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

David Carroll
Greg Dalhoff
Daya Bill Johnson
Dan Bausch
Michael Blasnik

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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

ORNL Principal Investigator
Dr. Bruce Tonn

Evaluation Team Task Manager
David Carroll

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Environmental Sciences Division

EVALUATION OF THE WEATHERIZATION ASSISTANCE PROGRAM DURING PROGRAM YEARS 2009-2011 (AMERICAN RECOVERY AND REINVESTMENT ACT PERIOD): ENERGY IMPACTS FOR MULTIFAMILY BUILDINGS

David Carroll, APPRISE
Greg Dalhoff, Dalhoff & Associates
Daya Bill Johnson, APPRISE
Dan Bausch, APPRISE
Michael Blasnik, Blasnik & Associates

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Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
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ACRONYMS AND ABBREVIATIONS

AC	Air Conditioning
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
Btu	British thermal unit
CFM50	Cubic Feet per Minute @ 50 pascals
CFR	Code of Federal Regulations
DOE	Department of Energy
ECM	Energy Conservation Measure
EIA	Energy Information Administration
kWH	Kilowatt Hour
LIHEAP	Low Income Home Energy Assistance Program
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
TH	Therm
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 multifamily buildings by DOE's Weatherization Assistance Program (WAP) during Program Years 2009, 2010, and 1011.

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

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

Grantee and Subgrantee Data Collection

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

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

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

Grantee Data Processing

APPRISE was responsible for extracting client data from program databases made available to the evaluation team by grantees. The APPRISE staff who contributed to this process were:

Ferit Ucar
Daya Bill
Dan Bausch
Chisoo Kim
Zach Tausanovitch
Leah Harrell
Deena Mitlak
Jeffery Ho
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Carlos Salguero

Energy Supplier Data Collection

APPRISE collected information on electric and gas usage from 365 electric companies and 220 gas companies, and on fuel oil usage from 31 fuel oil companies. The cooperation of and contributions made by the electric and gas companies were essential to the completion of the study.

The APPRISE staff responsible for the electric and gas company data collection and analysis for the PY 2010 study were:

Lisa Courtney
James Devlin
Kathy Davis
Arlene Shipley
Camille D'Andrea
Michael Brach
Alex McEwan
Anne Worth
David Slayback

Large Multifamily Building Data Collection

APPRISE collected information on-site at subgrantee offices for those subgrantees that weatherized a large number of multifamily buildings. The cooperation of and contributions made by those weatherization subgrantees were essential to the development of information for large multifamily buildings.

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David Carroll
Greg Dalhoff
Michael Blasnik

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 multifamily buildings treated by DOE's Weatherization Assistance Program (WAP) during the Recovery Act Period - Program Years 2009, 2010, and 2011. The focus of this study is on PY 2010. The analysis characterizes the population of multifamily buildings[1] served by the program, estimates the gross and net change in energy usage for treated buildings, 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 several energy impact reports developed for the PY 2010 WAP Evaluation. The full set of reports covers all housing types (single family homes, mobile homes, and multifamily buildings) and summarizes overall program performance for all building types in terms of energy and nonenergy benefits. The reports give policymakers detailed information on program performance for each building type, as well as information on the overall program performance.

Background

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

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

Study Overview

The multifamily building energy impact report furnishes information on the households, housing units, and buildings served by the program, including: the services delivered, the change in energy consumption and costs, and the program cost-effectiveness. The study procedures included:

- Development of a representative sample of households, housing units, and buildings served by the program using data from DOE, grantees, and subgrantees.
- Collection of information from subgrantees on household, housing unit, and building characteristics, installed measures, and measure costs.
- Collection of energy usage information from energy suppliers for treated housing units and buildings.

[1] Multifamily Buildings are defined as housing units in buildings with 5 or more units. The definition used in this evaluation is consistent with the WAP program definition of multifamily buildings.

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

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

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

Program Characterization

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

WAP serves low-income households in all types of housing units and in all parts of the country. According to DOE statistics, the network of WAP funded subgrantees served 340,158 housing units in PY 2010 with DOE funding. Table 1 shows the distribution of treated units by housing unit type. About 22 percent of the treated units were units in large multifamily buildings. Table 2 shows the distribution of treated large multifamily units by Climate Zone. The Cold Climate Zone had the largest share of treated units (47%).

Table 1 PY 2010 WAP/ARRA Units by Housing Unit Type

Housing Unit Type	PY 2010 Housing Units	Percent of PY 2010 Housing Units
Single Family Site-Built (1-4)	215,445	63%
Single Family Mobile Home	48,267	14%
Multifamily (5+)	73,240	22%
Shelter Units	3,206	1%
TOTAL	340,158	100%

Table 2PY 2010 WAP/ARRA Housing Units in Multifamily Buildings by Climate Zone

Climate Zone	PY 2010 Housing Units	Percent of PY 2010 Housing Units
Very Cold Climate	7,576	10%
Cold Climate	34,454	47%
Moderate Climate	9,195	13%
Hot/Humid Climate	11,429	16%
Hot/Dry Climate	10,586	14%
TOTAL	73,240[2]	100%

There are a number of factors that affect the way that a weatherization agency treats units in a multifamily building. In some cases the weatherization agency treats the whole building and in others the agency treats individual units. Some multifamily buildings have central heating and/or water heating equipment for the whole building, while in other buildings each housing unit has its own equipment. Table 3 shows how the weatherized housing units were distributed with respect to these two factors. For 57 percent of the housing units the agency treated the whole building, but only 30 percent of the housing units had central equipment for the building. About 38 percent of the treated units were "Individual Units" (i.e., housing units in multifamily buildings that were treated separately from the other units in the building).

Table 3PY 2010 WAP/ARRA Housing Units in Multifamily Buildings by Weatherization/Equipment Type

Weatherization Type	Heating Equipment Type	PY 2010 Units	Percent of PY 2010 Units
Whole Building	Central	20,527	30%
Whole Building	Unit	18,624	27%
Individual Unit	Unit	25,620	38%
Other Combinations		3,382	5%
TOTAL		68,153	100%

The WAP clients who live in units in multifamily buildings are diverse. For example:

- The median household income was $10,388. However, 10 percent of WAP clients had income of less than $625 and 10 percent had income of more than $25,000.
- The average WAP household had 1.9 members, but single person elderly households were 32 percent of households served by the program.
- White non-Hispanic households were 37 percent of the population, black non-Hispanic households were 27 percent, and Hispanic households were 32 percent.

[2] The analysis in this report is based on information for the 68,153 multifamily units in states where one or more subgrantees with multifamily units reported data.

WAP housing units in multifamily buildings also are diverse. Nationally, the average multifamily housing unit treated by WAP was 825 square feet, and was in a building that had 4 or fewer floors, 25 or more units, and was built in 1970 or later. However, while almost all units in the Moderate and Hot Climate Zones were four stories or fewer, 40 percent of the units in the Cold Climate Zone were in buildings with 5 or more floors. And, while over 50 percent of the units in the Cold Climate Zone had central heating equipment for the entire building, almost all of the units in the Moderate and Hot Climate Zones had their own heating equipment.

Table 4 shows how WAP housing units in multifamily buildings varied with respect to a number of important characteristics. It is most common for those housing units to use a natural gas central heating system without any secondary source of heat, to use gas water heating equipment, and to have a central air conditioning system with ducts to individual rooms. However, many WAP housing units use other heating fuels, have heating systems where the equipment is located in each room (e.g., electric baseboard heat), use electric or other supplemental heat, and have window/wall air conditioners. Low-income households live in all kinds of housing unit configurations and the WAP program serves that diverse array of individual circumstances.

Table 4 Characteristics of Housing Units in Multifamily Buildings Served by WAP in PY 2010

Characteristic	Statistics for Multifamily Units		
Year Built*	Pre 1940 = 15%	1940-1969 = 16%	1970 or Later = 69%
Space Heating Fuel	Natural Gas = 56%	Electric = 35%	Delivered = 9%
Heating System	Central = 73%	Room = 23%	Other = 4%
Supplemental Heat	Electric = 13%	Other = 14%	
Air Conditioning**	Central = 55%	Window/Wall = 20%	None = 25%
Water Heating Fuel	Natural Gas = 68%	Electric = 22%	Other = 10%

*Missing for 10% to 50%. **Missing for 50% to 90%

After extensive testing, WAP subgrantees install a comprehensive set of measures matched to the needs of each multifamily building and/or unit. Major measures such as air sealing, attic insulation, heating equipment replacement, water heating equipment replacement, air conditioner replacement, and window replacement are expected to have the greatest impact on the buildings and units in which they are installed. However, not every building needs every major measure. For example, a building with relatively new heating equipment would not save much energy if its equipment was replaced. Only measures projected to have a savings-to-investment ratio (SIR) greater than 1.0 are installed as energy conservation measures (ECMs).

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

Table 5 shows the PY 2010 measure installation rates for the WAP program for multifamily buildings. It also shows the installation rates by Climate Zone. The measures with the highest installation rates were

lighting and bypass air sealing; these measures were installed in 60 percent or more of the treated housing units. Duct sealing, attic insulation, and furnace replacement were all installed in 30 percent or more of units. Other common measures included windows and refrigerators.

Table 5 Measure Installation Rates for Multifamily Units Served by WAP in PY 2010

Measure	National	Very Cold	Cold	Moderate	Hot/Humid	Hot/Dry
Air Sealing						
Bypass Air Sealing	66%	80%	59%	87%	78%	45%
Mechanical Ventilation	10%**	***	8%**	42%**	4%	0%**
Duct Sealing	31%*	33%*	13%**	54%**	31%*	27%*
Insulation						
Attic Insulation	31%	32%	37%	31%	36%	7%
Wall Insulation	4%	5%	6%	0%	4%	0%
Other Insulation (floor, rim joist, foundation)	7%*	18%	6%*	12%	0%	10%**
Equipment						
Heating Equipment Replacement	33%	35%	27%	52%	61%	13%
Programmable Thermostat	18%*	9%**	15%**	12%	32%	10%
Water Heater Replacement	11%	35%	10%*	23%	3%	4%
Air Conditioner Replacement	16%	0%*	2%	25%	65%	7%
Other						
Windows	27%	5%	38%	25%	26%	8%
Refrigerator	23%*	20%*	22%*	47%	28%	9%
Lighting	72%	88%	62%*	77%	78%	77%

*10% to 50% missing. **50% to 90% missing. ***90% or more missing.

Energy Savings in Housing Units with Gas and Fuel Oil Main Heat

The evaluation directly measured gas, fuel oil, and electric usage for the Treatment Group and Comparison Group multifamily housing units that use natural gas and fuel oil as their main heating fuel. Gross program savings were estimated by comparing pre-weatherization usage (weather-normalized) to the post-weatherization usage (weather-normalized) for housing units treated during PY 2010 and PY 2011. Net program savings were estimated by comparing the savings for Treatment Group housing units to the savings for Comparison Group housing units. Table 6 shows that the gross gas savings for gas and fuel oil heated housing units treated by the program in PY 2010 and PY 2011 were 92 therms per housing unit per year. During the same period, the Comparison Group increased their usage by 7 therms per housing unit per year without receiving any treatments. Therefore, net savings due to the program are estimated to be 99 therms (14.2%) per housing unit per year.

Table 6 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Gross and Net Energy Savings (therms/year) for Units with Natural Gas and Fuel Oil Main Heat

Group	# Units	Pre-WAP Use	Post-WAP Use	Gross Savings	Net Savings	% of Pre
Treatment Group	1,205	700	608	92 (±6)	99 (±8)	14.2% (±1.2%)
Comparison	979	702	710	-7 (±5)		

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

- Housing units in small multifamily buildings (Table 7).
- Housing units that received more major measures (Table 8).
- Housing units with higher pre-weatherization gas usage (Table 9).

Table 7 shows that the amount of energy saved was substantially higher for small multifamily buildings (i.e., buildings with 25 or fewer units). Housing units in small multifamily buildings were estimated to save 137 therms (19.6% of pre-weatherization usage) compared to 76 therms for units (10.5% of pre-weatherization usage in large multifamily buildings.

Table 7 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Energy Savings (therms/year) for Natural Gas and Fuel Oil Main Heat by Building Size

Group/Breakout	# Units	Pre-WAP Use	Net Savings	% of Pre
All Units	1,205	700	99 (±8)	14.2% (±1.2%)
Small Multifamily	429	699	137 (±15)	19.6% (±2.1%)
Large Multifamily	692	722	76 (±10)	10.5% (±1.3%)

Table 8 shows that the amount of energy saved increased substantially as the number of major measures installed increased. Housing units that had three or more major measures installed saved more than twice as much energy as those with only one installed major measure.

Table 8 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Energy Savings (therms/year) for Natural Gas and Fuel Oil Main Heat by Measure Combination

Group/Breakout	# Units	Pre-WAP Use	Net Savings	% of Pre
No Major Measures	50	805	30 (±28)	4.6% (±4.2%)
Any One Major Measure	194	835	61 (±19)	7.4% (±8.8%)
Any Two Major Measures	371	627	108 (±15)	17.2% (±2.3%)
Three or More Major Measures	186	761	127 (±23)	16.6% (±3.0%)

Table 9 shows that housing units with higher pre-weatherization usage had higher energy savings even when the analysis controlled for the number of major measures installed. Housing units with pre-

weatherization usage of 750 to 1,000 therms received an average of 2.2 major measures and had average savings of 141 therms, while those with pre-weatherization usage of less than 500 therms received an average of 1.9 major measures and had average savings of 21 therms. The higher-usage housing units had 120 more therms of energy with only slightly more installed measures.

Table 9 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Energy Savings (therms/year) for Natural Gas and Fuel Oil Main Heat by Pre-Weatherization Usage

Pre-WAP Use (therms/year)	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	1.9	1,205	700	99 (±8)	14.2% (±1.2%)
<500 therms/year.	1.9	327	313	21 (±9)	6.6% (±2.9%)
500-<750	2.1	351	612	121 (±12)	19.8% (±1.9%)
750-<1,000	2.2	303	892	141 (±16)	15.8% (±1.8%)
>=1,000 therms/year.	1.4	224	1,143	124 (±24)	10.8% (±2.1%)

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

Savings for gas and fuel oil heated housing units varied considerably across Climate Zones, but higher savings were not always associated with a higher number of heating degree days (Table 10). Higher pre-weatherization usage and savings were observed for the Cold Climate Zone than in the Very Cold Climate Zone. However, in both cases, average energy savings was about 14 percent of pre-weatherization usage. Average savings and the saving percentages were high for the small sample of cases available for the Hot/Humid and Moderate Climate Zones.

Relatively few multifamily units with natural gas or fuel oil mail heat were available for analysis in the Moderate, Hot/Humid, and Hot/Dry Climate Zones. Data were missing for a large share of the sampled units in these Climate Zones for two reasons. First, some large subgrantees in those Climate Zones did not furnish the information needed for analysis. Second, a small number of large gas utilities in those Climate Zones did not furnish gas usage data. Because of the small sample size, it is not possible to ascertain whether the statistics presented in Table 10 are representative of the population of multifamily units treated by the WAP program in those Climate Zones in PY 2010 and 2011. However, the information is useful; it shows that for a small sample of multifamily units in the Moderate and Hot/Humid Climate Zones, the program was successful in achieving relatively high percent savings.

Table 10 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Unit Net Energy Savings (therms/year) for Natural Gas and Fuel Oil Main Heat by Climate Zone

Climate	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	1.9	1,205	700	99 (±8)	14.2% (±1.2%)
Very Cold	2.4	120	515	71 (±22)	13.9% (±4.2%)
Cold	1.9	1,017	746	105 (±9)	13.9% (±1.2%)
Moderate	1.5	30	424	99 (±43)	23.3% (±10.1%)
Hot/Humid	2.0	16	304	95 (±35)	31.6% (±11.4%)
Hot/Dry	1.3	22	273	-3 (±39)	-1.0% (±14.2%)

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

Weatherization of gas and fuel oil heated housing units also can result in savings of electricity. Air sealing and insulation can reduce the use of a furnace fan in the winter and demand for air conditioning in the summer. In addition, many WAP housing units also have baseload measures such as refrigerators and energy efficient lights installed. Table 11 shows that the gross electric savings for gas and fuel oil heated housing units was 315 kWh and the net savings was 304 kWh (6.4%). Note that these are unit level savings estimates. The evaluation was not able to develop estimates of savings per unit for common area energy measures.

Table 11 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Gross and Net Electric Savings (kWh/year) for Natural Gas and Fuel Oil Main Heat

Usage Component	# Units	Pre-WAP Use	Post-WAP Use	Gross Savings	Net Savings	% of Pre
Treatment Group	1,556	4,740	4,425	315 (±103)	304 (±61)	6.4% (±1.3%)
Comparison	948	5,246	5,235	11 (±49)		

Energy Savings in Housing Units with Electric Main Heat

The evaluation directly measured electric usage for Treatment Group and Comparison Group units 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 housing units treated during PY 2010 and PY 2011. Net program savings were estimated by comparing the savings for the Treatment Group to the savings for the Comparison Group. Table 12 shows that the gross savings for electric heat housing units was 864 kWh. During the same period, the Comparison Group reduced usage by 54 kWh without receiving any treatments; net savings due to the program are estimated to be 810 kWh (10.9%).

Table 12PY 2010 WAP Energy Impacts for Multifamily Housing Units Gross and Net Electric Savings per Unit for Electric Main Heat (kWh/year)

Usage Component	# Units	Pre-WAP Use	Gross Savings	Net Savings	% of Pre
Treatment	707	7,402	864 (±100)	810 (±152)	10.9% (±2.1%)
Comparison	400	8,142	54 (±97)		

Table 13 shows that one of the most important factors associated with higher savings was higher usage pre-weatherization usage. Housing units that used 5,000-<7,500 kWh prior to weatherization had average savings of 450 kWh, less than one-third the savings for housing units that used 10,000 kWh or more.

Table 13 PY 2010 WAP Energy Impacts for Multifamily Housing Units Gross and Net Electric Savings for Electric Main Heat by Pre-Weatherization Electric Usage

Pre-WAP Use	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre

Pre-WAP Use	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
< 5,000 kWh/yr	1.8	209	3,019	320 (±94)	10.6% (±3.1%)
5,000 -< 7,500	1.9	198	6,277	450 (±259)	7.2% (±4.1%)
7,500 -< 10,000	2.0	129	8,743	1,092 (±449)	12.5% (±5.1%)
>=10,000 kWh/yr	1.9	171	13,049	1,563 (±423)	12.0% (±3.2%)

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

For housing units with gas or fuel oil main heat, higher savings were associated with weatherization of small multifamily buildings and with the installation of more major measures. However, those patterns were not observed for housing units with electric main heat.

Savings for electric main heat housing units varied considerably across Climate Zones, but higher savings were not always associated with a higher number of heating degree days (Table 14). The highest savings amount and savings percentage were observed in the Hot/Humid Climate Zone. The Moderate Climate Zone also had higher than average savings.

The number of multifamily units with electric mail heat available for analysis in the Moderate, Hot/Humid, and Hot/Dry Climate Zones we modest. Data were missing for a large share of the sampled units in these Climate Zones for two reasons. First, some large subgrantees in those Climate Zones did not furnish the information needed for analysis. Second, a small number of large electric utilities in those Climate Zones did not furnish electric usage data. Because of the relatively small sample size, it is not possible to ascertain whether the statistics presented in Table 14 are representative of the population of multifamily units treated by the WAP program in those Climate Zones in PY 2010 and 2011. However, the information is useful; it shows that for a relatively small sample of multifamily units in the Moderate and Hot/Humid Climate Zones, the program was successful in achieving relatively high percent savings.

Table 14
PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Unit
Net Energy Savings (kWh/year) for Electric Main Heat
by Climate Zone

Climate	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	1.9	707	7,402	810 (±152)	10.9% (±2.1%)
Very Cold	1.0	114	6,243	354 (±272)	5.7% (±4.4%)
Cold	1.7	368	7,203	705 (±181)	9.8% (±2.5%)
Moderate	2.7	85	8,315	1,071 (±557)	12.9% (±6.7%)
Hot/Humid	2.6	88	8,976	2,033 (±692)	22.7% (±7.7%)
Hot/Dry	2.4	52	7,191	439 (±968)	6.1% (±13.5%)

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

Program Energy Cost Savings and Cost-Effectiveness

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

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

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

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

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

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

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

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

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

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

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

Table 15 shows the estimated average annual energy costs and first year cost savings for PY 2010 clients by main heating fuel type. On average, WAP clients had pre-weatherization energy bills of $1,068 and energy savings of $122 (11.4%). The cost savings for fuel oil and propane heated housing units is expected to be almost two times the cost savings for housing units heated 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 15 PY 2010 WAP Energy Impacts for Multifamily Housing Units Energy Costs and Cost Savings by Main Heating Fuel (2010 Dollars)

	Annual Energy Costs			Annual Savings (First Year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$483	$604	$1,086	$72	$35	$107	9.9%
Electricity	$0	$884	$884	$0	$120	$120	13.5%
Fuel Oil	$1,503	$345	$1,848	$190	$42	$232	12.6%
Propane	$1,321	$435	$1,756	$216	$19	$235	13.4%
Other*	$466	$585	$1,051	$46	$27	$74	7.0%
All Clients	**$377**	**$691**	**$1,068**	**$54**	**$68**	**$122**	**11.4%**

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

Table 16 furnishes a projection of the energy cost-effectiveness of the program for multifamily housing units. 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 0.61 for the overall program. The SIR is greater than 1.0 for clients who heat with fuel oil or propane; higher priced fuels result in higher cost savings and a higher SIR.

Table 16 PY 2010 WAP Energy Impacts for Multifamily Household Units Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2010 Dollars)

	Energy Cost Savings (Present Value of Lifetime Savings)			Costs & Cost-Effectiveness		
Heating Fuel	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**
Natural Gas	$1,351	$231	$1,582	$2,501	-$918	0.63
Electricity	-	$1,332	$1,332	$2,966	-$1,635	0.45
Fuel Oil	$4,263	$280	$4,542	$4,466	$77	1.02
Propane	$3,422	$133	$3,555	$3,073	$482	1.16
Other	$839	$178	$1,017	$1,264	-$247	0.80
All Clients	**$1,054**	**$656**	**$1,710**	**$2,818**	**-$1,107**	**0.61**

While it is useful to know how the program performed for PY 2010 clients, today's policymakers need to make decisions based on current energy prices and price projections, and current discount rates. Table 17 shows the projected average annual energy costs and first year cost savings for PY 2013 clients by main heating fuel type. On average, WAP clients would be projected to have pre-weatherization energy bills of $1,074 and first year energy savings of $121 (11.3%). When compared to the PY 2010 energy cost savings, Table 16 shows that the average projected energy cost savings for a program implemented in PY 2013 are about the same as the energy cost savings experienced by clients served in 2010.

Table 17 Projected PY 2013 WAP Impacts for Multifamily Housing Units 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	$465	$599	$1,065	$69	$35	$104	9.8%
Electricity	$0	$863	$863	$0	$114	$114	13.2%
Fuel Oil	$1,860	$341	$2,201	$235	$42	$277	12.6%
Propane	$1,138	$453	$1,591	$186	$21	$208	13.0%
Other*	$493	$584	$1,077	$49	$27	$76	7.1%
All Clients	**$393**	**$681**	**$1,074**	**$55**	**$66**	**$121**	**11.3%**

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

Table 18 shows that, from the 2013 Policy Perspective, the net present value of energy cost savings are higher because the specified discount rate for FY 2013 is lower than the specified discount rate for FY 2010 [see OMB Circular A-94 for 2013]; 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 0.67 for the overall program, somewhat higher than the SIR of 0.61 experienced by the clients served by the PY 2010 program.

Table 18 Projected PY 2013 WAP Energy Impacts for Multifamily Housing Units Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2013 Dollars)

	Energy Cost Savings (Present Value of Lifetime Savings)			Costs & Cost-Effectiveness		
Heating Fuel	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**
Natural Gas	$1,607	$252	$1,859	$2,641	-$782	0.70
Electricity	-	$1,517	$1,517	$3,133	-$1,616	0.48
Fuel Oil	$5,107	$300	$5,407	$4,717	$690	1.15
Propane	$3,951	$146	$4,097	$3,246	$851	1.26
Other	$958	$193	$1,150	$1,335	-$185	0.86
All Clients	**$1,256**	**$740**	**$1,996**	**$2,976**	**-$980**	**0.67**

1. INTRODUCTION

The purpose of this report is to disseminate the findings from an analysis of the energy savings, cost savings, and cost-effectiveness for multifamily buildings treated by DOE's Weatherization Assistance Program (WAP) during Program Years 2009, 2010, and 2011 (the American Recovery and Reinvestment Act Period). The main focus of this study is on PY 2010. The analysis uses data from a number of sources to characterize the population of multifamily[3] buildings that were served by the program, estimate the gross and net change in energy usage for treated buildings, make projections for the first year and longer-term cost savings associated with the energy savings, and assess the cost-effectiveness of the program in terms of direct energy benefits.

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

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

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

1.1 NATIONAL WEATHERIZATION ASSISTANCE PROGRAM EVALUATION OVERVIEW

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

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

1.2 MULTIFAMILY BUILDING ENERGY IMPACT STUDY OVERVIEW

The multifamily building energy impact study collected and analyzed information on the households, housing units, and buildings served by the WAP program in 2010, including household demographics,

[3] Multifamily Buildings are defined as housing units in buildings with 5 or more units. The definition used in this evaluation is consistent with the WAP program definition of multifamily buildings.

housing unit and building characteristics, program services and costs, and energy consumption and costs. The study procedures included:

- Sample of Clients and Buildings – The evaluation team worked with grantees and subgrantees to select a representative sample of clients and buildings served by the program in PY 2010.

- Client and Building Characteristics - The evaluation team worked with grantees and subgrantees to collect information on household demographics, housing unit characteristics, and building characteristics.

- Diagnostics and Measures – The evaluation team worked with subgrantees to collect information on diagnostic tests conducted, installed measures, and measure costs for a sample of housing units and buildings that were treated by the WAP program.

- Energy Data Collection – The evaluation team collected information from energy suppliers to assess the amount of energy used in the housing units and buildings before and after the installation of weatherization measures.

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

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

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

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

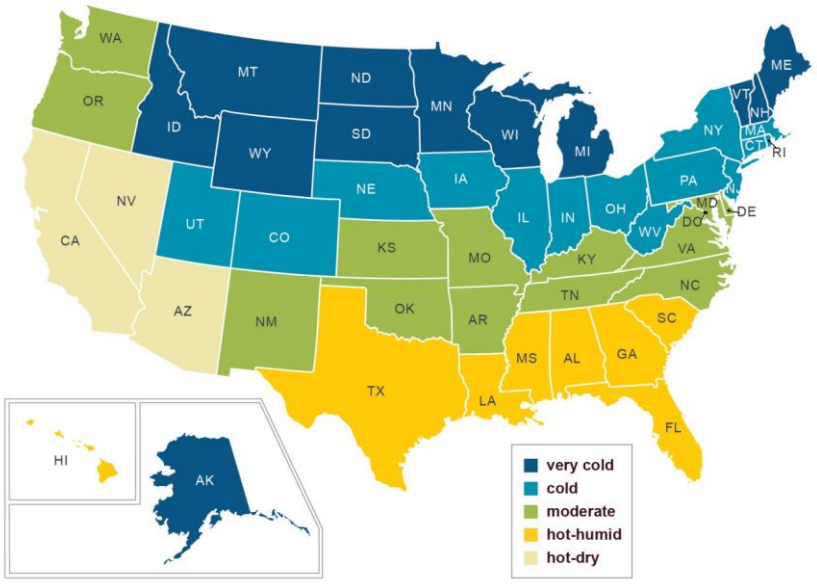

Figure 1.1: Climate Zone Map for the PY 2010 Evaluation

1.3 ORGANIZATION OF THE MULTIFAMILY BUILDING ENERGY IMPACT REPORT

The report consists of six sections, including:

- Section 1 - Introduction: Furnishes an overview of the ARRA Period Evaluation, the Impact Evaluation, and the evaluation of multifamily buildings.

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

- Section 3 – Program Participants and Services: Furnishes information on the households, housing units, and buildings that participated in the program, and documents services delivered by the program.

- Section 4 – Energy Impacts for Gas and Fuel Oil Main Heat: Furnishes estimates of the heating fuel and electric impacts for buildings with natural gas or fuel oil main heat.

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

- Section 6 – Cost Savings, Measure Costs, and Cost-Effectiveness: Compares the investments made in the treated buildings to the energy costs savings. Summarizes how the program performed in terms energy savings, cost savings, and cost-effectiveness.

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

2. OVERVIEW OF DATA COLLECTION METHODOLOGY

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

- Grantees (i.e., States)
- Subgrantees (i.e., Local Agencies)
- Electric and Gas Utilities
- Fuel Oil Vendors
- EIA Energy Price Data and Projections
- National Climate Data Center (NCDC) Weather Data

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

2.1 SUBGRANTEE AND CLIENT SAMPLE

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

2.1.1 Subgrantee Sampling Procedures

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

- Grantee Allocation – Each grantee was allocated a share of the sample of 356 subgrantees based on its share of PY 2010 program funding.[4]

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

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

2.1.2 Client Sampling Procedures

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

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

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

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

2.1.3 Subgrantee and Client Sampling Statistics and Response Rates

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

- Grantees (States and District of Columbia)
    - Population – 51 grantees received WAP funding in PY 2010.
    - Census – All 51 grantees were included in the sample.
    - Response – All 51 grantees (100%) responded to information requests

- Subgrantees
    - Population – 1,020 subgrantees were listed in grantee plans; 929 completed units in PY 2010.
    - Sample – 448 of the 929 subgrantees with PY 2010 units were sampled.
    - Response – 438 of the 448 sampled subgrantees (98%) furnished client lists.

The Evaluation Team selected a sample of 39,115 PY 2010 clients from the 438 sampled subgrantees that furnished a list of clients; 6,134 of those clients lived in multifamily buildings.

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. In some states, the utility account information was included in the grantee database.

2.2.1 Utility Account Information

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

- Sample – 448 sampled subgrantees were asked to furnish a list of clients.
- Client List Response – 438 of 448 sampled subgrantees (98%) furnished client lists.
- Utility Data Response – 409 of 448 sampled subgrantees (91%) furnished utility data for sampled clients.

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

- Sample – The Evaluation Team selected a sample of 5,881 PY 2010 clients who lived in a multifamily housing unit heated with natural gas or electricity from the 438 sampled subgrantees that furnished client lists.

- Responding Subgrantees – The 409 subgrantees that responded to the utility data request had 4,469 of these 5,881 sampled clients (80%).

- Main Heating Supplier – The 409 subgrantees that responded furnished the heating energy supplier information for 3,035 of their 4,469 multifamily building clients (68%). That represents 51% of all sampled clients.

- Electric Data Supplier - The 409 subgrantees that responded furnished electric supplier information for 3,413 of their 4,469 multifamily building clients (76%). That represents 58% of all sampled multifamily building clients.

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

2.2.2 Client Service Delivery Data

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

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

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

- Sample – 448 sampled subgrantees were asked to furnish a list of clients.
- Client List Response – 438 of 448 sampled subgrantees (98%) furnished a list of clients.
- Service Delivery Data Response – 390 of 448 sampled subgrantees (87%) furnished client service delivery data.

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

- Sample – The Evaluation Team selected a sample of 6,134 PY 2010 clients who lived in multifamily buildings from the 438 sampled subgrantees that furnished client lists.

- Responding Subgrantees – The 390 subgrantees that responded to the client service delivery data request had 4,636 of the 6,134 sampled clients (76%).

- Client Data – The 390 subgrantees that responded furnished service delivery data for 3,443 of their 4,636 multifamily building clients (74%). That represents 56% of all sampled multifamily building clients.

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

2.3 NATURAL GAS AND ELECTRIC USAGE DATA COLLECTION

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

- Natural Gas or Electric Main Heating Fuel

    - Companies – 140 natural gas and electric companies were identified for one or more sampled PY 2010 multifamily building clients.

    - Company Response – 120 of the 140 companies (86%) furnished data for one or more of the sampled clients.

    - Client Response – Data were received for 1,593 of the 3,001 PY 2010 multifamily building clients for whom a supplier was listed (53%). That is 33% of the 4,848 sampled multifamily building clients who heat with either natural gas or electricity.

- Electric Usage for Natural Gas Main Heat Clients

    - Companies – 91 electric companies were identified as the electric supplier for one or more PY 2010 multifamily building clients who heat with natural gas.

    - Company Response – 77 of the 91 electric companies (85%) furnished data for one or more of the sampled clients.

    - Client Response - Data were received for 1,073 of the 1,901 PY 2010 multifamily building clients for whom an electric supplier was listed (56%). That is 37% of the 2,899 sampled clients who heat with natural gas.

- Fuel Oil Main Heating Fuel

    - Companies – 47 fuel oil companies were identified for one or more sampled multifamily building clients.

    - Company Response – 31 of the 47 companies (66%) furnished data for one or more of the sampled clients.

    - Client Response – Data were received for 84 of the 161 multifamily buildings for whom a supplier was listed (52%).

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

3. PROGRAM PARTICIPANTS AND SERVICES

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

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

The evaluation furnishes information on all housing units served by the WAP program in PY 2010. This report focuses on characterizing multifamily buildings.

3.1 PROGRAM PRODUCTION - ARRA AND WAP PROGRAMS

During PY 2010, WAP subgrantees weatherized multifamily buildings using both PY 2010 WAP funding and ARRA program funding. This analysis furnishes an analysis of housing units and buildings treated during 2010 with at least one of those two funding sources. Table 3.1 shows that reports to DOE indicated that over 340,000 units were weatherized during PY 2010. Single family site built homes (1-4 units) represented the largest share of units weatherized (63%). About 22 percent of all weatherized units were in multifamily buildings. A very small share of units (1%) was shelters; shelter units were excluded from the analysis because of sampling and data collection issues.

Table 3.1 PY 2010 WAP/ARRA Housing Units by Housing Unit Type

Housing Unit Type	PY 2010 Housing Units	Percent of PY 2010 Housing Units
Single Family Site-Built	215,445	63%
Single Family Mobile Home	48,267	14%
Multifamily Building (5+)	73,240	22%
Shelter Units	3,206	1%
TOTAL	340,158	100%

Table 3.2 shows how the weatherized units were distributed by Climate Zone. Almost 40 percent of weatherized housing units were in the Cold Climate Zone. The Very Cold, Moderate, and Hot/Humid Climate Zones each had close to one-fifth of weatherized housing units. The Hot/Dry Climate Zone had about 10 percent of weatherized housing units.

Table 3.2 PY 2010 WAP/ARRA Housing Units by Climate Zone

Climate Zone	PY 2010 Housing Units	Percent of PY 2010 Housing Units
Very Cold Climate	58,584	17%
Cold Climate	127,386	38%
Moderate Climate	60,896	18%
Hot/Humid Climate	55,354	17%
Hot/Dry Climate	34,732	10%
TOTAL	336,952*	100%

*Excludes shelter units

Table 3.3 shows the share of treated housing units that were in multifamily buildings in PY 2010 by Climate Zone. For the overall program, 22 percent of treated housing units were in multifamily buildings. The Cold and Hot/Dry Climate Zones had the highest share of treated housing units in multifamily buildings (27% and 30%, respectively).

Table 3.3 PY 2010 WAP/ARRA Housing Units by Climate Zone and Housing Unit Type*

Climate Zone	Single Family	Mobile Home	Multifamily Building	All Housing Unit Types
Very Cold Climate	70%	17%	13%	100%
Cold Climate	62%	11%	27%	100%
Moderate Climate	68%	16%	16%	100%
Hot/Humid Climate	65%	14%	21%	100%
Hot/Dry Climate	57%	13%	30%	100%
TOTAL	64%	14%	22%	100%

*Excludes shelter units

3.2 PROGRAM PRODUCTION - MULTIFAMILY BUILDINGS

This report focuses on multifamily buildings (i.e., buildings with 5 or more housing units). Table 3.4 shows how weatherized units in multifamily buildings were distributed by Climate Zone. Almost one-half of the weatherized units in multifamily buildings were in the Cold Climate Zone. The other Climates had between 10 percent and 16 percent of the weatherized units in multifamily buildings. Table 3.5 shows that the weatherized housing units in multifamily buildings are concentrated in a relatively small number of states; the top seven states weatherized almost three-fourths of all multifamily units treated by the program. Almost one-half of weatherized multifamily units were in New York, Texas, and California.

Table 3.4 PY 2010 WAP/ARRA Housing Units in Multifamily Buildings by Climate Zone

Climate Zone	PY 2010 Housing Units in Multifamily Buildings	Percent of PY 2010 Housing Units in Multifamily Buildings
Very Cold Climate	7,576	10%
Cold Climate	34,454	47%
Moderate Climate	9,195	13%
Hot/Humid Climate	11,429	16%
Hot/Dry Climate	10,586	14%
TOTAL	73,240	100%

Table 3.5 PY 2010 WAP/ARRA Housing Units in Multifamily Buildings by State

Climate Zone	PY 2010 Housing Units in Multifamily Buildings	Percent of PY 2010 Housing Units in Multifamily Buildings
New York	15,579	21%
Texas	11,046	15%
California	8,176	11%
Ohio	6,496	9%
Wisconsin	4,398	6%
Washington	4,308	6%
Illinois	3,959	6%
All Other States	19,278	26%
TOTAL	73,240	100%

In addition to being concentrated at the state level, weatherized housing units also tend to be concentrated at the agency level. Since weatherizing a multifamily building requires special skills, some states had only one or two agencies weatherizing multifamily buildings. The evaluation was not able to collect information on weatherized units in multifamily buildings for six states because of agency non-response. Those states weatherized 5,087 housing units in weatherized buildings. The remainder of the analysis in this report will focus on the 68,153 weatherized housing units for which the evaluation was able to obtain data.

3.3 WEATHERIZATION OF MULTIFAMILY BUILDINGS

There are a number of factors that affect the way the weatherization agency treats housing units in multifamily buildings, including:

- Common Areas - Many multifamily buildings have common areas that are lighted and/or have conditioned space (e.g., entryways, hallways, stairways, and laundry rooms).

- Equipment - In some multifamily buildings, each housing unit (i.e., apartment) has its own heating, water heating, and cooling equipment. In others, there is building-level equipment for heat, hot water, and/or cooling. Sometimes the building-level equipment distributes heat and/or cooling to the common areas, sometimes the common area has its own equipment, and sometimes there are no common areas.

- Metering - In some multifamily buildings, there are master-meter accounts for all end uses (heating, water heating, and electric). In some buildings the heating and water heating end uses, as well as common area electric charges are on master-meters, but occupants pay for their electric. In some buildings, occupants pay for all energy used.

- Percent Low Income - Some multifamily buildings are special purpose and serve only low-income households. Other multifamily buildings have some households with incomes above WAP income-eligible thresholds. In order to serve the whole building, the subgrantee must be able to document that at least two-thirds of occupants qualify as low-income (50% percent in certain circumstances).

While there are many different permutations of the factors outlined above, the study found that most weatherization jobs can be divided into three types.

1. Building Weatherization/Central Heating Equipment - These are buildings with central heating equipment where the agency installs building-level and unit-level measures. The building-level measures may include shell measures, repair or replacement of equipment, repair or replacement of windows and/or doors, and common area measures. The unit-level measures may include lighting, refrigeration, water flow measures, and air conditioning. Most of these buildings have master-meter accounts for the heating and water heating equipment, master-meter electric accounts for the common areas, and client electric accounts for the unit level electric.

2. Building Weatherization/Unit-Level Heating Equipment - These are buildings with unit level equipment where the agency installs both building-level and unit-level measures. The building-level measures may include shell measures, windows, and common area measures. The unit-level measures may include work on or replacement of heating, water heating, and air conditioning equipment, as well as lighting, refrigeration, and water flow measures. Most of these buildings have master-meter accounts for the common areas and client accounts for the heating fuel and electricity.

3. Unit Weatherization/Unit-Level Heating Equipment (IUs) - For these buildings, all services are delivered to individual housing units. Any shell measures (e.g., air sealing or insulation) are done for the individual unit. In addition, the work scope may include unit-level heating equipment and water heating equipment measures, and other unit-level measures (e.g., measures related to water usage, lighting, refrigeration, and air conditioning). Most of these buildings have maste- meter accounts for the common areas and client accounts for the heating fuel and electricity

Table 3.6 shows how the housing units in multifamily buildings were distributed in terms of the weatherization approach and heating equipment location. Whole building weatherization was observed for 57 percent of units in multifamily buildings, while weatherization of Individual Units (IUs) was observed for 38 percent of units. There were a small number of weatherized units (3%) where the individual unit was treated, but the building had central heating equipment. There also were a small number of weatherized units where the agency did not report the location of the heating equipment. In this section, some tables furnish breakouts by the weatherization type and heating equipment. In those tables, the "Other" units are excluded.

Table 3.6 PY 2010 WAP/ARRA Housing Units in Multifamily Buildings by Weatherization Approach Used

Weatherization Type	Heating Equipment	Number of Units	Percent of Units
Whole Building	Central	20,527	30%
Whole Building	Unit	18,624	27%
Individual Unit	Unit	25,620	38%
Other			
Individual Unit	Central	1,864	3%
Individual Unit	Not Reported	812	1%
Whole Building	Not Reported	706	1%
TOTAL		68,153	100%

Another factor affecting multifamily buildings is the size of the building. The logistics for weatherizing a building with 5 units is quite different from the logistics for weatherizing a building with 500 units. Table 3.7 shows the distribution of weatherized units by the number of units in the building. The building size variable was not available for over 20 percent of housing units. For those units where the building size was reported, about one-half were in the group classified by DOE as large multifamily buildings (more than 25 units per building) and the other half were in the group classified as small multifamily buildings (5 to 25 units per building).

Table 3.7 PY 2010 WAP/ARRA Housing Units in Multifamily Buildings by Number of Units in Building

Building Type	Number of Units	Percent of Units
Units Not Reported*	14,971	22%
5-9 Units (SMF)	15,128	22%
10-25 Units (SMF)	11,786	17%
More than 25 Units (LMF)	26,268	39%
TOTAL	68,153	100%

* Note: Some grantees did not report the total units in the building.

Table 3.8 shows how the Weatherization Approach varies by the size of the building. Whole building weatherization for buildings with central heating equipment is more common for larger buildings (54 percent of buildings with more than 25 units, but only 14 percent of buildings with 5 to 9 units). Whole building weatherization for buildings with unit-level equipment is more common for smaller buildings (51 percent of buildings with 5 to 9 units, but only 18 percent of buildings with more than 25 units). It is somewhat difficult to generalize about IU weatherization, since the number of housing units in the

building is often missing for this group. But, it appears that IU weatherization is most common for smaller buildings (i.e., those with 5 to 9 units).

Table 3.8 PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Weatherization Approach by Number of Units in Building

Weatherization Type	Units Not Reported	5-9 Units	10-25 Units	More than 25 Units
Whole Building/Central Equipment	2%	14%	33%	54%
Whole Building/Unit Equipment	7%	51%	42%	18%
Individual Units/Unit Equipment	88%	33%	22%	18%
Other	3%	2%	2%	9%
TOTAL	100%	100%	100%	100%

Throughout this report, statistics will be reported by Climate Zone, Weatherization Type, and Building Size so that important differences in the population of multifamily buildings can be examined.

3.4 HOUSEHOLD CHARACTERISTICS

As part of the evaluation, agencies were asked to furnish data on the household characteristics for a sample of households within each multifamily building that was weatherized. In this section, statistics on demographic variables are furnished for sampled households. Since not every agency collected all of the requested information for individual households there is some missing data. Whenever data were available for less than 90 percent of the sampled households, this is noted in the table. Where data were available for less than 10 percent of the sampled households, the data are not reported.

Table 3.9 furnishes national and Climate Zone statistics for PY 2010 clients in multifamily buildings. The overall finding is that households in multifamily buildings served by WAP are renters with incomes below the poverty level that have a vulnerable individual in the home. Some important household characteristics vary by Climate Zone, including:

- Income – Households in the Hot/Humid Climate Zone have the lowest average income; almost 70 percent have income at or below the poverty line.
- Vulnerability Status – The Very Cold Climate Zone has the highest percentage of households with an elderly member. The Hot/Humid Climate Zone has the highest percentage of households with a child.
- Renters - Almost all of the occupants of the multifamily buildings weatherized through the program are renters.
- Race/Ethnicity – White non-Hispanic households are in the majority in the Very Cold and Moderate Climate Zones. Black and Hispanic household are in the majority in the Cold and Hot/Humid Climate Zones.

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

Table 3.9 PY 2010 WAP/ARRA Clients in Multifamily Buildings 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	$10,388*	$11,496*	$9,999*	$11,310*	$9,600*	$12,168
Median % of Poverty	86%*	95%*	84%*	83%*	78%*	94%
% < 100% of Poverty	63%*	53%*	64%*	58%*	69%*	63%
Vulnerability Status						
% w/Elderly Individual	32%	50%	29%	29%*	24%*	37%
% w/Disabled Individual	16%	34%	10%	17%*	11%*	24%
% w/Children	25%	16%	18%	28%*	48%*	37%
Household Status						
% Homeowner	2%*	1%	3%*	<1%*	0%*	5%
Mean Household Size	1.9	1.5	1.8	1.8*	2.3*	2.5
% Single Parent	28%**	25%**	***	25%**	38%**	14%**
% Single Elderly	27%	47%	24%	24%*	20%*	27%
Race/Ethnicity						
% White non-Hispanic	37%**	81%**	35%**	65%*	20%*	***
% Black non-Hispanic	27%**	15%**	30%**	11%*	30%*	***
% Hispanic	32%**	4%**	33%**	14%*	43%*	***
% Asian	3%**	0%**	2%**	<1%*	6%	***
% Native American	1%**	<1%**	<1%**	7%*	0%	***
% Other	<1%**	0%**	0%**	2%*	1%*	***

*10% to < 50% missing. **50% to < 90% missing. ***More than 90% missing.

Table 3.10 furnishes details on the distribution of income and poverty for households.

- Income – The Cold and Hot/Humid Climate Zones serve households with lower incomes than households in the other zones; median income is less than $10,000 per year.

- Poverty – In general, the Cold, Moderate and Hot/Humid Climate Zones served households at lower poverty levels than households in the other zones.

Changes in the program eligibility guidelines were implemented for PY 2009. The program served some households with income above 150 percent of poverty.

Table 3.10 PY 2010 WAP/ARRA Clients in Multifamily Buildings Distribution of Income and Poverty by Climate Zone

	Percent of Population				
Variable	**10%**	**25%**	**Median**	**75%**	**90%**
Income					
Very Cold Zone	$2,250*	$8,712*	$11,496*	$16,252*	$21,577*
Cold Zone	$0*	$7,536*	$9,999*	$17,076*	$28,882*
Moderate Zone	$5,376*	$8,088*	$11,310*	$15,600*	$24,180*
Hot/Humid Zone	$0*	$3,660*	$9,600*	$16,800*	$21,632*
Hot/Dry Zone	$6,000	$9,960	$12,168	$18,955	$27,040
ALL ZONES	$621*	$7,968*	$10,388*	$17,076*	$25,355*
Percent of Poverty					
Very Cold Zone	16%*	71%*	95%*	132%*	178%*
Cold Zone	0%*	53%*	84%*	125%*	175%*
Moderate Zone	37%*	60%*	83%*	125%*	178%*
Hot/Humid Zone	0%*	27%*	78%*	111%*	149%*
Hot/Dry Zone	33%	58%	94%	123%	163%
ALL ZONES	11%*	55%*	86%*	123%*	172%*

*10% to < 50% missing.

3.5 HOUSING UNIT AND BUILDING CHARACTERISTICS

Data for weatherized housing units were collected in two different ways. When the weatherization measures were restricted to the individual unit, the data were collected with a DF2 form that asked questions only about the unit. However, when there were some whole building measures, information was collected for the building using the DF3 Building form and for a sample of units using the DF3 Unit form. For that reason, the data available are not completely consistent across all weatherized multifamily units.

In this section and those that follow, three different sets of tables are presented. For each topic, the data are presented by Climate Zone, Building Size (e.g., 5-9 units, 10-25 units, and more than 25 units), and Weatherization Type/Heating Equipment Type (e.g., Whole Building/Central Equipment, Whole Building/Unit Equipment, and Individual Unit). These tables show some important differences in terms of building characteristics and installed measures.

Table 3.11a furnishes national and Climate Zone statistics on the housing unit characteristics for PY 2010 housing units in multifamily buildings. Important differences by Climate Zone include:

- Unit Size – The Cold Climate Zone has the largest average housing unit size and the Moderate Climate Zone has the smallest average housing unit size.

- Housing Unit Age – Almost 70 percent of the housing units are in buildings constructed in 1970 or later. The Cold Climate Zone has the highest incidence of older buildings (40 percent). In the other Climates Zones, more than 80 percent of the weatherized units are in buildings built in 1970 or later.

- Number of Stories -- Most of the weatherized units are in buildings that are 4 stories or less. In the Cold Climate Zone, about 28 percent of the units are in buildings with 5 to 9 stories and 11 percent are in buildings with 10 or more stories. In the Moderate, Hot/Humid, and Hot/Dry Climate Zones, almost all of the buildings had 1 to 4 stories.

- Number of Units - In the Very Cold and Cold Climate Zones about one-half of the weatherized units are in buildings with more than 25 units. In the Moderate Climate Zone buildings with 10 to 25 units are more common. It is difficult to determine building size for the Hot/Humid and Hot/Dry Climate Zones because many subgrantees in those Climate Zones weatherized individual units and did not report the number of units in the building.

- Weatherization Type/Heating Equipment Type - In the Very Cold and Cold Climate Zones, about one-half of weatherized units were in buildings that had central heating equipment and for which the entire building was weatherized. For those Climate Zones, over 90 percent of the units were in buildings where the whole building was weatherized, even for those buildings where individual units had their own heating equipment. In the Hot/Humid and Hot/Dry Climate Zones, almost 90 percent of multifamily units were weatherized as an individual unit, with no building-level measures.

These differences suggest that it is likely to be difficult to compare and contrast weatherization measures and energy savings across climate zones.

Table 3.11a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Housing Unit Characteristics by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Heated Space Per Unit						
Median Heated Space	825*	759*	871*	668	773	840*
Mean Heated Space	842*	780*	894*	723	783	817*
Building Vintage						
% pre 1940	15%*	5%*	23%*	0%*	0%*	0%**
% 1940-1969	16%*	11%*	17%*	11%*	18%*	18%**
% 1970 or later	69%*	84%*	60%*	89%*	82%*	82%**
Number of Stories						
1 to 4	74%*	82%*	61%*	98%	100%*	100%*
5 to 9	19%*	14%*	28%*	2%	0%*	0%*
10 or More	7%*	5%*	11%*	0%	0%*	0%*
Number of Units						
Units Not Reported	22%	7%	4%	9%	67%	49%
5 to 9	22%	22%	25%	18%	15%	23%
10 to 25	17%	23%	20%	40%	10%	3%
More than 25	39%	48%	51%	33%	8%	25%
WX Type/Equipment						
Whole Building/Central	32%	48%*	54%	1%	0%	0%
Whole Building/Unit	29%	45%*	37%	27%	12%	11%
Individual Unit	40%	7%*	10%	72%	88%	89%

*10% to < 50% missing. **50% to < 90% missing.

Table 3.11b furnishes statistics on the housing unit characteristics for PY 2010 housing units in multifamily buildings by building size. Important differences by building size include:

- Number of Stories - The number of units in the building is correlated with the number of stories in the building. More than half of the weatherized units in buildings with more than 25 units were in buildings with more than 5 floors. Almost all of the weatherized units in buildings with 5 to 9 units were in buildings with 4 or fewer floors.

- Weatherization Type/Heating Equipment Type - Sixty percent of buildings with more 25 units had central heating equipment and had building-level measures, and eighty percent of those buildings had building-level measures even if they did not have central heating equipment.

These differences suggest that it is likely to be difficult to compare and contrast weatherization measures and energy savings by building size.

Table 3.11b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Housing Unit Characteristics by Number of Units in Building

Statistic	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units	Units Not Reported
Heated Square Footage Per Unit					
Median Heated Space	825*	822*	819*	851*	800*
Mean Heated Space	842*	878*	828*	849*	810*
Building Vintage					
% pre 1940	15%*	8%*	21%*	19%*	1%**
% 1940-1969	16%*	14%*	10%*	19%*	23%**
% 1970 or later	69%*	78%*	69%*	63%*	76%**
Number of Stories					
1 to 4	74%*	100%*	95%*	48%	100%**
5 to 9	19%*	<1%*	5%*	37%	0%**
10 or More	7%*	0%*	0%*	15%	0%**
WX Type/Equipment					
Whole Building/Central	32%	15%	34%	60%	2%
Whole Building/Unit	29%	52%	43%	20%	7%
Individual Unit	40%	33%	23%	20%	91%

*10% to <50% missing. **50% to <90% missing.

Table 3.11c furnishes statistics on the housing unit characteristics for PY 2010 housing units in multifamily buildings by weatherization type. Important differences include:

- Housing Unit Age – About 30 percent of units in buildings with central heating equipment and whole building weatherization were built prior to 1940. All of the units that were weatherized as individual units were built after 1940.

- Number of Stories - Almost all of the buildings with unit-level heating equipment have four stories or fewer. Half of the buildings with central heating equipment that received building-level measures were 5 or more stories.

- Number of Units - Most of the units in buildings with central heating equipment and whole building weatherization were in large multifamily buildings (more than 25 units), while most of units in buildings with unit heating equipment and whole building weatherization were small multifamily buildings (25 units or less). Among IU buildings that reported the number of units, 40 percent were in buildings with 25 or more units.

- Air Leakage - The average air leakage rate for IUs was 1,384 CFM50; air leakage rates were measured for 61 percent of those units. It was much less common for air leakage rates to be measure for units that were weatherized at the building level; it was measured for 36 percent of

units that had unit heating equipment and was measured for less than 10 percent of the units with central heating equipment.

All of these differences are likely to contribute to differences in installed measures and energy savings.

Table 3.11c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Housing Unit Characteristics by Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Heated Square Footage Per Unit				
Median Heated Space	825*	861	873*	756*
Mean Heated Space	842*	889	878*	774*
Building Vintage				
% pre 1940	15%*	30%*	5%*	0%**
% 1940-1969	16%*	24%*	5%*	20%**
% 1970 or Later	69%*	46%*	90%*	80%**
Number of Stories				
1 to 4	74%*	50%	90%*	100%*
5 to 9	19%*	38%	4%*	0%*
10 or More	7%*	12%	6%*	0%*
Number of Units				
Units Not Reported	22%	1%	6%	52%
5 to 9	22%	11%	42%	19%
10 to 25	17%	19%	27%	10%
More than 25	39%	69%	26%	19%
PreWX Status				
Mean CFM 50	1,423**	***	1,407**	1,384*

*10% to <50% missing. **50% to <90% missing. ***More than 90% missing.

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

- Heating Fuel – Natural gas is the most common heating fuel in the Very Cold, Cold, and Hot/Dry Climate Zones. Electric heat is the most common heating fuel in the Moderate and Hot/Humid Climate Zones. Less than 10 percent of the weatherized multifamily units are in buildings that heat with fuel oil.

- Main Heating Equipment – In all Climate Zones, the most common main heating equipment was central equipment (i.e., central forced air or boilers). In the Very Cold and Moderate Climate Zones, more than 30 percent of units had baseboard electric heat, and in the Hot/Dry Climate Zone 41 percent of units had wall or room heaters.

- Building Level/Unit Level Heating Equipment - In the Very Cold and Cold Climate Zones, about one-half of units were in buildings with whole building heating equipment. In the other Climates Zones, almost all units were in buildings with unit-level equipment.

- Air Conditioning – About three fourths of weatherized units have air conditioning. In the Very Cold Climate Zone, only about one-fourth have air conditioning units. In the Cold Climate Zone, more than one-half of the households have window/wall units. And, in the Hot/Humid Climate Zone, most units have central air conditioning.

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

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

Table 3.12a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings 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	56%	48%	67%	30%	31%	62%
% Electric	35%	38%	19%	70%	69%	34%
% Fuel Oil	8%	12%	13%	0%	0%	0%
% Other	1%	2%	1%	0%	0%	3%
Heating System Type						
% Central Forced Air	41%	15%*	31%*	50%	78%	49%
% Boiler (hydronic/steam)	32%	51%*	53%*	0%	0%	0%
% Wall/Room Heater	7%	<1%*	0%*	0%	2%	41%
% Electric Baseboard	16%	31%*	14%*	37%	16%	1%
% Other or None	4%	3%*	2%*	13%	4%	10%
Heating System Location						
% Building Level	34%	50%	55%	1%	0%	2%
% Unit Level	66%	50%	45%	99%	100%	98%
Supplemental Heat						
% Electric	13%**	57%**	7%*	35%*	6%**	5%**
% Other	14%**	10%**	14%*	12%*	18%**	15%**
Air Conditioning Type						
% Central AC	55%**	14%**	28%**	61%*	86%	44%
% Window/Wall	17%**	13%**	55%**	24%*	6%	10%
% Evaporative Cooler	3%**	0%**	1%**	0%*	7%	1%
% None	25%**	72%**	16%**	16%*	1%	45%
Water Heating Fuel						
% Natural Gas	68%	64%*	73%	37%	49%*	79%
% Electric	22%	22%*	12%	63%	51%*	17%
% Other	10%	13%*	15%	<1%	0%*	4%

*10% to <50% missing. **50% to <90% missing.

Table 3.12b furnishes statistics on the heating and cooling systems by the number of units in the building. The table shows that the largest buildings are most likely to have boilers and to have whole building equipment. The table also shows that, in larger buildings, households are more likely to use electric supplemental heating equipment.

Table 3.12b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Heating and Cooling System Characteristics by Number of Units in Building

Statistic	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
Heating Fuel				
% Natural Gas	56%	69%	52%	59%
% Electric	35%	29%	37%	25%
% Fuel Oil	8%	2%	10%	15%
% Other	1%	1%	1%	1%
Heating System Type				
% Central Forced Air	41%	63%	40%	16%
% Boiler (hydronic/steam)	32%	12%	32%	60%
% Wall/Room Heater	7%	9%	1%	5%
% Electric Baseboard	16%	10%	25%	16%
% Other or None	4%	6%	2%	3%
Heating System Location				
% Building Level	34%	15%	35%	62%
% Unit Level	66%	85%	65%	38%
Supplemental Heat				
% Electric	13%**	7%**	13%**	16%*
% Other	14%**	22%**	5%**	19%*
Air Conditioning Type				
% Central AC	55%**	44%**	51%**	52%**
% Window/Wall	17%**	22%**	33%**	20%**
% Evaporative Cooler	3%**	1%**	1%**	3%**
% None	25%**	33%**	15%**	26%**
Water Heating Fuel				
% Natural Gas	68%	73%*	57%	70%
% Electric	22%	24%*	32%	12%
% Other	10%	3%*	11%	18%

*10% to <50% missing. **50% to <90% missing.

Table 3.12c furnishes statistics on the heating and cooling systems by weatherization type and equipment type. The table shows that almost all of the buildings with central equipment have boilers, that a significant percentage use fuel oil for heat and hot water, and that very few have either building level or unit level central air conditioning equipment.

Table 3.12c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Heating and Cooling System Characteristics by Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Heating Fuel				
% Natural Gas	56%	71%	55%	41%
% Electric	35%	3%	45%	57%
% Fuel Oil	8%	25%	0%	0%
% Other	1%	1%	1%	2%
Heating System Type				
% Central Forced Air	41%	10%	59%*	57%
% Boiler (hydronic/steam)	32%	90%	2%*	1%
% Wall/Room Heater	7%	0%	2%*	16%
% Electric Baseboard	16%	0%	35%*	17%
% Other or None	4%	0%	3%*	9%
Heating System Location				
% Building Level	34%	100%	0%	0%
% Unit Level	66%	0%	100%	100%
Supplemental Heat				
% Electric	13%**	8%*	27%**	11%*
% Other	14%**	17%*	10%**	11%*
Air Conditioning Type				
% Central AC	55%**	2%**	46%**	60%*
% Window/Wall	17%**	36%**	30%**	13%*
% Evaporative Cooler	3%**	0%**	4%**	3%*
% None	25%**	62%**	19%**	23%*
Water Heating Fuel				
% Natural Gas	68%	71%	74%*	58%
% Electric	22%	1%	26%*	41%
% Other	10%	28%	<1%*	1%

*10% to <50% missing. **50% to <90% missing.

3.6 INSTALLED MEASURES

Table 3.13a shows the diagnostic approach used by subgrantees to identify which measures should be installed. At the national level, 69 percent of units were assessed using a calculation procedure. In the Hot/Dry Climate Zones subgrantees most often used a priority list, while in the other Climate Zones they were more likely to use a calculation procedure.

Table 3.13a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Diagnostic Approach by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Diagnostic Approach						
% Priority List	30%*	27%	27%	18%	12%	95%*
% Calculation Procedure	69%*	73%	72%	82%	88%	5%*
% Other	1%*	0%	1%	0%	0%	0%*

*10% to <50% missing.

Table 3.13b shows the diagnostic approach used by the number of units in the building. The table shows that the larger the building, the more likely it was that a calculation procedure was used.

Table 3.13b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Diagnostic Approach by Number of Units in Building

Statistic	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
Diagnostic Approach				
% Priority List	30%*	51%*	36%	17%
% Calculation Procedure	69%*	47%*	64%	83%
% Other	1%*	2%*	0%	<1%

*10% to <50% missing.

Table 3.13c shows the diagnostic approach used by weatherization type and heating equipment type. The table shows that almost all buildings with whole building weatherization and central heating equipment used a calculation procedure. IUs were more often assessed using a calculation procedure. Buildings with whole building weatherization and unit heating equipment were more likely to be assessed using a priority list.

Table 3.13c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Diagnostic Approach by Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Diagnostic Approach				
% Priority List	30%*	8%	53%	32%*
% Calculation Procedure	69%*	92%	45%	68%*
% Other	1%*	<1%	2%	0%*

*10% to <50% missing.

Table 3.14a shows the rate at which air sealing and shell measures were installed in PY 2010 by Climate Zone. The findings include:

- Air Sealing – Subgrantees reported air sealing in about 66 percent of units; blower guided air sealing was used for 58 percent of units. In the Very Cold and Cold Climate Zones, subgrantees most often reported doing air sealing at the building level. In the other climate zones, air sealing was done at the unit level.

- Ceiling/Attic/Roof Insulation – Ceiling/attic/roof insulation was reported for one-third of units. About two-thirds of the units where this was reported had building level insulation installed. Building level installation was most common in the Very Cold and Cold Climate Zones. Unit level installation was most common in the Moderate and Hot/Humid Zones.

- Wall Insulation – Wall insulation installation rates were very low; only 4 percent of units had wall insulation installed.

- Other Insulation – Other insulation installation rates were very low; only 7 percent of units had other insulation installed.

- Duct Sealing - Duct sealing was reported for 31 percent of weatherized units. In the Very Cold and Cold Climate Zones, building level duct sealing was most often reported, while unit level duct sealing was reported in the other Climate Zones.

- Mechanical Ventilation – In the Moderate Climate Zone, 42 percent of units had mechanical ventilation installed (e.g., a kitchen or bathroom exhaust fan). In all other Climate Zones, less than 10 percent of units had mechanical ventilation installed.

Air sealing, ceiling/attic/roof insulation, and duct sealing are the most common measures installed in housing units. Other measures installed at relatively low rates.

Table 3.14a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings 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						
% Building	37%	70%	47%	17%	10%	8%
% Unit	28%	10%	12%	70%	68%	37%*
% Any Installed	66%	80%	59%	87%	78%	45%*
Blower Door						
% Building	18%**	47%**	20%**	12%*	12%*	14%**
% Unit	40%*	17%*	34%**	60%	46%*	23%**
% Any Installed	58%**	64%**	54%**	72%*	58%*	37%**
Ceiling/Attic/Roof Insulation						
% Building	21%	27%	34%	5%	3%	2%
% Unit	11%	5%	3%*	26%	33%	6%
% Any Installed	31%	32%	37%	31%	36%	7%
Wall Insulation						
% Building	3%	5%	4%	0%	1%	0%
% Unit	2%	0%	2%*	0%	3%	0%
% Any Installed	4%	5%	6%	0%	4%	0%
Other Insulation						
% Building	6%	17%	5%	4%	0%	10%
% Unit	1%*	1%	1%*	8%	0%	0%**
% Any Installed	7%*	18%	6%*	12%	0%	10%**
Duct Sealing						
% Building	11%*	30%**	12%*	19%**	9%**	5%*
% Unit	20%	3%	2%*	35%**	22%*	22%*
% Any Installed	31%*	33%*	13%**	54%**	31%*	27%*
Ventilation						
% Installed	10%**	***	8%**	42%**	4%*	0%**

*10% to <50% missing. **50% to <90% missing. ***More than 90% missing.

Table 3.14b shows the rate at which air sealing and shell measures were installed in PY 2010 by the number of units in the building. The table shows that air sealing and duct sealing is done less often in the

largest buildings. It also shows that the smallest buildings were the least likely to have mechanical ventilation installed.

Table 3.14b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Air Sealing and Shell Measures by Number of Units in Building

Statistic	NATIONAL	5 to 9 Units	10 to 25 Units	More Than 25 Units
Air Sealing				
% Building	37%	51%	50%	37%
% Unit	28%	24%*	23%	19%*
% Any Installed	66%	76%*	73%	56%
Blower Door				
% Building	18%**	16%**	33%**	19%**
% Unit	40%*	36%*	39%*	37%**
% Any Installed	58%**	52%**	72%**	56%**
Ceiling/Attic/Roof Insulation				
% Building	21%	22%	35%	24%
% Unit	11%	9%	8%	4%
% Any Installed	31%	31%	43%	28%
Wall Insulation				
% Building	3%	1%	8%	3%
% Unit	2%	3%	<1%	1%
% Any Installed	4%	4%	8%	4%
Other Insulation				
% Building	6%	7%	11%	5%
% Unit	1%*	1%*	2%	<1%*
% Any Installed	7%*	8%*	13%	5%
Duct Sealing				
% Building	11%*	8%**	32%*	10%*
% Unit	20%	28%*	14%	16%
% Any Installed	31%*	36%*	45%*	26%
Ventilation				
% Installed	10%**	7%**	24%**	20%**

*10% to <50% missing. **50% to <90% missing.

Table 3.14c shows the rate at which air sealing and shell measures were installed in PY 2010 by the weatherization type and heating equipment type. The table shows that ceiling/attic/roof insulation is most often done in buildings with central heating equipment when the whole building was treated. It also

shows that duct sealing was most often reported for unit level heating equipment. It shows that mechanical ventilation was only reported for IUs.

Table 3.14c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Air Sealing and Shell Measures by Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Air Sealing				
% Any Installed	66%	53%	68%	76%*
Blower Door				
% Any Installed	58%**	50%**	68%**	55%*
Ceiling/Attic/Roof Insulation				
% Any Installed	31%	44%	28%	25%
Wall Insulation				
% Any Installed	4%	5%	4%	4%
Other Insulation				
% Any Installed	7%*	8%	9%	3%**
Duct Sealing				
% Any Installed	31%*	6%**	51%*	27%
Ventilation				
% Installed	10%**	***	***	11%*

*10% to <50% missing. **50% to <90% missing. ***More than 90% missing.

Table 3.15a shows the rate at which heating and water heating equipment measures were installed in PY 2010 by Climate Zone. The table shows whether or not the equipment was estimated to be a cost-effective energy conservation measure. The table shows that 33 percent of units had heating equipment replaced and that 11 percent of units had water heating equipment replaced. Climate Zone findings include:

- Heating Equipment - The Moderate and Hot/Humid Climate Zones had the highest rate of equipment replacement.
- Water Heating Equipment - Water heating equipment replacement was reported most often in the Very Cold Climate Zone.

In some Climate Zones, most of the replaced equipment was reported as an energy conservation measure (ECM). See, for example, furnace replacements in the Hot/Humid Climate Zone. However, in other Climate Zones, there was a significant amount of non-ECM equipment replacement. See, for example, furnace replacements in the Moderate Climate Zone.

Table 3.15a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings 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						
Furnace (non-ECM)	1%	<1%*	0%	19%	0%	<1%
Furnace (ECM)	13%	3%*	<1%	33%	57%	3%
Furnace (Unknown)	19%	31%*	27%	0%	4%	10%
Any Furnace	33%	35%*	27%	52%	61%	13%
Water Heating Equipment						
Water Heater (non-ECM)	1%	3%	<1%*	<1%	<1%	<1%
Water Heater (ECM)	4%	3%	4%*	17%	1%	2%
Water Heater (unknown)	7%	29%	6%*	6%	2%	2%
Any Water Heating Equipment	11%	35%	10%*	23%	3%	4%

*10% to <50% missing.

Table 3.15b shows the rate at which heating and water heating equipment measures were installed in PY 2010 by the number of units in the building. For both heating equipment and water heating equipment, the largest buildings had the highest rate of replacement.

Table 3.15b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Heating and Water Heating Equipment Measures by Number of Units

Statistic	NATIONAL	5 to 9 Units	10 to 25 Units	More Than 25 Units
Heating Equipment				
Furnace (non-ECM)	1%	4%*	2%	<1%
Furnace (ECM)	13%	5%*	7%	5%
Furnace (Unknown)	19%	7%*	18%	32%
Any Furnace	33%	16%*	27%	38%
Water Equipment				
Heater (non-ECM)	1%	1%*	1%	1%
Heater (ECM)	4%	6%*	3%	3%
Heater (unknown)	7%	4%*	4%	13%
Any Water Heating Equipment	11%	11%*	7%	18%

*10% to <50% missing.

Table 3.15c shows the rate at which heating and water heating equipment measures were installed in PY 2010 by heating equipment and weatherization type. Findings include:

- Heating Equipment - Heating equipment was most often replaced in buildings with a central heating system (48%) and in IUs (42%).

- Water Heating Equipment - Water heating equipment was replaced at a higher rate for buildings with central heating equipment.

Table 3.15c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Heating and Water Heating Equipment Measures by Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Heating Equipment Replacement				
Furnace (non-ECM)	1%	0%	<1%*	3%
Furnace (ECM)	13%	0%	1%*	32%
Furnace (Unknown)	19%	48%	3%*	7%
Any Furnace	33%	48%	4%*	42%
Water Heating Equipment				
Heater (non-ECM)	1%	1%	1%*	<1%
Heater (ECM)	4%	6%	2%*	3%
Heater (unknown)	7%	14%	11%*	<1%
Any Water Heating Equipment	11%	20%	14%*	4%

*10% to <50% missing.

Table 3.16a shows the installation rate for other measures by Climate Zone. Findings include:

- Windows - About one-fourth of units had window replacements; the highest replacement rate was in the Cold Climate Zone and the lowest was in the Very Cold Climate Zone.

- Air Conditioning Equipment – Nationally, about 15 percent of units had air conditioning equipment replaced and most were considered to be ECM measures. The rate was 65 percent in the Hot/Humid Climate Zone and 24 percent in the Moderate Climate Zone.

- Other Equipment – Over two-thirds of housing units (71%) received energy efficient lighting and almost one-fourth of units replacement refrigerators (23%).

Since many WAP clients received air conditioner, energy efficient lighting, and refrigerators, it is expected that units will have electric savings even if they do not have electric heat.

Table 3.16a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Other Measures by Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Windows						
Window (non-ECM)	1%	0%	<1%	0%	2%	<1%
Window (ECM)	8%	4%	3%	25%	23%	6%
Window (unknown)	18%	1%	34%	0%	1%	2%
Window (any reason)	27%	5%	38%	25%	26%	8%
Air Conditioner						
AC Unit (non-ECM)	<1%	0%*	0%	0%	0%	<1%
AC Unit (ECM)	13%	0%*	1%	12%	62%	4%
AC Unit (unknown)	2%	0%*	1%	13%	4%	3%
Any AC Unit	16%	0%*	2%	25%	65%	7%
Other Equipment						
Programmable T-stat	18%*	9%**	15%**	12%	32%	10%
Lighting	72%	88%	62%*	77%	78%	77%
Refrigerator	23%*	20%*	22%*	47%	28%	9%

*10% to <50% missing. **50% to <90% missing.

Table 3.16b shows the rate at which other measures were installed in PY 2010 by the number of units in the building. Findings include:

- Windows - Larger buildings were more likely to have window replacements; 37 percent of buildings with 25 or more units had windows replaced, compared to 17 percent of units in buildings with 5 to 9 units.

- Air Conditioning Equipment – There was little variation in air conditioning equipment replacement by buildings size.

- Other Equipment – Units in larger buildings were more likely to receive new refrigerators and lighting, while units in smaller buildings were more likely to receive setback thermostats.

It appears that there is expected to be variation in the types of energy savings related to these measures by the number of units in the building.

Table 3.16b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Other Measures by Number of Units in Building

Statistic	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
Windows				
Window (non-ECM)	1%	2%	<1%	<1%
Window (ECM)	8%	8%	4%	8%
Window (unknown)	18%	9%	23%	29%
Window (any reason)	27%	19%	27%	37%
Air Conditioner				
AC Unit (non-ECM)	<1%	<1%*	0%	0%
AC Unit (ECM)	13%	6%*	6%	3%
AC Unit (unknown)	2%	1%*	3%	3%
Any AC Unit	16%	8%*	9%	6%
Other Equipment				
Programmable T-stat	18%*	18%*	25%*	9%**
Lighting	72%	62%*	66%	77%*
Refrigerator	23%*	18%*	21%	29%*

*10% to <50% missing.

Table 3.16c shows the rate at which other measures were installed in PY 2010 by the weatherization type and heating equipment type. Findings include:

- Windows - Buildings with central heating equipment were more likely to have window replacements; 45 percent of units in those buildings had windows replaced, compared to about 20 percent of units in other buildings.

- Air Conditioning Equipment – Very few units in buildings with whole building weatherization received new air conditioning units, while about one-third of the IUs had air conditioner replacements.

- Other Equipment – Most of the thermostat replacements were reported for units in buildings where each unit has its own heating and air conditioning equipment.

It appears that there is expected to be variation in the types of energy savings related to these measures by the weatherization approach and the type of heating equipment.

Table 3.16c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Other Measures by Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Windows				
Window (non-ECM)	1%	0%	2%	<1%
Window (ECM)	9%	3%	5%	16%
Window (unknown)	18%	42%	14%	2%
Window (any reason)	27%	45%	21%	18%
Air Conditioner				
AC Unit (non-ECM)	<1%	0%	0%*	<1%
AC Unit (ECM)	13%	0%	7%*	28%
AC Unit (unknown)	2%	0%	3%*	4%
Any AC Unit	16%	0%	10%*	33%
Other Equipment				
Programmable T-stat	18%*	7%*	25%*	18%
Lighting	72%	75%*	66%*	76%
Refrigerator	23%*	31%*	18%*	20%

*10% to <50% missing.

Statistical analysis of energy savings shows that four measures – furnace replacement, attic insulation, wall insulation, and major air sealing (i.e., more than 1,000 CFM50 air leakage reduction) – are responsible for a large share of the total energy savings for single family homes. However, in multifamily buildings, wall insulation is rarely installed and it is difficult to measure effective air leakage reductions because of unit to unit air leakage. In addition, because of the stack effect in multi-story buildings, it is perceived that replacement of windows can be an effective energy conservation measure. For those reasons, the multifamily building analysis considered five measures to be major measures in terms of cost and potential energy savings; attic/roof/ceiling insulation, heating equipment, water heating equipment, air conditioning equipment, and windows. Table 3.17a shows the distribution of the number of major measures by climate zone. On average, 1.2 major measures were installed per housing unit. No housing units received all five major measures. The installation rate was much lower for the Hot/Dry Climate Zone than for the other zones.

Table 3.17a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Percent of Units by Number of Major Measures and Climate Zone

Statistic	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Major Measures						
No Major Measures	34%*	39%*	28%*	18%*	10%	77%
One Major Measure	27%*	22%*	32%*	51%*	24%	13%
Two Major Measures	27%*	18%*	31%*	9%*	49%	7%
Three Major Measures	11%*	22%*	9%*	14%*	17%	2%
Four Major Measures	1%*	0%*	0%*	8%*	<1%	2%
All Jobs	100%*	100%*	100%*	100%*	100%	100%
Mean # of Measures	1.2*	1.2*	1.2*	1.4*	1.7	0.4

*10% to <50% missing.

Table 3.17b shows the distribution of the number of major measures by the number of housing units in the building. Buildings with more housing units had more measures installed. Large multifamily buildings were more likely to have central heating and water heating equipment that needed replacement. Smaller units were more likely to have no major measures, but were more likely to have air sealing work done (see Table 3.14b).

Table 3.17b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Percent of Units by Number of Major Measures and Number of Units in Building

Statistic	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
Major Measures				
No Major Measures	34%*	53%*	33%*	27%*
One Major Measure	27%*	21%*	35%*	32%*
Two Major Measures	27%*	15%*	19%*	30%*
Three Major Measures	11%*	8%*	13%*	11%*
Four Major Measures	1%*	3%*	<1%*	1%*
All Jobs	100%*	100%*	100%*	100%*
Mean # of Measures	1.2*	0.9*	1.1*	1.3*

*10% to <50% missing.

Table 3.17c shows the distribution of the number of major measures by weatherization type and equipment type. Buildings with central heating equipment receive more major measures than other types of units. Buildings with building-level weatherization and unit level heating equipment were the least likely to receive major measures.

Table 3.17c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Percent of Units by Number of Major Measures and Weatherization Type/Equipment Type

Statistic	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Major Measures				
No Major Measures	34%*	17%	47%*	38%
One Major Measure	27%*	25%	36%*	25%
Two Major Measures	27%*	40%	13%*	26%
Three Major Measures	11%*	19%	4%*	9%
Four Major Measures	1%*	0%	1%*	2%
All Jobs	100%*	100%	100%*	100%
Mean # of Measures	1.2*	1.6	0.7*	1.1

*10% to <50% missing.

3.7 WEATHERIZATION JOB COSTS

Subgrantees have developed systems to track the costs of each weatherization job. These systems allow subgrantees to track the average cost per job and the share of funding that is allocated to health and safety measures. In addition, many grantees and subgrantees leverage DOE funding with other funding sources, including Low Income Home Heating Assistance Program (LIHEAP) funds, other Federal funds, and utility system benefit charge funds. Subgrantees that have leveraged funding have cost tracking systems that allocate job costs among different funding sources. For multifamily buildings, building owners are usually expected to contribute to the cost of weatherization. Subgrantees also track those costs.

Table 3.18a shows the mean and median total job cost for PY10 by climate zone. These are the costs per housing unit that are allocated to individual jobs. These statistics do not include program administration or training costs. They also exclude program operations costs incurred at the agency for functions like intake and job scheduling. One of the program costs for weatherization of multifamily buildings is the work that needs to be done with building owners to arrange for building access; those costs generally are not included in the job cost data presented in Tables 3.18a through 3.18c.

The mean cost per job is $3,111 and the median is $2,651. Average costs in Hot/Humid Climate Zones are about 60 percent above the national average; this may be associated with a high rate of equipment replacement for units in this Climate Zone. Average costs in the Hot/Dry Climate Zone are less than one-half the national average; units in this Climate Zone had few major measures installed. (See Table 3.17a)

Table 3.18a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean and Median Cost Per Unit by Climate Zone

Climate Zone	Mean Cost per Unit	Median Cost per Unit
Very Cold Climate	$2,132	$1,845
Cold Climate	$3,266	$2,951
Moderate Climate	$2,975	$2,945
Hot/Humid Climate	$5,096	$5,439
Hot/Dry Climate	$1,203	$434
TOTAL	$3,111	$2,651

Table 3.18b shows the mean cost by the number of units in the building. The units in buildings with 5 to 9 units had the lowest spending, about 25 percent less than the national average.

Table 3.18b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean and Median Cost Per Unit by Number of Units in Building

Number of Units	Mean Cost per Unit	Median Cost per Unit
5-9 Units	$2,298	$1,202
10-25 Units	$3,582	$3,378
More Than 25 Units	$3,255	$3,017
TOTAL	$3,111	$2,651

Table 3.18c shows the mean cost by the weatherization type and heating equipment type. The units in buildings with whole building weatherization and central heating equipment had the highest costs, about one-third higher than the average for all units.

Table 3.18c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean and Median Cost Per Unit by Weatherization Type/Equipment Type

Weatherization Type	Mean Cost per Unit	Median Cost per Unit
Whole Building/Central Heating	$4,122	$3,655
Whole Building/Unit Heating	$2,531	$1,763
Individual Unit/Unit Heating	$2,955	$2,129
TOTAL	$3,111	$2,651

Tables 3.19a through 3.19c show the distribution of total cost for PY10 by Climate Zone, number of units in the building, and weatherization type/equipment type. The findings from the tables include:

- Distribution of Cost - Table 3.19a shows that there is considerable variation in the cost per unit for weatherization jobs in multifamily buildings. Ten percent of units had spending of less than $300 and 10 percent had spending over $6,500. Looking at the two middle quartiles (25% to 75%) the job cost varied from less than $1,000 to almost $5,000. Given this variability in spending per unit there is likely to be considerable variation in savings per unit.

- Climate Zone - Table 3.19a shows that the Hot/Humid Climate Zone had higher average job spending and a little less variability in job spending; 90 percent of the units had more than $2,300 in spending. The Hot/Dry Climate Zone had lower average job spending; 75 percent of the units had less than $1,211 in spending.

- Number of Units in Building - Table 3.19b shows that the distribution of costs is similar for buildings with 10-24 units and buildings with 25 or more units. Buildings with 5-9 units had a much lower median cost ($1,202), but for 25 percent of the units, the cost exceeded the $3,000.

- Weatherization Type and Equipment Type - Table 3.19c shows that the units in buildings that had whole building weatherization and central heating equipment were somewhat higher cost per unit, while the costs for IUs were more variable than for other job types.

There is considerable variability in job cost by Climate Zone, number of units in the building, and by weatherization type. It is expected that some unit would have substantial energy savings and that others would have almost no savings.

Table 3.19a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Distribution of Cost by Climate Zone

	Percent of Population				
Climate Zone	**10%**	**25%**	**Median**	**75%**	**90%**
Very Cold Zone	$591	$1,050	$1,845	$2,884	$4,200
Cold Zone	$436	$953	$2,951	$4,798	$6,899
Moderate Zone	$368	$1,294	$2,945	$4,650	$6,013
Hot/Humid Zone	$2,326	$3,911	$5,439	$6,277	$7,601
Hot/Dry Zone	$22	$182	$434	$1,211	$4,437
ALL ZONES	$283	$911	$2,651	$4,820	$6,553

Table 3.19b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Distribution of Cost by Number of Units in Building

	Percent of Population				
Number of Units	**10%**	**25%**	**Median**	**75%**	**90%**
5-9 Units	$321	$832	$1,202	$3,298	$4,998
10-25 Units	$441	$1,464	$3,378	$5,466	$6,622
More Than 25 Units	$423	$1,136	$3,017	$4,798	$6,650
ALL BUILDINGS	$283	$911	$2,651	$4,820	$6,553

Table 3.19c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Distribution of Cost by Weatherization Type/Equipment Type

	Percent of Population				
WX Type / Equipment Type	**10%**	**25%**	**Median**	**75%**	**90%**
Whole Building/Central Equipment	$824	$2,170	$3,655	$5,589	$7,998
Whole Building/Unit Equipment	$600	$961	$1,763	$4,035	$5,665
Individual Unit/Unit Equipment	$173	$441	$2,129	$5,439	$6,500
ALL BUILDINGS	$283	$911	$2,651	$4,820	$6,553

One important factor in job cost is the number of measures installed in each building and housing unit. Table 3.20a shows the average job cost by the number of major measures installed by Climate Zone. The average job cost for those units that did not get any of the listed major measures was $1,211. Units with no major measures were likely to get air sealing, water measures, and baseload measures. However, they did not receive heating equipment, water heating equipment, air conditioning equipment, insulation, or windows.

Table 3.20a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean Cost by Number of Major Measures and Climate Zone

Number of Measures	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
No Major Measures	$1,211*	$1,944*	$1,183*	$1,683*	$4,738	$487
One Major Measure	$3,109*	$1,871*	$3,177*	$2,340*	$4,277	$2,667
Two Major Measures	$5,195*	$2,980*	$5,658*	$2,822*	$5,267	$3,754
Three Major Measures	$5,222*	$2,571*	$6,173*	$4,223*	$5,954	$5,659
Four Major Measures	$5,719*	NA	NA	$6,322*	$3,910	$4,833
All Jobs	$3,316*	$2,249*	$3,686*	$2,863*	5,098	$1,176

*10% to <50% missing.

Table 3.20a shows that, nationally, it appears that each major measure added about $2,000 to the cost of a job. Units with no major measures had costs of about $1,200. Units with two major measures had costs of about $3,100. Units with two major measures had costs of about $5,200. However, the average cost did not continue to increase for units with three or four measures; those jobs averaged $5,222 per unit and $5,719 per unit, respectively. Similar patterns are observed in Tables 3.20b and 3.20c.

Table 3.20b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean Cost by Number of Major Measures and Number of Units in Building

Number of Measures	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
No Major Measures	$1,211*	$1,347*	$2,362*	$1,143*
One Major Measure	$3,109*	$2,390*	$3,293*	$3,146*
Two Major Measures	$5,195*	$4,857*	$5,965*	$5,103*
Three Major Measures	$5,222*	$5,356*	$6,086*	$4,105*
Four Major Measures	$5,719*	$5,479*	$6,622*	$6,036*
All Jobs	$3,316*	$2,542*	$3,880*	$3,335*

*10% to 50% missing.

Table 3.20c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean Cost by Number of Major Measures and Weatherization Type/Equipment Type

Number of Measures	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
No Major Measures	$1,211*	$1,561	$2,357*	$625
One Major Measure	$3,109*	$3,065	$3,522*	$3,146
Two Major Measures	$5,195*	$5,410	$5,647*	$4,939
Three Major Measures	$5,222*	$5,008	$4,848*	$5,613
Four Major Measures	$5,719*	NA	$4,430*	$5,858
All Jobs	$3,316*	$4,118	$3,325*	$2,972

*10% to <50% missing.

Tables 3.21a through 3.21c shows the average measures costs for those units the received only one major measure. These tables can help to show the relative cost of measures. From the tables, it appears that attic insulation and water heater replacement are comparatively less expensive, while furnace replacement and window replacement are more expensive.

Table 3.21a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean Cost by Major Measure and Climate Zone

Measure Type	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
No Major Measures	$1,212*	$1,944*	$1,183*	$1,683*	$4,738	$487
Attic Insulation Only	$1,915*	$1,377*	$2,196*	$461*	$2,774	$1,444
Furnace Only	$3,983*	$4,343*	$3,967*	$3,100*	$5,238	$3,287
Water Heater Only	$2,375*	$1,974*	$2,504*	$916*	$6,500*	NA
Windows Only	$3,362*	$3,323*	$3,827*	$2,556*	$2,043*	$2,260
One Major Measure	$3,109*	$1,871*	$3,177*	$2,340*	$4,277	$2,667

*10% to <50% missing.

Table 3.21b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean Cost by Major Measure and Number of Units in Building

Measure Type	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
No Major Measures	$1,212*	$1,347*	$2,362*	$1,143*
Attic Insulation Only	$1,915*	$1,439*	$3,004*	$1,299*
Furnace Only	$3,983*	$3,818*	$4,097*	$3,867*
Water Heater Only	$2,375*	$3,636*	$3,702*	$1,770*
Windows Only	$3,362*	$2,748*	$3,038*	$3,973*
One Major Measure	$3,109*	$2,390*	$3,291*	$3,146*

*10% to <50% missing.

Table 3.21c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings Mean Cost by Major Measure and Weatherization Type/Equipment Type

Measure Type	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
No Major Measures	$1,212*	1,561	2,357*	625
Attic Insulation Only	$1,915*	$900	$3,817*	$1,240
Furnace Only	$3,983*	$4,425	$1,850*	$3,996
Water Heater Only	$2,375*	$2,224	$2,368*	$5,450
Windows Only	$3,362*	$3,833	$3,714*	$2,330
One Major Measure	$3,109*	$3,065	$3,522*	$3,146

*10% to <50% missing.

The WAP program installs energy saving measures and addresses health and safety problems. Tables 3.22a to 3.22c show the share of costs allocated between energy conservation measure (ECM) and non-ECM (i.e., health and safety) costs. Table 3.22a shows that, on average, 8 percent of job costs were spent on non-ECM measures. Jobs in the Very Cold Climate Zone had the highest non-ECM share of spending (17%). In the Cold Climate Zone, non-ECM costs were only 6 percent of the total cost.

Table 3.22a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings ECM and non-ECM Costs by Climate Zone

Cost Type	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Mean ECM Costs	$3,097*	$1,761	$3,093	$2,790	$4,648	$1,293**
Mean Non-ECM Costs	$279*	$369	$199	$369	$482	$124**
Mean non-ECM %	8%*	17%	6%	12%	9%	9%**
Mean TOTAL Costs	$3,376*	$2,130	$3,292	$3,158	$5,129	$1,417**

*10% to <50% missing. **50% to <90% missing.

Table 3.22b shows that there is little variation in ECM percentage by units in the building and Table 3.22c shows that there are only small differences by weatherization type.

Table 3.22b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings ECM and non-ECM Costs by Number of Units in Building

Cost Type	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
Mean ECM Costs	$3,097*	$2,157*	$3,293*	$3,119
Mean Non-ECM Costs	$279*	$248*	$376*	$302
Mean non-ECM %	8%*	10%*	10%*	9%
Mean TOTAL Costs	$3,376*	$2,405*	$3,668*	$3,420

*10% to <50% missing.

Table 3.22c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings ECM and non-ECM Costs by Weatherization Type/Equipment Type

Cost Type	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Mean ECM Costs	$3,097*	$3,939	$2,249	$3,357*
Mean Non-ECM Costs	$279*	$276	$279	$309*
Mean non-ECM %	8%*	7%	11%	8%*
Mean TOTAL Costs	$3,376*	$4,215	$2,529	$3,666*

*10% to <50% missing.

Many grantees make other funds available for weatherization (e.g., LIHEAP, SBC funds, and other Federal program funds) that are used to pay for some measures in DOE funded weatherization jobs. In addition, sometimes WAP subgrantees receive direct grants (i.e., not through the WAP grantee) for leveraged funds that also are used to pay for some measures in DOE funded weatherization jobs. Finally, for multifamily buildings, owners often pay for at least part of the program measures. Tables 3.23a to 3.23c show the share of the costs for DOE jobs that were allocated to non-DOE funds. On average, non-DOE funds covered about 20 percent of job costs. The share paid by non-DOE funds is 20 to 25 percent in the Very Cold, Cold, and Hot/Humid Climate Zones. It was only 4 percent in the Moderate Climate Zone.

Table 3.23a PY 2010 WAP/ARRA Housing Units in Multifamily Buildings DOE and non-DOE Costs for DOE Jobs by Climate Zone

Source of Funding	NATIONAL	Very Cold Climate	Cold Climate	Moderate Climate	Hot/Humid Climate	Hot/Dry Climate
Mean DOE Costs	$2,497	$1,665	$2,612	$2,802*	$3,840	$1,109
Mean Non-DOE Costs	$639	$468	$687	$105*	$1,264	$107
Mean non-DOE %	20%	22%	21%	4%*	25%	9%
Mean TOTAL Costs	$3,136	$2,132	$3,299	$2,907*	$5,103	$1,216

*10% to <50% missing.

Table 3.23b shows that the non-DOE spending was highest for the units in buildings with 25 or more units; in those buildings, non-DOE funds paid 21 percent of weatherization costs. For units in the smallest buildings, non-DOE funds covered only 9 percent of job costs.

Table 3.23b PY 2010 WAP/ARRA Housing Units in Multifamily Buildings DOE and non-DOE Costs for DOE Jobs by Number of Units in Building

Source of Funding	NATIONAL	5-9 Units	10-25 Units	More Than 25 Units
Mean DOE Costs	$2,497	2,045	3,022	2,636
Mean Non-DOE Costs	$639	206	580	700
Mean non-DOE %	20%	9%	16%	21%
Mean TOTAL Costs	$3,136	2,251	3,602	3,336

Table 3.23c shows that the non-DOE spending was highest for the units in buildings with whole building weatherization and central heating (26%).

Table 3.23c PY 2010 WAP/ARRA Housing Units in Multifamily Buildings DOE and non-DOE Costs for DOE Jobs by Weatherization Type/Equipment Type

Source of Funding	NATIONAL	Whole Building with Central Heating	Whole Building with Unit Heating	Individual Unit with Unit Heating
Mean DOE Costs	$2,497	$3,059	$2,281	$2,361
Mean Non-DOE Costs	$639	$1,067	$256	$621
Mean non-DOE %	20%	26%	10%	21%
Mean TOTAL Costs	$3,136	$4,126	$2,537	$2,982

4. ENERGY IMPACTS FOR GAS AND FUEL OIL MAIN HEAT BUILDINGS

The WAP evaluation directly measured gas, fuel oil, and electric usage for units in multifamily buildings that use natural gas or fuel oil as their main heating fuel. This section presents the findings with respect to overall energy impacts as well as breaking out savings for important subgroups of the population. Statistics are presented by:

- End Use – The share of savings attributable to changes in heating, cooling, and baseload usage levels.
- Weatherization Approach and Equipment Type - Building level weatherization compared to unit level weatherization, with additional breakout of buildings with central heating equipment compared to those with heating equipment in each unit.
- Building Size - Differences in energy savings between small multifamily buildings and large multifamily buildings.
- Installed Measures – Differences in savings for groups of housing units 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.
- Expenditures and Leveraging – Variation in savings by levels of spending on efficiency measures, total job costs, job funding sources, and agency funding sources.
- Climate Zone - Differences in saving for units in each of the Climate Zones.

A further statistical analysis of explanatory factors related to observed energy savings was performed to estimate the energy savings attributable to individual program factors. The models developed by this analysis were used to extrapolate the savings from the gas and fuel oil analysis samples to the full population of gas and fuel oil heated units in multifamily buildings served by the program.

4.1 METHODOLOGY

4.1.1 Analysis Procedures

The therm and kWh savings analysis approach was a standard pre/post treatment/comparison design using weather-normalized billing data. The weather-normalization approach employed was similar to PRISM[5] and produces estimates of weather-adjusted annual energy consumption for each building or unit, depending on whether master-meter or unit-level data were available, based on monthly usage data and daily outdoor temperatures using a variable degree day base regression analysis.

Gross energy savings for each building or unit were calculated as the difference in the normalized annual consumption between the pre-treatment and post-treatment periods for buildings treated in PY 2010 and PY 2011. Buildings and units treated in PY 2011 were used as a Comparison Group for the PY 2010 analysis. Comparison Group usage was analyzed by subtracting one year from the actual treatment date to create pseudo pre-treatment and post-treatment periods after removing all actual post-treatment usage

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

data. Net program savings were then calculated as the average gross savings for participants minus the average savings (i.e., change in usage) found for the Comparison Group.

The results of the weather-normalization analysis were 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.

4.1.2 Sample Attrition

A total of 4,736 multifamily gas and oil heated housing units were sampled for analysis. Table 4.1 summarizes the disposition of this sample for the gas, fuel oil, and electric usage analysis. The data collection process was successful in obtaining gas savings data for 24 percent of the sampled housing units, fuel oil savings data for 21 percent of the sampled and housing units, and baseload electric savings data for 25 percent of the sampled housing units. There were a number of different sources of attrition:

- Subgrantee Response - In some states with a large number of multifamily housing units, there was substantial subgrantee nonresponse. This appeared to be a problem in states where there was a very large increase in funding during the ARRA period. For housing units served by those subgrantees, the energy company was unknown because the subgrantee did not furnish any information for the evaluation.

- Company Response - In some states with a large number of multifamily housing units, one or more major gas companies were unwilling to furnish information for the evaluation. For housing units served by those gas companies, there was no usage data for the evaluation.

- Other Issues - Among the remaining sources of attrition, the major problem was that units had an inadequate usage record. The gas and fuel oil usage analysis required a minimum of 183 of data for both the pre-weatherization and post-weatherization periods. The data were insufficient for 12 percent of natural gas cases and 54 percent of fuel oil cases.

Data collection for multifamily housing units included some on-site data collection at agencies. When there was data for non-sampled buildings available at the agency, evaluation staff collected those data for use in the energy savings analysis. While the data for those buildings are not included in the ARRA multifamily energy saving statistics, they were useful in helping to develop the energy savings models.

For baseload electric data, an additional source of attrition was that subgrantees often did not collect electric account numbers for households when the main heating fuel (gas or fuel oil) was a master-metered account.

Table 4.1 PY 2010 Multifamily Housing Units Gas, Fuel Oil, and Baseload Electric Usage Sample Attrition - Gas and Fuel Oil Main Heat

	Gas Analysis		Fuel Oil Analysis		Baseload Electric Analysis	
Attrition Reason	**Units**	**% of Sample**	**Units**	**% of Sample**	**Units**	**% of Sample**
Sampled	4,376	100%	400	100%	4,879	100%
No Usage Data Available	2,782	64%	100	25%	2,495	51%
Insufficient Data / Poor Model Fit / Outlier	540	12%	216	54%	1,164	24%
Total Usable Sampled Cases	1,054	24%	84	21%	1,220	25%
Non-Sampled Cases	58		9		336	
Total Usable Cases	1,112		93		1,556	

4.2 KEY PROGRAM FACTORS FOR HOUSING UNITS WITH GAS MAIN HEAT

Table 4.2 summarizes information about climate, building characteristics, housing unit characteristics, and major measures for the full multifamily sample compared to multifamily units with gas or fuel oil main heat. The last three columns summarize these same characteristics for the gas, fuel oil, and electric usage analysis samples. The table shows that gas and oil heated units were more likely to be located in the Cold Climate Zone and less likely to be in the Moderate or Hot/Humid zones than other multifamily units. In addition, the tables show that the gas and oil heated housing units are more likely to be in buildings with more than 25 units, to have building level heating systems, and to be built before 1970.

Because of the attrition, the gas and fuel oil usage analysis sample has more housing units in the Very Cold and Cold Climate Zones, slightly larger housing units, and more weatherization measures than the full population. The gas and fuel oil analysis sample in the Hot/Humid and Hot/Dry Climate Zones had the greatest amount of attrition because of the non-participation of two major utility companies in those Climate Zones. The electric analysis sample is similar to the gas and fuel oil sample, although better represents the Hot/Humid and Hot/Dry climates. The impacts of these differences between the analysis sample and population are addressed in developing program population impact estimates in Section 4.8.

Table 4.2 Characteristics of Multifamily Housing Units for PY 2010

Characteristic	All Units	Gas and Fuel Oil Heated Housing Units		
		Gas and Fuel Oil Heat Population	Gas and Fuel Oil Analysis Sample	Electric Baseload Analysis Sample
Climate				
Very Cold	10%	11%	6%	13%
Cold	47%	63%	86%	71%
Moderate	13%	3%	2%	3%
Hot/Humid	16%	8%	4%	8%
Hot/Dry	14%	15%	2%	5%
Building Characteristics				
% 5+ Stories	26%	33%	56%	20%
% More than 25 Units	39%	45%	61%	46%
Building Level Heating System	34%	51%	74%	54%
% Built 1970 or Later	69%	59%	48%	50%
Housing Unit Characteristics				
Mean Square Footage	825	879	932	908
% Central Heat	73%	90%	94%	90%
% Electric Supplemental Heat	13%	9%	6%	12%
% with Air Conditioning	75%	68%	59%	75%
Major Measures				
Furnace/Boiler Replacement	33%	32%	36%	34%
Water Heater Replacement	11%	13%	11%	12%
Air Conditioning Replacement	16%	7%	4%	10%
Attic Insulation	31%	36%	48%	43%
Window Replacement	27%	30%	42%	22%

Note: Results weighted by sample design selection probabilities.

4.3 ENERGY SAVINGS OVERALL AND BY END USE

Table 4.3 summarizes natural gas and fuel oil impacts and shows a breakout of savings by weather-normalization component – heating[6] vs. baseload (non-heating) consumption. The overall savings are estimated at 99 therms per year, equal to 14.2 percent of pre-program usage. Space heating accounted for 69 percent of the usage and achieved 73 percent of the total savings. The heating savings averaged 14.9 percent of pre-program heating use. There was also a 12.7 percent reduction in the baseload portion of usage.

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

Table 4.3 PY 2010 and 2011 Energy Impacts for Multifamily Housing Units Gross and Net Gas and Fuel Oil Savings Total and by End Use (therms/year)

Group/Breakout	Units	Pre-WAP Use	Post-WAP Use	Gross Savings	Net Savings	% of Pre
Total Use	1,205	700	608	92 (±6)	99 (±8)	14.2% (±1.2%)
Comparison	979	702	710	-7 (±5)		
Heating Use	1,205	486	418	68 (±6)	72 (±9)	14.9% (±1.9%)
Comparison	979	480	485	-4 (±7)		
Baseload Use	1,205	214	189	25 (±5)	27 (±7)	12.7% (±3.3%)
Comparison	979	222	225	-2 (±5)		

Table 4.4 summarizes unit-level electric impacts by end use among gas and fuel oil heated housing units. The terms "Heating/Winter" and "Cooling/Summer" are used to describe the end uses rather than just heating and cooling because some electric end uses vary seasonally, and so a portion of their consumption is statistically allocated to the heating or cooling component. About 82 percent of the electric use and about 76 percent of electric savings are classified as baseload.

Table 4.4 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Gross and Net Electric Savings for Natural Gas and Fuel Oil Main Heat by End Use (kWh) Unit Level Savings

Usage Component	# Units	Pre-WAP Use	Post-WAP Use	Gross Savings	Net Savings	% of Pre
Total Use	1,556	4,740	4,425	315 (±103)	304 (±61)	6.4% (±1.3%)
Comparison	948	5,246	5,235	11 (±49)		
Heating/Winter Use	1,556	338	272	67 (±58)	26 (±38)	7.7% (±11.3%)
Comparison	948	510	469	40 (±13)		
Cooling/Summer Use	1,556	514	491	24 (±31)	47 (±46)	9.1% (±9.0%)
Comparison	948	444	467	-23 (±29)		
Baseload Use	1,556	3,887	3,662	225 (±23)	231 (±83)	5.9% (±2.1%)
Comparison	948	4,293	4,299	-6 (±95)		

Some multifamily housing units are in buildings with master-meter electric accounts for common areas. The study was not able to develop common area savings estimates. However, it is expected that additional saving accrued in many of these buildings from common area measures.

4.4 ENERGY SAVINGS BY WEATHERIZATION APPROACH, BUILDING SIZE, AND INSTALLED MEASURES

As discussed in Section 3.3 of this report, most of the multifamily housing units that received weatherization services fell into one of the following types: building weatherization with building-level heating equipment, building weatherization with unit-level heating equipment, and unit-level weatherization with unit-level heating equipment. It is important to consider whether these different approaches to weatherization result in different savings outcomes. Table 4.5 shows how estimated energy

savings vary by these factors. The savings were highest for buildings that were weatherized at the building level.

Table 4.5 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings for Natural Gas or Fuel Oil Main Heat by Weatherization Type/Heating Equipment Type (therms/year)

Weatherization and Heating Equipment Type	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Units	1.9	1,205	700	99 (±8)	14.2% (±1.2%)
Building WX and Heating Equipment	1.9	976	740	102 (±9)	13.8% (±1.2%)
Building WX and Unit Heating Equipment	1.6	168	532	97 (±21)	18.3% (±3.9%)
Unit WX and Heating Equipment	2.1	55	496	55 (±51)	11.2% (±10.2%)

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

Section 3 of this report also shows that installed measures vary considerably by the size of the building. Table 4.6 compares average energy savings by building size. It shows that the savings per unit for small multifamily buildings (25 units or less) were substantially higher than the savings per unit for large multifamily buildings (more than 25 units).

Table 4.6 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings for Natural Gas or Fuel Oil Main Heat by Building Size (therms/year)

Building Size	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Units	1.9	1,205	700	99 (±8)	14.2% (±1.2%)
Small Multifamily	2.0	429	699	137 (±15)	19.6% (±2.1%)
Large Multifamily	1.9	692	722	76 (±10)	10.5% (±1.3%)

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

WAP provides a customized set of measures for each building and housing unit 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 4.8, identified five major measures that appeared to drive a significant fraction of the observed gas and fuel oil savings: air sealing, attic/rooftop insulation, heating system replacement, water heating system replacement, and window replacement. Table 4.7 shows the differential savings by the number of major measures installed. In general, savings increased substantially as the number of major measures increased; units with one major measure only saved 61 therms of energy, while those with three major measures saved more than twice that amount.

Table 4.7 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Savings for Units with Natural Gas or Fuel Oil Main Heat By Number of Major Measures (therms/year)

Group/Breakout	# Units	Pre-WAP Use	Net Savings	% of Pre
No Major Measures	50	805	30 (±28)	4.6% (±4.2%)
Any One Major Measure	194	835	61 (±19)	7.4% (±8.8%)
Any Two Major Measures	371	627	108 (±15)	17.2% (±.2.3%)
Any Three Major Measures	141	779	136 (±23)	17.5% (±3.0%)
Four Major Measures or More	45	707	100 (±47)	14.2% (±6.7%)

4.5 ENERGY SAVINGS BY PRE-WEATHERIZATION USAGE LEVEL

Previous research has shown that housing units with higher levels of pre-weatherization usage get higher energy savings. This relationship may be driven in part by greater opportunities to install major measures in buildings with higher pre-participation energy use. Table 4.8 summarizes use and savings by level of pre-weatherization energy use. Energy savings increase significantly with pre-weatherization usage; buildings with units that average less than 500 therms per year saving less than one fifth of those that use 500 or more therms per year prior to weatherization. The buildings with more than 1,000 therms per unit in usage had lower savings than the buildings in the group with 750 to less than 1,000 therms. But, they also had fewer measures installed.

Table 4.8 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings for Natural Gas and Fuel Oil Main Heat by Pre-Weatherization Usage (therms/year)

Pre-WAP Use (therms/year)	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	1.9	1,205	700	99 (±8)	14.2% (±1.2%)
< 500 therms/yr	1.9	327	313	21 (±9)	6.6% (±2.9%)
500 -< 750	2.1	351	612	121 (±12)	19.8% (±1.9%)
750 -< 1,000	2.2	303	892	141 (±16)	15.8% (±1.8%)
>=1,000 therms/yr	1.4	224	1,143	124 (±24)	10.8% (±2.1%)

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

Table 4.9 shows electric savings by pre-weatherization electric usage level for housing units with gas or fuel oil main heat. The relationship between pre-weatherization electric usage and savings is not quite as linear as it is for gas and fuel oil usage and savings, but high-use housing units still achieve larger savings than those with low-use for most groups of housing units.

Table 4.9 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Electric Savings for Units with Natural Gas or Fuel Oil Main Heat by Pre-Weatherization Electric Use (kWh/year)

Pre-WAP Usage	Refrigerator Replacement %	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	31%	1,554	4,740	315 (±60)	6.6% (±1.3%)
<2,500 kWh/yr	27%	459	1,352	74 (±33)	5.4% (±2.4%)
2,500<5,000	35%	520	3,748	379 (±93)	10.1% (±2.5%)
5,000-<7,500	25%	364	6,258	504 (±118)	8.1% (±1.9%)
7,500-<10,000	45%	116	8,367	57 (±386)	0.7% (±4.6%)
>=10,000 kWh/yr	31%	95	16,211	868 (±400)	5.4% (±2.5%)

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

4.6 ENERGY SAVINGS BY SPENDING LEVEL

There are a number of important dimensions of program costs to be considered in the analysis of how energy savings relate to program spending, including:

- ECM Costs - The amount of spending on energy conservation measures (i.e., measures that are projected to have an SIR of greater than 1.0).
- Leveraged Spending - The share of spending contributed by non-DOE funding sources, including LIHEAP, utility programs, and building owners.
- Total Measure Costs - The total amount of spending on measures, including both energy conservation measures (ECMs) and health and safety measures.

Tables 4.10 through 4.12 furnish information on how energy savings vary by those factors.

Table 4.10 summarizes savings by the amount of spending on efficiency measures for each job. This cost breakout was available for about 62 percent of the cases in the analysis. The savings increase with increasing spending on ECMs – from 75 therms average savings when less than $2,000 was spent to 117 therms when more than $6,000 was spent. However, the spending appears to increase at a more rapid pace than savings.

Table 4.10 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (therms per year) for Natural Gas and Fuel Oil Main Heat by Efficiency Measure Cost

Efficiency Measure Costs	# Units	ECM Measure $/Unit	Pre-WAP Use	Net Savings	% of Pre
<$2,000	254	$1,088	607	75 (±19)	12.3% (±3.1%)
$2,000-<$4,000	344	$3,056	663	96 (±14)	14.4% (±2.1%)
$4,000-<$6,000	270	$5,067	808	99 (±17)	12.2% (±2.1%)
>=$6,000	106	$9,133	839	117 (±39)	13.9% (±4.6%)

Table 4.11 compares savings based on whether or not the job received non-DOE funds. The table also includes average spending on efficiency measures (ECM = energy conservation measure). Since in most

building owners were required to contribute to the weatherization project, only about 5 percent of jobs were funded by DOE funds only. Those jobs had higher savings, but they also had higher average spending.

Table 4.11 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (therms per year) for Natural Gas and Fuel Oil Main Heat by Funding Sources

Use of non-DOE Funds	# Units	ECM Measure $/Unit	Pre-WAP Use	Net Savings	% of Pre
Only DOE Funds	47	$5,865	743	146 (±58)	19.6% (±7.8%)
DOE & Non-DOE Funds	915	$3,592	699	90 (±9)	12.8% (±1.4%)

Table 4.12 shows a breakout of gas savings by total job costs (ECM + non-ECM measure costs). The lowest cost jobs (less than $2,000 per unit) had the lowest savings. But, higher spending per unit above $2,000 did not always result in higher savings.

Table 4.12 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (therms per year) for Natural Gas and Fuel Oil Main Heat by Total Job Cost

Total Job Cost	# Units	ECM Measure $/Unit	Pre-WAP Use	Net Savings	% of Pre
< $2,000	240	$1,003	601	69 (±20)	11.5% (±3.3%)
$2,000 -< $4,000	319	$2,878	662	101 (±14)	15.2% (±2.1%)
$4,000 -< $6,000	284	$4,776	781	92 (±16)	11.8% (±2.0%)
$6,000 -< $8,000	58	$6,366	775	121 (±52)	15.6% (±6.8%)
>= $8,000	61	$10,497	859	101 (±51)	11.7% (±5.9%)

4.7 ENERGY SAVINGS BY CLIMATE ZONE

The Climate Zones were defined to provide insight into how energy use and program savings vary due to climate. One might expect that gas and fuel oil usage and savings potential would be higher in the colder zones while electric usage and savings potential would be higher in warmer zones for housing units with air conditioning. Table 4.13 summarizes gas and fuel oil impacts for housing units with natural gas or fuel oil main heat by climate zone. The highest pre-weatherization usage and savings were observed for the Cold Climate Zone. Usage and savings was lower in the Very Cold Climate Zone; it is interesting to note that the savings percentage in the Very Cold and Cold Climate Zones were each about 14 percent of usage. Average savings were high and saving percent were very high for a relatively small sample in the Moderate and Hot/Humid Climate Zones.

Relatively few multifamily units with natural gas or fuel oil mail heat were available for analysis in the Moderate, Hot/Humid, and Hot/Dry Climate Zones. Data were missing for a large share of the sampled units in these Climate Zones for two reasons. First, some large subgrantees in those Climate Zones did not furnish the information needed for analysis. Second, a small number of large gas utilities in those Climate Zones did not furnish gas usage data. Because of the small sample size, it is not possible to ascertain whether the statistics presented in Table 10 are representative of the population of multifamily units treated by the WAP program in those Climate Zones in PY 2010 and 2011. However, the information is

useful; it shows that for a small sample of multifamily units in the Moderate and Hot/Humid Climate Zones, the program was successful in achieving relatively high percent savings.

Table 4.13 also shows the average number of installed major measures by Climate Zone. The Hot/Humid and Hot/Dry Climate Zones had similar pre-weatherization average usage. However, an average of 2.0 major measures were installed in each housing unit in the Hot/Humid Climate Zone and only 1.3 major measures were installed in each housing unit in the Hot/Dry Climate Zone. The energy savings were much higher in the Hot/Humid Climate Zone than in the Hot/Dry Climate Zone for the small sample of housing units.

Table 4.13 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (therms per year) for Natural Gas and Fuel Oil Main Heat by Climate Zone

Climate Zone	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	1.9	1,205	700	99 (±8)	14.2% (±1.2%)
Very Cold	2.4	120	515	71 (±22)	13.9% (±4.2%)
Cold	1.9	1,017	746	105 (±9)	13.9% (±1.2%)
Moderate	1.5	30	424	99 (±43)	23.3% (±10.1%)
Hot/Humid	2.0	16	304	95 (±35)	31.3% (±11.4%)
Hot/Dry	1.3	22	273	-3 (±39)	-1.0% (±14.2%)

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

Table 4.14 shows the gross and net electric impacts for gas and fuel oil heated housing units by Climate Zone. The highest usage and savings appear to be in the Moderate Climate Zone.

Table 4.14 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Electric Savings (kWh per year) for Natural Gas and Fuel Oil Main Heat by Climate Zone

Climate	Refrigerator Replacement %	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	31%	1,556	4,740	304 (±61)	6.4% (±1.3%)
Very Cold	22%	170	3,716	474 (±154)	12.8% (±4.3%)
Cold	31%	1,088	4,822	237 (±67)	4.9% (±1.4%)
Moderate	43%	58	4,485	653 (±531)	14.6% (±11.8%)
Hot/Humid	36%	185	5,394	349 (±355)	6.5% (±6.6%)
Hot/Dry	33%	55	4,330	50 (±368)	1.1% (±8.5%)

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

4.8 EXPLANATORY FACTORS ANALYSIS AND POPULATION SAVINGS ESTIMATES

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 as 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.

The gas and fuel oil savings results from the explanatory factors model are summarized in Table 4.15. Findings include:

- Air Sealing – Air sealing is estimated to have provided the largest fraction of program savings – an average of 29 therms per unit equal to 37 percent of total gas savings.

- Attic/Rooftop Insulation - Insulation is estimated to have the largest gas savings per installation at 56 therms, but contributed less to overall savings than air sealing because it was installed in only 36 percent of units.

- Heating System Replacement - Heating system replacement was installed in 32 percent of units and is estimated to have contributed 19 percent of total savings.

Overall, the gas explanatory factors model estimates that the program produced average annual natural gas savings of 79 therms – 20 therms less than the 99 therms net savings of the billing analysis sample. This reduction in savings reflects the differences in measure installation rates and locations between the sample and the program population.

Table 4.15 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Energy Savings (therms/year) by Measure for Natural Gas and Fuel Oil Main Heat

Measure	% of Units	Savings per installation	Contribution to Overall Savings	% of Total Savings
Air Sealing	62%	48	29	37%
Attic Insulation	36%	56	20	26%
Heater Replacement	32%	48	15	19%
Water Heating Replacement	13%	27	3	4%
Window Replacement	30%	33	10	12%
No Major Measures	10%	44	4	6%
Other/Unattributed	100%	-4	-4	-5%
Total			79	100%

The evaluation worked to develop an explanatory factors model for electric savings. However, two analysis problems made it difficult to develop a reliable model. First, some of the weatherization measures (e.g. air sealing and unit-level heating equipment replacement) have an impact on electric usage for air conditioning and space heating furnace fans. Second, since many subgrantees did not collect data on electric measures installed in individual units, it was difficult to develop a model that effectively allocates electric savings to specific measures. For that reason, estimated electric baseload savings are based on the Climate Zone averages shown in Table 4.14.

Table 4.16 shows the combined energy savings estimates for all multifamily housing units served by the program by main heating fuel. The largest number of multifamily housing units had natural gas main heat and were estimated to save 80 therms per unit in the first year after weatherization. The highest average savings were for housing units with fuel oil main heat, which were estimated to save 105 therms per unit in the first year after weatherization.

Table 4.16
PY 2010 WAP Energy Impacts for Multifamily Housing Units
Estimated Energy Savings for Housing Units Heated by Natural Gas and Delivered Fuels

Main Heating Fuel	# of Units	Heating Fuel Savings (therms/year)	Electric Savings (kWh/year)
Natural Gas	36,125	80	279
Fuel Oil	5,027	105	250
Propane	346	79	178
Other	520	49	213
Total	42,018	83	274

5. ENERGY IMPACTS FOR ELECTRIC MAIN HEAT BUILDINGS

The WAP evaluation directly measured electric usage for units in multifamily buildings 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 for important subgroups of the population. Statistics are presented by:

- End Use – The share of savings attributable to changes in heating, cooling, and baseload usage levels.
- Weatherization Approach and Equipment Type - Building level weatherization compared to unit level weatherization, with additional breakout of buildings with central heating equipment compared to those with heating equipment in each unit.
- Building Size - Differences in energy savings between small multifamily buildings and large multifamily buildings.
- Installed Measures – Differences in savings for groups of housing units 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.
- Expenditures and Leveraging – Variation in savings by levels of spending on efficiency measures, total job costs, job funding sources, and agency funding sources.
- Climate Zone - Differences in saving for units in each of the Climate Zones.

A further statistical analysis of explanatory factors related to observed energy savings was performed to estimate the energy savings attributable to individual program factors. The model developed by this analysis was used to extrapolate savings from the electric analysis sample to the population of electric main heat units in multifamily buildings served by the program.

5.1 METHODOLOGY

5.1.1 Analysis Procedures

The kWh savings analysis approach was a standard pre/post treatment/comparison design using weather-normalized billing data. The weather-normalization approach employed was similar to PRISM[7] and produces estimates of weather-adjusted annual energy consumption for each building or unit, depending on whether master-meter or unit-level data were available, based on monthly usage data and daily outdoor temperatures using a variable degree day base regression analysis. The Energy Impact Methodology Report contains details about the data cleaning procedures and analysis procedures.

Gross energy savings for each building or unit were calculated as the difference in the normalized annual consumption between the pre-treatment and post-treatment periods for buildings treated in PY 2010 and PY 2011. Buildings and units treated in PY 2011 were used as a Comparison Group for the PY 2010 analysis. Comparison Group usage was analyzed by subtracting one year from the actual treatment date to create pseudo pre-treatment and post-treatment periods after removing all actual post-treatment usage

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

data. Net program savings were then calculated as the average gross savings for participants minus the average savings (i.e., change in usage) found for the Comparison Group.

The results of the weather-normalization analysis were 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.

5.1.2 Sample Attrition

A total of 2,878 multifamily electric main heat housing units were sampled for analysis. Table 5.1 summarizes the disposition of this sample for the electric usage analysis. The data collection process was successful in obtaining savings data for 25 percent of the sampled housing units. There were a number of different sources of attrition:

- Subgrantee Response - In some states with a large number of multifamily housing units, there was substantial subgrantee non-response. This appeared to be a problem in states where there was a very large increase in funding during the ARRA period. For housing units served by those subgrantees, the energy company was unknown because the subgrantee did not furnish any information for the evaluation.

- Company Response - In some states with a large number of multifamily housing units, one or more major electric companies were unwilling to furnish information for the evaluation. For housing units served by those companies, there was no usage data for the evaluation.

- Other Issues - Among the remaining sources of attrition, the major problem was that units had an inadequate usage record. The electric usage analysis required a minimum of 270 days of data for both the pre-weatherization and post-weatherization periods, in addition to some other weather requirements. The data were insufficient for 22 percent of cases.

Data collection for multifamily housing units included some on-site data collection at agencies. When there was data for non-sampled buildings available at the agency, evaluation staff collected those data for use in the energy savings analysis. While the data for those buildings are not included in the ARRA multifamily energy saving statistics, they were useful in helping to develop the energy savings models.

Table 5.1
PY 2010 Multifamily Housing Units
Sample Attrition - Electric Main Heat

	Analysis Housing Units	
Attrition Reason	**Units**	**% of Sample**
Sampled	2,878	100%
Company Unknown / No Usage Data Available	1,534	53%
Insufficient Data / Poor Model Fit / Outlier	640	22%
Total Usable Sampled Cases	704	25%
Non-sampled Cases	3	-
Total Usable Cases	707	

5.2 KEY PROGRAM FACTORS FOR HOUSING UNITS WITH ELECTRIC MAIN HEAT

Table 5.2 summarizes information about climate, building characteristics, housing unit characteristics, and major measures for the full multifamily sample compared to multifamily units with electric main heat. The third column summarizes these same characteristics for the electric usage analysis samples. The table shows that electric main heat housing units were more likely to be located in the Hot/Humid Climate Zone and less likely to be in the Cold Climate Zone than other multifamily units. In addition, the tables show that the electric main heat housing units are less likely to be in buildings with more than 25 units, to unit level heating systems, and to be built after 1970.

Because of attrition, the electric main heat analysis sample has more housing units in the Cold Zones, slightly larger housing units, fewer heating and cooling equipment replacement measures, and more water heating and window replacement measures than the full population of electric main heat housing units. The impacts of these differences between the analysis sample and population are addressed in developing program population impact estimates in Section 5.8.

Table 5.2 Characteristics of Multifamily Housing Units for PY 2010

Characteristic	All Units	Electric Main Heat Housing Units	
		Electric Main Heat Population	Electric Main Heat Analysis Sample
Climate			
Very Cold	10%	12%	16%
Cold	47%	28%	50%
Moderate	13%	13%	15%
Hot/Humid	16%	32%	11%
Hot/Dry	14%	15%	9%
Building Characteristics			
% 5+ Stories	26%	11%	18%
% More than 25 Units	39%	27%	41%
Building Level Heating System	34%	3%	4%
% Built 1970 or Later	69%	92%	96%
Housing Unit Characteristics			
Mean Square Footage	825	761	802
% Central Heat	73%	41%	22%
% Electric Supplemental Heat	13%	20%	13%
% with Air Conditioning	75%	82%	78%
Major Measures			
Furnace/Boiler Replacement	33%	37%	25%
Water Heater Replacement	11%	9%	21%
Air Conditioning Replacement	16%	29%	14%
Attic Insulation	31%	23%	21%
Window Replacement	27%	21%	32%

Note: Results weighted by sample design selection probabilities.

5.3 ENERGY SAVINGS OVERALL AND BY END USE

Table 5.3 summarizes overall electric savings and savings separated into baseload, heating/winter, and cooling/summer usage. Net electricity savings averaged 810 kWh, equal to 10.9 percent of total pre-program usage. These percent savings are lower than the 14.2 percent found for housing units heated with gas or fuel oil, but much of this difference is due to the greater number of electric end uses that are not affected by WAP measures. The savings in the heating portion of electric use were estimated to average 13.2 percent, which is slightly less than the 14.9 percent heating savings found in gas and fuel oil heated housing units.

Table 5.3 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Gross and Net Electric Savings for Electric Main Heat by End Use (kWh/year) Unit Level Savings

Usage Component	# Units	Pre-WAP Use	Gross Savings	Net Savings	% of Pre
Total Use	707	7,402	864 (±100)	810 (±152)	10.9% (±2.1%)
Comparison	400	8,142	54 (±97)		
Heating/Winter Use	707	1,994	396 (±108)	263 (±177)	13.2% (±8.9%)
Comparison	400	2,769	132 (±137)		
Cooling/Summer Use	707	340	85 (±51)	31 (±86)	9.2% (±25.3%)
Comparison	400	375	54 (±69)		
Baseload Use	707	5,068	384 (±152)	516 (±244)	10.2% (±4.8%)
Comparison	400	4,999	-132 (±181)		

5.4 ENERGY SAVINGS BY WEATHERIZATION APPROACH, BUILDING SIZE, AND INSTALLED MEASURES

As discussed in Section 3.3 of this report, most of the multifamily housing units that received weatherization services fell into one of the following types: building weatherization with building-level heating equipment, building weatherization with unit-level heating equipment, and unit-level weatherization with unit-level heating equipment. It is important to consider whether these different approaches to weatherization result in different savings outcomes. Table 5.4 shows how estimated energy savings vary by these factors. The savings and percent savings for housing units with unit level weatherization and heating equipment were more than two times the savings for other types of housing units.

Table 5.4 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings for Electric Main Heat by Weatherization Type/Heating Equipment Type (kWh/year)

Weatherization and Heating Equipment Type	# Units	Pre-WAP Use	Net Savings	% of Pre
All Units	707	7,402	810 (±152)	10.9% (±2.1%)
Building WX and Heating Equipment	126	4,005	371 (±148)	9.3% (±3.7%)
Building WX and Unit Heating Equipment	357	7,808	587 (±219)	7.5% (±2.8%)
Unit WX and Heating Equipment	224	8,665	1,515 (±389)	17.5% (±4.5%)

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

Section 3 of this report also shows that installed measures vary considerably by the size of the building. Table 5.5 compares average energy savings by building size. It also shows the average savings for Individuals Units (IUs) for which the building size was not reported. It shows that the savings per unit for small multifamily buildings (25 units or less) were higher than the savings per unit for large multifamily buildings (more than 25 units). However, IUs with size unknown had much higher saving than the other building size categories.

Table 5.5 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings Electric Main Heat by Building Size (therms/year)

Building Size	# Units	Pre-WAP Use	Net Savings	% of Pre
All Units	707	7,402	810 (±152)	10.9% (±2.1%)
Small Multifamily	380	7,988	752 (±246)	9.4% (±3.1%)
Large Multifamily	241	5,830	569 (±154)	9.6% (±2.6%)
IUs (Size Unknown)	86	9,215	2,259 (±817)	24.5% (±8.9%)

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

WAP provides a customized set of measures for each building and housing unit prescribed by an energy auditor who follows the local program design and measure selection approach based on cost-effectiveness and health and safety requirements. Analyses for other building types and other main heating fuels have shown that increasing the number of major measures is associated with increases in the average saving per housing unit. That analysis could not be done for multifamily housing units with electric main heat because a large number of the sampled housing units were missing data on major measures.

5.5 ENERGY SAVINGS BY PRE-WEATHERIZATION USAGE LEVEL

Previous research has shown that housing units with higher levels of pre-weatherization usage get higher energy savings. This relationship may be driven in part by greater opportunities to install major measures in buildings with higher pre-participation energy use. Table 5.6 summarizes use and savings by level of pre-weatherization energy use. Energy savings increase significantly with pre-weatherization usage; housing units that use less than 5,000 kWh per year have savings less than one-half of the average, while housing units that use more than 10,000 kWh have savings almost twice the average.

Table 5.6 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings for Electric Main Heat by Pre-Weatherization Usage (kWh/year)

Pre-WAP Use	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	707	7,402	810 (±152)	10.9% (±2.1%)
< 5,000 kWh/yr	209	3,019	320 (±94)	10.6% (±3.1%)
5,000 -< 7,500	198	6,277	450 (±259)	7.2% (±4.1%)
7,500 -< 10,000	129	8,743	1,092 (±449)	12.5% (±5.1%)
>=10,000 kWh/yr	171	13,049	1,563 (±423)	12.0% (±3.2%)

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

5.6 ENERGY SAVINGS BY SPENDING LEVEL

There are a number of important dimensions of program costs to be considered in the analysis of how energy savings relate to program spending, including:

- ECM Costs - The amount of spending on energy conservation measures (i.e., measures that are projected to have an SIR of greater than 1.0).

- Total Measure Costs - The total amount of spending on measures, including both energy conservation measures (ECMs) and health and safety measures.

Table 5.7 summarizes savings by the amount of spending on efficiency measures for each job. This cost breakout was available for about 60 percent of the cases in the analysis. For the housing units with cost data, there does not appear to be a relationship between ECM spending and savings. The highest ECM spending group (i.e., more than $6,000 per unit) did have substantially higher savings than the other groups. But, that is a small sample of housing units.

Table 5.7 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (kWh per year) for Electric Main Heat by Efficiency Measure Cost

Efficiency Measure Costs	# Units	ECM Measure $/Unit	Pre-WAP Use	Net Savings	% of Pre
<$2,000	193	$1,037	6,329	728 (±218)	11.5% (±3.4%)
$2,000-<$4,000	133	$2,762	7,513	763 (±434)	10.2% (±5.8%)
$4,000-<$6,000	63	$4,983	7,044	378 (±514)	5.4% (±7.3%)
>=$6,000	32	$9,055	6,186	1,455 (±392)	23.5% (±6.3%)

Table 5.8 shows a breakout of savings by total job costs (ECM + non-ECM measure costs). For the housing units with cost data, there does not appear to be a relationship between total job costs and savings. The highest spending group (i.e., more than $8,000 per unit) did have substantially higher savings than the other groups. But, that is a small sample of housing units.

Table 5.8 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (kWh per year) for Electric Main Heat by Total Job Cost

Total Job Cost	# Units	ECM Measure $/Unit	Pre-WAP Use	Net Savings	% of Pre
< $2,000	202	$1,030	6,160	645 (±212)	10.5% (±3.4%)
$2,000 -< $4,000	146	$2,651	7,597	742 (±439)	9.8% (±5.8%)
$4,000 -< $6,000	69	$4,865	7,061	454 (±497)	6.4% (±7.0%)
$6,000 -< $8,000	22	$6,725	4,258	752 (±183)	17.7% (±4.3%)
>= $8,000	12	$12,743	10,175	2,855 (±890)	28.1% (±8.8%)

The analysis found that, among electric main heat housing units, almost all buildings were weatherized with at least some non-DOE funds. For that reason, there is no analysis of the difference between housing units that had leveraged funding and those that did not.

5.7 ENERGY SAVINGS BY CLIMATE ZONE

The Climate Zones were defined to provide insight into how energy use and program savings vary due to climate. Table 5.9 shows the average number of major measures, the average pre-weatherization usage, and the net savings for electric main heat housing units by Climate Zone. The highest average usage and average savings were observed in the Hot/Humid Climate Zone. The Moderate Climate Zone also had savings above the average.

The number of multifamily units with electric mail heat available for analysis in the Moderate, Hot/Humid, and Hot/Dry Climate Zones we modest. Data were missing for a large share of the sampled units in these Climate Zones for two reasons. First, some large subgrantees in those Climate Zones did not furnish the information needed for analysis. Second, a small number of large electric utilities in those Climate Zones did not furnish electric usage data. Because of the relatively small sample size, it is not possible to ascertain whether the statistics presented in Table 14 are representative of the population of multifamily units treated by the WAP program in those Climate Zones in PY 2010 and 2011. However, the information is useful; it shows that for a relatively small sample of multifamily units in the Moderate and Hot/Humid Climate Zones, the program was successful in achieving relatively high percent savings.

Table 5.9 PY 2010 and 2011 WAP Energy Impacts for Multifamily Housing Units Net Savings (kWh per year) for Electric Main Heat by Climate Zone

Climate Zone	# Major Measures	# Units	Pre-WAP Use	Net Savings	% of Pre
All Clients	1.9	707	7,402	810 (±152)	10.9% (±2.1%)
Very Cold	1.0	114	6,243	354 (±272)	5.7% (±4.4%)
Cold	1.7	368	7,203	705 (±181)	9.8% (±2.5%)
Moderate	2.7	85	8,315	1,071 (±557)	12.9% (±6.7%)
Hot/Humid	2.6	88	8,976	2,033 (±692)	22.7% (±7.7%)
Hot/Dry	2.4	52	7,191	439 (±968)	6.1% (±13.5%)

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

5.8 ESTIMATED ENERGY SAVINGS FOR ALL ELECTRIC HEATED UNITS

Similar to the approach described in Section 4.8, an explanatory factors model was also developed to assess electric savings in electric heated units. However, there were only a small number of sampled housing units that had sufficient information on installed measures to develop an effective model. The modeling did confirm that there were significant differences in energy savings by Climate Zone (See Table 5.9). The most significant factor in terms of energy savings was pre-weatherization usage; in the regression model, pre-weatherization usage was the single most important predictor of energy savings (See Table 5.6). However, pre-weatherization usage was not available for a large share of weatherized housing units. Applying climate zone factors to account for differences in attrition across Climate Zone, the analysis found that estimated savings for all multifamily housing units with electric heat were 1,065 kWh per unit for the first year after weatherization.

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

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

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

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

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

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

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

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

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

6.1 PRICE AND DISCOUNT RATE SCENARIOS

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

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

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

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

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

6.2 IMPACT ON PY 2010 CLIENTS

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

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

Table 6.1 summarizes the average energy costs and annual cost savings for the first year after participation in WAP in 2010 dollars.

Table 6.1 PY 2010 WAP Energy Impacts for Multifamily Housing Units Energy Costs and Cost Savings by Main Heating Fuel (2010 Dollars)

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$483	$604	$1,086	$72	$35	$107	9.9%
Electricity	$0	$884	$884	$0	$120	$120	13.5%
Fuel Oil	$1,503	$345	$1,848	$190	$42	$232	12.6%
Propane	$1,321	$435	$1,756	$216	$19	$235	13.4%
Other	$466	$585	$1,051	$46	$27	$74	7.0%
All Clients	**$377**	**$691**	**$1,068**	**$54**	**$68**	**$122**	**11.4%**

Participant annual energy costs averaged $1,068 prior to WAP, and WAP reduced these costs by an average of $122, equal to an 11.4% reduction in total energy costs. The energy costs and value of the

savings were almost twice as large in housing units heated by fuel oil or propane than they were in housing units heated by natural gas.

Table 6.2 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 $1,710 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spent an average of $2,818 on efficiency measures in these housing units, yielding a net benefit of negative $1,107 per unit and an SIR of 0.61. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.50 to 0.75. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 6.2 PY 2010 WAP Energy Impacts for Multifamily Housing Units Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Main Heating Fuel (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness			
Heating Fuel	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**	**SIR 90% c.i.**
Natural Gas	$1,351	$231	$1,582	$2,501	-$918	0.63	0.50 - 0.83
Electricity	-	$1,332	$1,332	$2,966	-$1,635	0.45	0.37 - 0.52
Fuel Oil	$4,263	$280	$4,542	$4,466	$77	1.02	0.72 - 1.43
Propane	$3,422	$133	$3,555	$3,073	$482	1.16	0.90 - 1.54
Other	$839	$178	$1,017	$1,264	-$247	0.80	0.66 - 0.99
All Clients	**$1,054**	**$656**	**$1,710**	**$2,818**	**-$1,107**	**0.61**	**0.50 - 0.75**

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

A number of factors, including differences in investment levels and heating fuel mix have an impact on the cost-effectiveness of the program by Climate Zone. Cost-effectiveness results by Climate Zone are summarized in Table 6.3. The Very Cold Climate Zone produced the highest SIR because it had the second lowest average spending on efficiency measures. The Moderate Climate Zone had the lowest SIR; this zone had higher than average expenditures per job, but lower than average savings.

Table 6.3 PY 2010 WAP Energy Impacts for Multifamily Housing Units Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Climate Zone (2010 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Climate	Fuel	Electric	Total	Measure Costs	Net Benefits	Savings/ Investment Ratio
Very Cold	$996	$358	$1,354	$1,624	-$269	0.83
Cold	$1,603	$370	$1,974	$3,000	-$1,026	0.66
Moderate	$387	$808	$1,195	$2,900	-$1,705	0.41
Hot/Humid	$334	$2,057	$2,391	$4,515	-$2,124	0.53
Hot/Dry	$345	$250	$595	$1,245	-$650	0.48

6.3 PY 2013 POLICY PERSPECTIVE

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

The following parameters are used in this analysis.

- First Year Energy Savings – Procedures are presented in Sections 4 and 5 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 6.4 summarizes the average energy costs and annual cost savings for the first year after participation in WAP in 2013 dollars.

Table 6.4 Projected PY 2013 WAP Energy Impacts for Multifamily Housing Units 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	$465	$599	$1,065	$69	$35	$104	9.8%
Electricity	$0	$863	$863	$0	$114	$114	13.2%
Fuel Oil	$1,860	$341	$2,201	$235	$42	$277	12.6%
Propane	$1,138	$453	$1,591	$186	$21	$208	13.0%
Other	$493	$584	$1,077	$49	$27	$76	7.1%
All Clients	**$393**	**$681**	**$1,074**	**$55**	**$66**	**$121**	**11.3%**

For PY 2013 participants, annual energy costs are expected to average $1,074 prior to WAP; it is projected that WAP would reduce these costs by an average of $121, equal to a 11.3% reduction in total energy costs. The energy costs and value of the savings are expected to be about two to three times as large in housing units heated by fuel oil or propane than in housing units heated by natural gas.

Table 6.5 summarizes the projected life-cycle energy cost savings, the cost of installing energy efficiency measures, and the cost-effectiveness for the national program by main heating fuel. Cost-effectiveness is summarized in two ways:

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

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

The table shows that a PY 2013 program would be expected to produce an average of $1,996 worth of energy bill savings over the lifetime of the measures (discounted to present value) and spend an average of $2,976 on efficiency measures in these housing units, yielding a net benefit of negative $980 per unit and an SIR of 0.67. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.55 to 0.84. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 6.5 Projected PY 2013 WAP Energy Impacts for Multifamily Housing Units 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	$1,607	$252	$1,859	$2,641	-$782	0.70	0.54 - 0.94
Electricity	-	$1,517	$1,517	$3,133	-$1,616	0.48	0.40 - 0.57
Fuel Oil	$5,107	$300	$5,407	$4,717	$690	1.15	0.80 - 1.62
Propane	$3,951	$146	$4,097	$3,246	$851	1.26	0.96 - 1.70
Other	$958	$193	$1,150	$1,335	-$185	0.86	0.71 - 1.07
All Clients	**$1,256**	**$740**	**$1,996**	**$2,976**	**-$980**	**0.67**	**0.55 - 0.84**

The projected SIR is greater than unity for oil and propane heated housing units 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.

6.4 LONGER-TERM POLICY PERSPECTIVE

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

For future participants, the first year savings are similar to those of the PY 2013 Policy Perspective. Annual energy costs are expected to average $1,074 prior to WAP, and it is projected that WAP would reduce these costs by an average of $121, equal to an 11.3% reduction in total energy costs.

Table 6.6 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 $1,642 worth of energy bill savings over the lifetime of the measures (discounted to 2013 dollars) and spend an average of $2,976 on efficiency measures in these housing units, yielding a net loss of $1,334 per unit and an SIR of 0.55. The significant uncertainties in future energy prices as well as in the energy savings and costs yields a 90% confidence interval that extends from 0.46 to 0.68. The uncertainty is not symmetric around the estimate due to the greater potential for energy cost increases vs. decreases.

Table 6.6 Projected Future WAP Energy Impacts for Multifamily Housing Units 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	$1,295	$224	$1,519	$2,641	-$1,123	0.58	0.45 - 0.75
Electricity	-	$1,277	$1,277	$3,133	-$1,857	0.41	0.34 - 0.47
Fuel Oil	$4,120	$268	$4,388	$4,717	-$329	0.93	0.66 - 1.29
Propane	$3,180	$130	$3,311	$3,246	$65	1.02	0.79 - 1.34
Other	$792	$172	$963	$1,335	-$372	0.72	0.60 - 0.88
All Clients	**$1,012**	**$630**	**$1,642**	**$2,976**	**-$1,334**	**0.55**	**0.46 - 0.68**

The projected SIR is greater than unity for oil and propane heated housing units 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.