savings that would be expected if these had been gas heated homes in the same locations that received the same mix of measures. In other words, the results supported 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 the findings of the metering study, the gas explanatory factors model savings estimation approach described in Section 4.10 was applied to all mobile homes heated with delivered fuels. Similarly, electric baseload savings were estimated based on electric savings found in gas heated homes as a function of electric measures.

Table 6.1 summarizes the resulting estimated net energy savings for mobile homes that heat with delivered fuels. The differences in energy savings are a function of differences in measure installation rates and locations.

Table 6.1
PY 2008 WAP Energy Impacts for Mobile Homes
Net Savings for Delivered Fuel Main Heat

Main Heating Fuel	Heating Fuel Savings (MMBtu*/yr)	Electric Savings (kWh/yr)
Fuel Oil	11.5	321
Propane	10.7	370
Other	12.1	321
All Delivered Fuels	**11.2**	**342**

***** Mean Million British Thermal Units

7.0 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 analysis 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 who 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 Mobile 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	$784	$872	$1,656	$96	$34	$130	7.9%
Electricity	-	$1,989	$1,989	-	$134	$134	6.7%
Fuel Oil	$1,912	$1,256	$3,168	$242	$38	$280	8.8%
Propane	$2,157	$924	$3,081	$270	$36	$306	9.9%
Other	$855	$1,021	$1,876	$106	$28	$134	7.1%
All Clients	$956	$1,086	$2,042	$119	$48	$167	8.2%

Participant annual energy costs averaged $2,042 prior to WAP, and WAP reduced these costs by an average of $167, equal to an 8.2 percent reduction in total energy costs. The annual energy costs for homes heated by fuel oil or propane were almost twice the costs for homes heated by natural gas. The energy cost savings for homes heated by fuel oil or propane were more than twice the savings for homes heated by natural gas or electricity.

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 $2,419 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spent an average of $2,721 on efficiency measures in these homes, yielding an SIR of 0.89 meaning that measure costs exceeded energy savings. This finding stands in contrast to the analysis of site-built homes which found an overall SIR of 1.47. Site-built homes achieved energy cost savings that were 73 percent greater than those for mobile homes at a measure cost just 5 percent greater.

Table 7.2. PY 2008 WAP Energy Impacts for Mobile 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	$1,450	$314	$1,764	$2,506	-$742	0.70	0.55 - 0.92
Electricity	-	$1,989	$1,989	$3,218	-$1,229	0.62	0.48 - 0.78
Fuel Oil	$4,558	$372	$4,930	$2,532	$2,398	1.95	1.45 - 2.67
Propane	$3,940	$324	$4,264	$2,589	$1,675	1.65	1.28 - 2.17
Other	$2,522	$262	$2,784	$2,879	-$95	0.97	0.73 - 1.29
All Clients	**$1,644**	**$775**	**$2,419**	**$2,721**	**-$302**	**0.89**	**0.73 - 1.11**

The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.73 to 1.11. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases. Therefore, if energy prices increase at a greater pace than assumed, the retrofits may be considered cost-effective (from an energy-only perspective).

Although the SIR is estimated to be less than one for mobile homes overall, the retrofits were quite cost-effective for mobile homes heated with fuel oil and propane due to the high costs of these fuels.

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.

Table 7.3. PY 2008 WAP Energy Impacts for Mobile 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	$2,186	$574	$2,760	$3,365	-$605	0.82
Cold	$1,698	$543	$2,241	$1,760	$481	1.27
Moderate/Hot	$1,245	$1,094	$2,339	$3,101	-$762	0.75

The Cold Climate Zone produced an SIR greater than 1.0 due to having the lowest spending on efficiency measures. The mobile homes in the Very Cold Climate Zone achieved the largest energy cost savings but also had the greatest measure costs. A significant portion of this cost difference is that heating system replacements are more often classified as efficiency measures in the Very Cold climate due to differences in state program rules.

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[19] 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 category of homes with no major measures is not shown because the sample of homes with both reliable energy savings results and measure cost data is smaller than 30.

[19] Note that cost-effectiveness results shown in Tables 7.4 through 7.6 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 and after 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 does the overall population.

Table 7.4. PY 2008 WAP Impacts for Mobile 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
One	$863	$170	$1,033	$2,122	-$1,089	0.49
Two	$1,686	$408	$2,094	$3,355	-$1,261	0.62
Three	$2,878	$358	$3,236	$4,943	-$1,707	0.65
Four or Five	$2,793	$2,388	$5,181	$6,116	-$935	0.85
All Clients (N=253)	**$1,772**	**$491**	**$2,263**	**$3,639**	**-$1,376**	**0.62***

* See footnote 14 for explanation of lower SIR.

The cost effectiveness as measured by SIR increases with the number of measures, but stays below unity for all categories. The overall SIR of 0.62 is 0.08 lower than the 0.70 value shown in Table 7.2 for gas heated homes. This discrepancy is 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.

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 highest usage category of 1,250 therms and above is omitted due to having fewer than 30 homes that had reliable savings results and energy conservation measure cost data. The SIR increases dramatically with pre-weatherization gas use with an SIR greater than one for mobile homes that used more than 1,000 therms of natural gas annually.

Table 7.5. PY 2008 WAP Impacts for Mobile 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 th/yr.	$955	$385	$1,340	$3,640	-$2,300	0.37
750-<1,000	$1,481	$386	$1,867	$3,431	-$1,564	0.54
1,000-<1,250	$3,616	$1,207	$4,823	$3,951	$872	1.22

Table 7.6 summarizes the cost-effectiveness of program treatments based on whether the home was treated using just DOE funds or with DOE funds plus other funding sources.

Table 7.6
PY 2008 WAP Impacts for Mobile 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	$1,496	$369	$1,865	$1,720	$145	1.08
DOE + Non-DOE Funds	$1,865	$551	$2,416	$4,285	-$1,869	0.56

The DOE-only jobs were much more cost-effective than were jobs that received other funds and had a SIR greater than one. The DOE-only jobs produced 77 percent of the bill savings at 40 percent of the energy measure cost compared to jobs that also received funds from other sources. The same pattern was found for site-built homes. It appears the DOE funds were used to capture the most cost-effective opportunities, while additional funding sources addressed less cost-effective measures. Measure installation data for these homes revealed a stark difference in heating system replacements rates – 8 percent of DOE-only jobs vs. 54 percent of jobs that received other funds. There were also differences in the installation rates of attic insulation (26% DOE-only vs. 20% DOE+), floor insulation (34% DOE-only vs. 58% DOE+) and duct sealing (56% DOE-only vs. 69% DOE+).

Based on these cost-effectiveness results that focus solely on the value of the energy savings compared to the cost of the efficiency measures, WAP work in mobile homes, for the packages of measures included in this evaluation and the low frequency in which high saving measures were installed, is only cost-effective in homes with oil or propane heat, homes with high levels of pre-program gas use (>1,000 therms), and homes where only DOE funds were used. The additional resources from non-DOE sources may have produced other benefits of value, but did not provide sufficient gas and electric bill reductions in proportion to the additional funds expended.

7.3 PY 2013 ANALYSIS PERSPECTIVE

This section presents the estimated energy cost savings and cost-effectiveness from the perspective of analysis 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, 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 analysis decisions across all Federal programs currently use these rates for budgetary decision-making. Consequently, the PY 2013 Analysis Perspective is most useful for 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 7.7 summarizes the average energy costs and annual cost savings for the first year after participation in WAP in 2013 dollars.

Table 7.7
Projected PY 2013 WAP Energy Impacts for Mobile 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	$632	$952	$1,584	$77	$37	$114	7.2%
Electricity	-	$2,159	$2,159	-	$145	$145	6.7%
Fuel Oil	$2,066	$1,321	$3,387	$261	$40	$301	8.9%
Propane	$1,728	$1,010	$2,738	$216	$39	$255	9.3%
Other	$930	$1,095	$2,025	$115	$30	$145	7.2%
All Clients	$844	$1,177	$2,021	$105	$53	$158	7.8%

For PY 2013 participants, annual energy costs are expected to average $2,021 prior to WAP, and it is projected that WAP would reduce these costs by an average of $157, equal to a 7.8 percent reduction in total energy costs. The energy costs and value of the savings are expected to be up to two times as large in homes heated by fuel oil or propane than in homes heated by natural gas.

Table 7.8 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 $3,053 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spend an average of $2,961 on efficiency measures in these homes, yielding a net benefit of $92 per home and an SIR of 1.03. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.83 to 1.32. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.8. Projected PY 2013 WAP Energy Impacts for Mobile 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	$1,865	$376	$2,241	$2,727	-$486	0.82	0.62 - 1.11
Electricity	-	$2,450	$2,450	$3,501	-$1,051	0.70	0.53 - 0.89
Fuel Oil	$6,063	$441	$6,504	$2,755	$3,749	2.36	1.72 - 3.28
Propane	$4,807	$386	$5,193	$2,817	$2,376	1.84	1.40 - 2.49
Other	$3,128	$309	$3,437	$3,132	$305	1.10	0.82 - 1.48
All Clients	$2,107	$946	$3,053	$2,961	$92	1.03	0.83 - 1.32

The projected SIR 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 analysis 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 analysis 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 percent 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 $2,021 prior to WAP, and it is projected that WAP would reduce these costs by an average of $158, equal to a 7.8 percent reduction in total energy costs.

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

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

The table shows that future programs would be expected to produce an average of $2,481 worth of energy bill savings over the lifetime of the measures (discounted to 2013 dollars) and spend an average of $2,961 on efficiency measures in these homes, resulting in a SIR of 0.84. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.68 to 1.05. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 7.9. Projected Future WAP Energy Impacts for Mobile 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	$1,498	$322	$1,820	$2,727	-$907	0.67	0.52 - 0.88
Electricity	-	$2,008	$2,008	$3,501	-$1,493	0.57	0.44 - 0.71
Fuel Oil	$4,876	$376	$5,252	$2,755	$2,497	1.91	1.42 - 2.58
Propane	$3,878	$332	$4,210	$2,817	$1,393	1.49	1.16 - 1.97
Other	$2,537	$266	$2,803	$3,132	-$329	0.89	0.68 - 1.19
All Clients	$1,695	$786	$2,481	$2,961	-$480	0.84	0.68 - 1.05

The projected SIR 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.