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September 2014

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

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Environmental Sciences Division

WEATHERIZATION WORKS – SUMMARY OF FINDINGS FROM THE RETROSPECTIVE EVALUATION OF THE U.S. DEPARTMENT OF ENERGY'S WEATHERIZATION ASSISTANCE PROGRAM

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ACRONYMS AND ABBREVIATIONS

ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BPI	Building Performance Institute
CO2	Carbon dioxide
CO	Carbon monoxide
DOE	Department of Energy
ECM	Energy conservation measure
EPA	Environmental Protection Agency
F	Fahrenheit degrees
HERS	Home Energy Rating System
HHD	Household
HVAC	Heating, ventilation and air conditioning
IEQ	Indoor environmental quality
KWH	Kilowatt hours
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy & Environmental Design
LIHEAP	Low Income Home Energy Assistance Program
LMF	Large multifamily building
MH	Mobile home
MMBTU	Million British Thermal Units
NASCSP	National Association of State & Community Service Programs
NG	Natural gas
NCAF	National Community Action Foundation
NOAA	National Oceanic and Atmospheric Administration
NOX	Nitrogen oxide
NRC	National Research Council
NYC	New York City
O2	Oxygen
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OWIP	Office of Weatherization and Intergovernmental Programs
PIPP	Percentage of income payment program
PM	Particulate matter
pCi/l	Pico-Curies per liter
ppb	Parts per billion
ppm	Parts per million
PSU	Primary sampling unit
PUMA	Public Use Microdata Area
PY	Program Year
SERC	Sustainable Energy Resources for Consumers Program
SF	Single family
SIR	Savings-to-investment ratio
SMF	Small multifamily
SOx	Sulfur oxide
T&TA	Training and technical assistance
THERM	100,000 British Thermal Units
VOCS	Volatile organic compounds

WAP	Weatherization Assistance Program
WHO	World Health Organization

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Additional thanks are due to:

- The Grantees and Subgrantees that filled out the program implementation surveys
- The subset of Subgrantees that provided measure installation and utility information
- The utility companies that provided the billing histories
- The household members that participated in the national occupant survey
- The weatherization staff and trainees that participated in our surveys
- The survey specialists that patiently worked with all of the above to collect high quality data
- The numerous technicians that worked on the in-field IEQ, bulk fuels, ventilation, and performance study studies
- The weatherization experts and social scientists that went into the field to observe weatherization in action
- The local weatherization program staff and residents that contributed their time to the case studies effort

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EXECUTIVE SUMMARY

In April 2009, the U.S. Department of Energy (DOE) tasked Oak Ridge National Laboratory with conducting an evaluation of DOE's low-income Weatherization Assistance Program (WAP). This directive came at the same time that the American Recovery and Reinvestment Act of 2009 was passed. The Recovery Act boosted WAP's funding from approximately $225M per year to $5B over a three year period. It was decided at that time to evaluate WAP as it was administered both before and during the Recovery Act period. The former is known as the 'retrospective' evaluation of WAP and focuses on Program Year (PY) 2008. This report summarizes findings from the twenty individual studies that comprise the retrospective evaluation.[1]

Through WAP, DOE provides grants to states, territories, and Washington, DC (i.e. Grantees) to fund the weatherization of low-income homes. The Grantees provide grants to local weatherization agencies (also known as Subgrantees) to deliver weatherization services. Grantees and Subgrantees also leverage their DOE funds to acquire additional funds for low-income weatherization. Subgrantees accept applications for weatherization, confirm households' income eligibility for the program, conduct energy audits of the homes, install weatherization measures, and inspect each home post-weatherization. Common weatherization measures include: air sealing, wall and attic insulation, duct sealing, and furnace repair and replacement. The program operates across all climate zones in the United States, and weatherizes all manner of homes, from single family detached units to mobile homes to large multifamily buildings.

The retrospective evaluation concentrated on estimating program impacts (e.g., energy savings) and on assessing program administration. To accomplish these tasks, the retrospective evaluation collected a great deal of data, including:

- Housing characteristics and weatherization measures installed in ~20,000 single family and mobile homes
- Building characteristics and weatherization measures installed in ~10,000 multifamily building units and detailed data on over 100 large multifamily buildings weatherized in New York City
- Fuel type and basic occupant characteristics for ~20,000 homes
- Electricity and natural gas billing histories for ~8,000 weatherized and comparison homes collected from over 1000 natural gas and electric utilities
- Program implementation survey data from 50+ Grantees and ~900 Subgrantees
- Demographic, health-related, energy use behavior, and client satisfaction survey data from ~1400 households (treatment plus comparison group homes)
- Demographic and career-related survey data from ~600 weatherization auditors, crew leaders, crew members
- Indoor environmental quality data measurements (CO, radon, formaldehyde, humidity and temperature) pre- and post-weatherization for a national sample of ~500 treatment and control group homes and radon measurements post-weatherization in ~18 homes that received ventilation packages meeting ASHRAE 62.2 standards

[1] A similar summary report will be prepared for the Recovery Act Period WAP evaluation. All reports will be posted at http://weatherization.ornl.gov

- Detailed in-field observations of ~450 weatherization audits, measure installation processes, and final inspections conducted by 19 Subgrantees around the country

- In-field assessments of 105 homes weatherized in 2008 that appeared to save much more or much less energy than expected from modeling analyses

- Materials and interview notes to prepare 14 in-depth case studies of high-performing and unique local weatherization agencies

- Training experiences and career path expectations from a survey of over 800 individuals who received training at DOE weatherization training centers

In PY 2008, the impact component of the retrospective evaluation found that:

- Approximately 35 million households were eligible for WAP in PY 2008

- WAP funds supported the weatherization of 97,965 units in PY 2008: 59% single family site built, 18% mobile home, 5% small multifamily, and 18% large multifamily

- DOE expenditures on WAP were $236,000,000; including leveraged funding, the total expenditures on units weatherized were $481,000,000. The total spent by the national weatherization network in PY 2008 for weatherization was $850,000,000

- The average cost to weatherize a unit was $4,695 (the DOE share was 48%)

- WAP and leveraged expenditures supported directly and indirectly 8,500 jobs and increased national economic output by $1.2 billion

- The estimated first year program energy savings is 2,270,000 MMBtus.[2] This is equivalent to nearly 400,000 barrels of oil.

- Site built homes averaged 29.3 MMBtus of savings in the first year[3]

- Households appeared not to take-back energy savings post-weatherization

- Large variations in energy savings are more influenced by changes in occupant behaviors and changes in primary heating fuel and use of secondary heating sources than by work quality issues

- The net present value of the program energy cost savings in 2013 dollars is $420,000,000 and the net present value per unit weatherized is $4,890, $340,000,000 and $4243 in 2008 dollars.

- 78% of these savings accrued to households and 22% to rate payers of utilities that have Percentage of Income Payment Programs

- Carbon emissions were reduced by 2,246,000 metric tons[4]; criteria pollutants by 5,271 short tons

[2] This is a conservative estimate as it only includes about one-third of the units weatherized in large multifamily buildings in PY 2008, those in New York City.
[3] For comparison purposes, WAP saved an average of 17.6 MMBtus of energy in site built homes in PY 1989.
[4] This about the amount of carbon emitted by 600,000 average automobiles in the US.

- The net present value of the environmental emissions benefits is $252,000,000; the net present value per weatherized unit is $2,932; a water savings benefit is $186 per unit for a total benefit of $14,000,0000

- Weatherization effectively deals with CO issues found in homes, and increases formaldehyde in mobile homes and radon levels in site built homes located in high radon areas of the country

- Ventilation installed according to ASHRAE5 62.2 guidelines may reduce radon levels in weatherized homes

- The surveyed households reported that post-weatherization: their homes were less drafty: the general health of the household members improved; respondents suffered fewer asthma symptoms; their homes were less infested with pests; there were fewer instances of thermal stress; and respondents missed fewer days of work

- The present value of a limited set household health and home-related non-energy benefits for the WAP is approximately $1,137,000,000; the present value per single family and mobile home is $14,148

The process component of the evaluation found that:

- There is a richness and diversity in how local weatherization programs are organized and operated across the country, by crew (in-house vs. contractor), energy audits (computerized vs. priority lists), context (urban vs. rural impacts job scheduling)

- Weatherization is complex, involving over 100 different categories of work and over 800 different actions

- The national weatherization network offers a comprehensive set of training opportunities and certifications

- Weatherization work performed in the field is generally well done but there are opportunities to improve the technical aspects of the work and client energy education

- Successful local programs exhibit the characteristics of well-managed non-profit organizations with respect to mission, commitment, respect, quality, innovation, and resilience

- 94% of surveyed households were satisfied or very satisfied with the weatherization program

- Over 80% of auditors, crew chiefs, and crew members are satisfied or very satisfied with almost every aspect of their jobs

WAP faces numerous challenges and opportunities moving forward. The main challenges are related to maintaining and improving work quality, dealing with health and safety issues found in homes, and meeting the likely growing demand for program services over time. Major opportunities are related to increasing cooperation and leveraging relationships with the healthy homes and medical communities to achieve even higher levels of energy savings and non-energy benefits.

[5] American Society of Heating, Refrigerating and Air Conditioning Engineers

1. INTRODUCTION

This report presents a summary of the results from ORNL's retrospective evaluation of the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP). The retrospective evaluation focused mainly on WAP Program Year (PY) 2008, which covers the period from April 2008 to June 2009. The retrospective evaluation plan was developed during the 2005-2007 time period and the actual evaluation commenced in August 2009.[6] Energy savings, energy cost savings, non-energy benefit estimates, and program cost effectiveness were all based on data collected (e.g., energy bills) from the PY 2008 time period. Other analyses, such as a national occupant survey, field process study and case study interviews were conducted during PY's 2010, 2011, and 2012. These years fall within the Program's American Recovery and Reinvestment Act Period (alternatively referred to as the ARRA Period or the Recovery Act Period). A separate Recovery Act period evaluation is being conducted by ORNL.[7] It should be noted that the previous national evaluation of WAP addressed PY 1989.[8]

DOE's Weatherization Assistance Program provides grants to states (Grantees), and states provide grants to local weatherization agencies (Subgrantees) to weatherize homes occupied by income-eligible households. The program serves a very diverse client-base residing in a wide array of housing types located across a range of climate zones. DOE encourages states and local agencies to leverage WAP funding to secure additional funding for low-income weatherization. Section 2.0 describes WAP processes and administration in more detail.

The next three sections summarize findings from the impact, process, and case study components of the evaluation, respectively. Section 3 begins by summarizing energy savings attributable to WAP. Estimated energy savings are presented by housing type (single family, mobile home, multifamily), fuel type (natural gas, electricity, bulk fuels[9]), and climate zone. This section also presents estimated energy cost savings, non-energy benefits, and program cost-effectiveness. More detailed results and descriptions of the methodologies used to collect the data and estimate the results are contained in a separate set of reports, which are cited in footnotes throughout this report and are listed in the References Section 8.

Section 4.1 depicts a program that not only must address diversity with respect to clients, climates, house types and fuel types but also is quite complex technically. Section 4.2 describes the training provided by the national WAP network to take-on these complexities. Section 4.3 summarizes the results of a field process study that observed weatherization work on-site in the field. Section 4.4 presents the results of a study that revisited homes to assess their energy savings performance. Section 4.5 presents the results of a national indoor environmental quality study. The last segment of this section of the report presents descriptive statistics from surveys of clients and weatherization staff about their satisfaction with WAP.

Lastly, Section 5 depicts a program that is quite mission-driven at the local level. The retrospective evaluation went 'beyond the numbers' to conduct a set of case studies with Subgrantees around the country. This section presents a synthesis of how these agencies approach their missions and describes how the national weatherization network finds innovative ways to provide services to their clients.

The Program faces many issues and challenges as it moves forward. Three of these are addressed in Section 6: improving program operations, addressing health and safety issues, and integrating with the national healthy homes and medical communities. This section ends with a futures view of some of the

[6] The retrospective evaluation plan (Ternes et al. 2007) can be found at http://weatherization.ornl.gov
[7] The ARRA period evaluation plan (Tonn et al. 2011) can also be found at http://weatherization.ornl.gov.
[8] See Brown et al. 1993.
[9] "Bulk fuels" refers to fuels delivered to the home, such as fuel oil and propane.

challenges and opportunities surrounding low-income weatherization. Appendix A presents a summary of all of the information collection instruments utilized by this evaluation.

2. OVERVIEW OF THE WEATHERIZATION ASSISTANCE PROGRAM

This section presents an overview of the Weatherization Assistance Program. Section 2.1 describes how the program is implemented in the field. Section 2.2 addresses the eligible population that the program serves, from their various housing types to their essential demographics.

2.1 PROGRAM CHARACTERIZATION

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) 10CRF 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) To be eligible for the program in PY 2008, households had to meet one of two criteria: income at 150% of the federal poverty rate or income 60% or less of the state medium income.

As indicated in the introduction, DOE provides grants to Grantees (i.e., states, territories, District of Columbia, a small number of Tribes), and the states provide grants to their Subgrantees (e.g., local weatherization agencies) to do the actual weatherization work (~900 in PY 2008). A national weatherization network has evolved over the years. The National Association of State Community Services Programs (NASCSP) is the professional organization that provides support for the Grantees. NASCSP maintains the Weatherization Assistance Program Technical Assistance Center, which provides up-to-date information about WAP, such as formal program notices issued by DOE, as well as training and technical assistance information.[10] The National Community Action Foundation (NCAF) is the professional home for the traditional weatherization Subgrantees that operate as Community Action Agencies.[11]

It is common practice for states and agencies to leverage DOE WAP funds to acquire additional funds for weatherization from their states, regional utilities, and other sources.[12] During PY 2008, DOE's investment of approximately $236 million was leveraged to acquire an additional $614 million for low-income weatherization (See Figure 2.1), $460 million spenton DOE units.[13] Of this total, approximately 70% of the funds were spent on energy conservation measure installation, 10% on health and safety measures, 7% on audits and inspections, 12% on program management, and 1% on training and technical assistance.[14]

The magnitudes of leveraged resources and their sources differed across groups of Subgrantees. As illustrated in Figure 2.2, there are a relatively small number of Subgrantees that receive virtually no leveraged funds (see the first column). The column at the far right-hand side depicts about an equal number of Subgrantees that receive most of their funding from non-federal sources, such as states and

[10] See http://www.waptac.org
[11] See http://www.ncaf.org
[12] The results presented in this subsection were drawn from surveys of all Grantees (S1) and Subgrantees (S2) and data collected about a large sample of homes that were weatherized in PY 2008 (DF2/3). Please see Appendix A for more information on these information collection instruments, sampling and response rates.
[13] To be included in this study, at least $1 of DOE funds needed to be invested in the weatherized home. Homes weatherized with no DOE funds invested were determined to be beyond the purview of this DOE-funded evaluation.
[14] The evaluation team was not able to collect data from states or agencies to allow the estimation of what DOE funds paid for and what leveraged funds paid for overall or on a job-by-job basis.

utilities. The rest of the Subgrantees rely more or less on WAP and Low-Income Home Energy Assistance Program (LIHEAP) funding.[15]

LIHEAP is important to WAP in two ways. First, as indicated, LIHEAP is a source of weatherization funding. Under current regulations, states have the flexibility to allocate a small portion of their LIHEAP funds to their weatherization programs. The motivation is to use these funds to weatherize high-energy consuming low-income homes whose households appear to be suffering extreme energy burdens. Second, because of this motivation, the lists of LIHEAP recipients provide a steady stream of homes into the local weatherization programs. This is a very straightforward process because the majority of local weatherization agencies also administer LIHEAP in their communities.

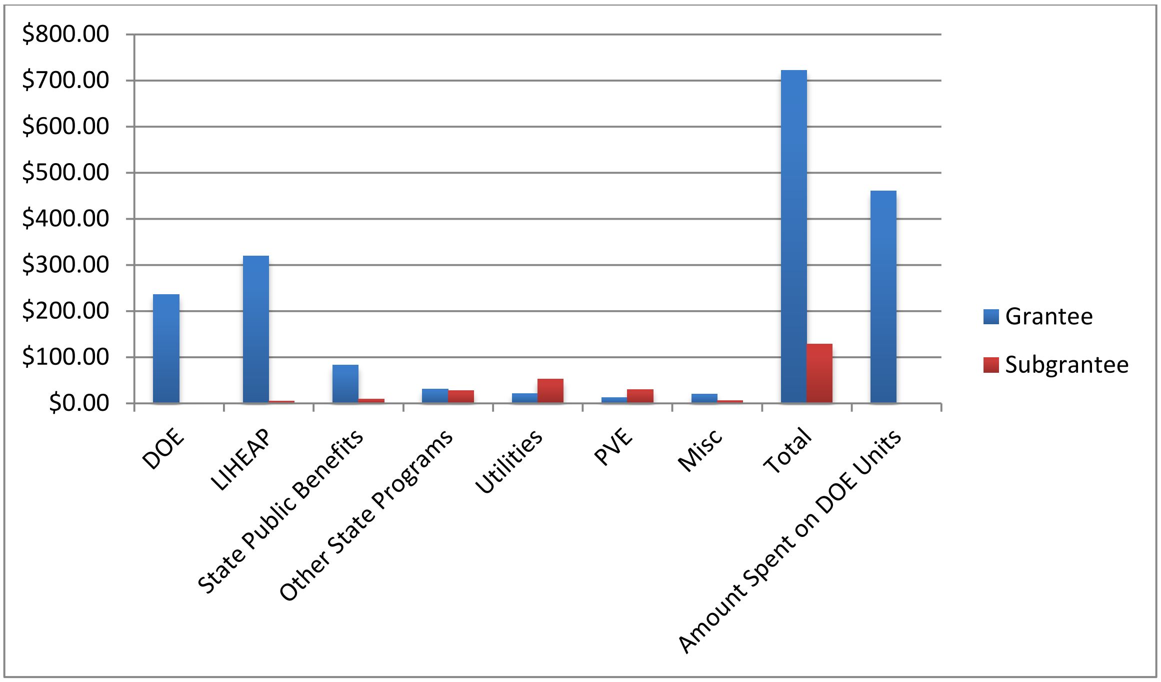
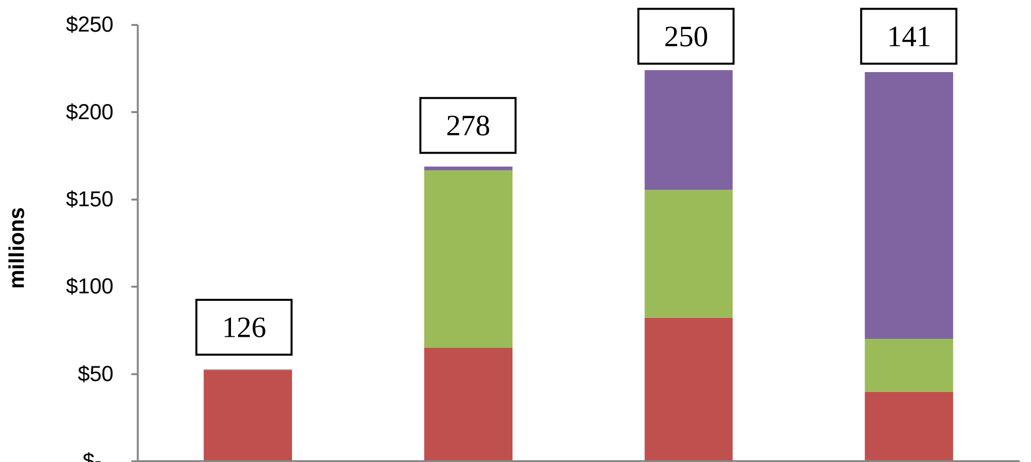


Figure 2.1. Funding Leveraged for Low-Income Weatherization in PY 2008 Given Directly to Grantees and Subgrantees (millions $)

[15] LIHEAP is a federal program that provides money to subsidize the payment of energy bills incurred by low-income households. http://www.acf.hhs.gov/programs/ocs/programs/liheap



	WAP dominated	WAP / LIHEAP dominated	WAP / LIHEAP majority	WAP / LIHEAP minority
Other $s	$280,616	$2,258	$68,704,958	$152,791,462
LIHEAP $s	$8,942	$101,655,449	$73,028,986	$30,378,723
DOE $s	$52,445,473	$65,006,409	$82,341,899	$39,855,923

Figure 2.2. Leveraging Patterns Among Local Weatherization Agencies (PY 2008)[16]

Thus, many households are referred to their local weatherization programs through LIHEAP referrals and referrals from other community service programs. Word-of-mouth about weatherization is also exceptionally strong.[17] As a result, most local weatherization agencies did not have to market their programs in PY 2008. In fact, the substantial majority of agencies had waiting lists for weatherization services that extended many months and in some cases, years into the future.

"The two small kids that live in this house had to sleep in the bedroom with their parents, but after weatherization, they are now back in the kids' room." *St. Johns Housing Partnership weatherization client*.

Prior to weatherization, all homes receive an energy audit to determine what measures should be installed in each specific home. Energy auditors use DOE approved computerized audits (33%), priority lists (53%), or both (12%). The priority lists allow Subgrantees to install measures that are known to be generally cost-effective without having to conduct computerized audits for every home. Auditors employ a range of diagnostic tests to support their assessments. The most common diagnostic measure is the blower door test. Essentially, a large fan is attached to an outside door and the home is depressurized. The test indicates how airtight a home is and can also indicate the sources of major air leaks throughout the home. Other common diagnostics include carbon monoxide measurements in flues of space and water heating systems.

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[16] The results presented in this figure are based on survey responses from 795 out of 900 Subgrantees. Thus, the average leveraged funds reported may differ slightly from the results presented in Figure 2.1.

[17] See Recovery Act Evaluation report Rose et al. (2015b) for a description of word-of-mouth communication in the social networks of program recipients.

In general, each installed measure needs to pass a Savings-to-Investment Ratio (SIR) test, where the present value of the energy cost savings over the life of the measure (e.g., 20 years) needs to exceed the present value of its cost (i.e., SIR >= 1.0). Additionally, during PY 2008, states and agencies were constrained to spend an average of $2966 of DOE funds per weatherized home. Lastly, the local programs were allowed to invest a small amount of money to deal with health and safety issues found in homes (typically around 15% of funds invested in a weatherized unit). It is common for agencies to encounter homes that are in such poor physical condition structurally that weatherization would have virtually no impact on energy consumption or simply cannot be installed. It is also common to encounter homes whose conditions pose health and safety risks to agency staff. In the cases where the agency does not have the resources to help the households with rectifying these types of problems, weatherization is deferred. The homes can re-enter the weatherization queue once the household has addressed the reason(s) for the deferral.[18]

After the audit is complete, the agency implements its weatherization model. There are two dominant models. In the first, agencies use in-house crews to do the weatherization work. In the other, agencies hire private-sector contractors. Most agencies that use in-house crews contract out for heating and cooling system repair and replacement work. Most agencies that use contractors use in-house staff to conduct the audits. After weatherization work is completed, the agencies are required to inspect all weatherized homes. To address conflict-of-interest issues, whenever possible inspectors do not inspect homes they had initially audited.[19] It should be noted that state weatherization staff and DOE Project Officers also inspect a sample of weatherized homes. Figure 2.4 graphically depicts the weatherization process.

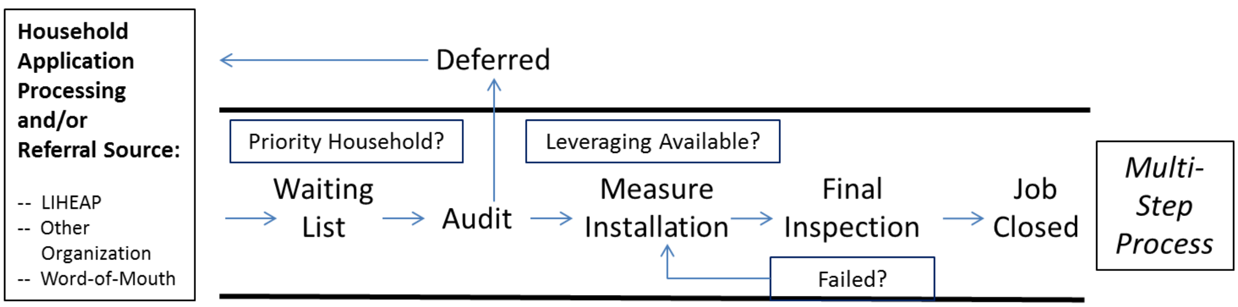


Figure 2.3. The Weatherization Process

2.2 CHARACTERIZATION OF HOMES WEATHERIZED IN PY2008

Over the years, WAP has supported the weatherization of over six million homes, with over one million homes weatherized during the Recovery Act period. In PY 2008, WAP supported the weatherization of almost 98 thousand units: 59% of these were single family, site built, detached homes (SF), 18% mobile homes (MH), with the balance being units in small multifamily (SMF) (5%) and large multifamily buildings (LMF) (18%).

One quarter of the weatherized units are found in very cold climates, and 42% in cold climates. Only 12% of the units weatherized in PY 2008 fell into the hot dry or hot humid climate zones (see Figure 2.4 for the climate zone designations used in this research). The dominant fuel for space heating for the weatherized single family homes was natural gas (60%), followed by bulk fuels (26%) and electricity (14%). Well over one-half of the homes weatherized were built before 1980. A large majority of the units weatherized were owner-occupied: e.g., 91% of single family and 92% of mobile homes. Figure 2.5

[18] For more on deferrals, see Recovery Act Evaluation report Rose et al. (2015c).
[19] This is often difficult to avoid in very small programs.

indicates the frequency of measures installed in homes in PY 2008, with air sealing and insulation measures leading the way.[20]

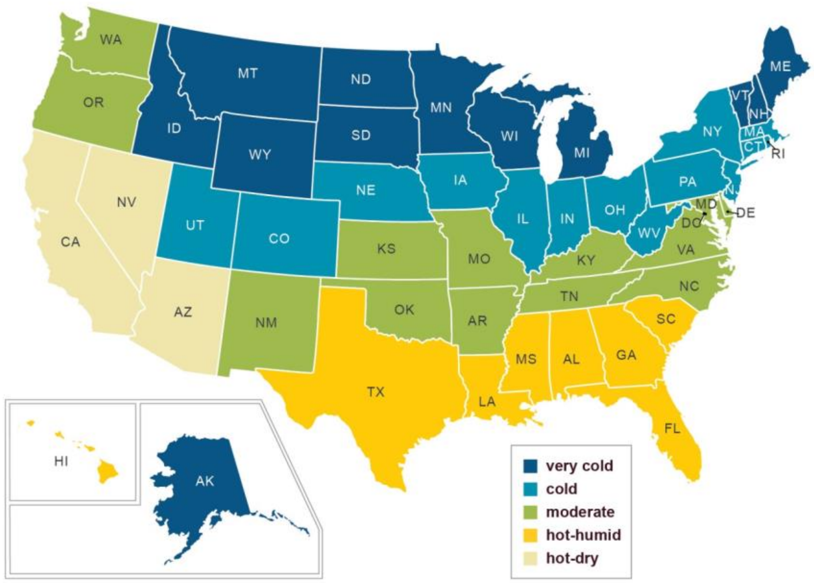


Figure 2.4. Climate Zone Designations

[20] These and other program characterization statistics can be found in Retrospective Evaluation report Bensch et al. (2014).

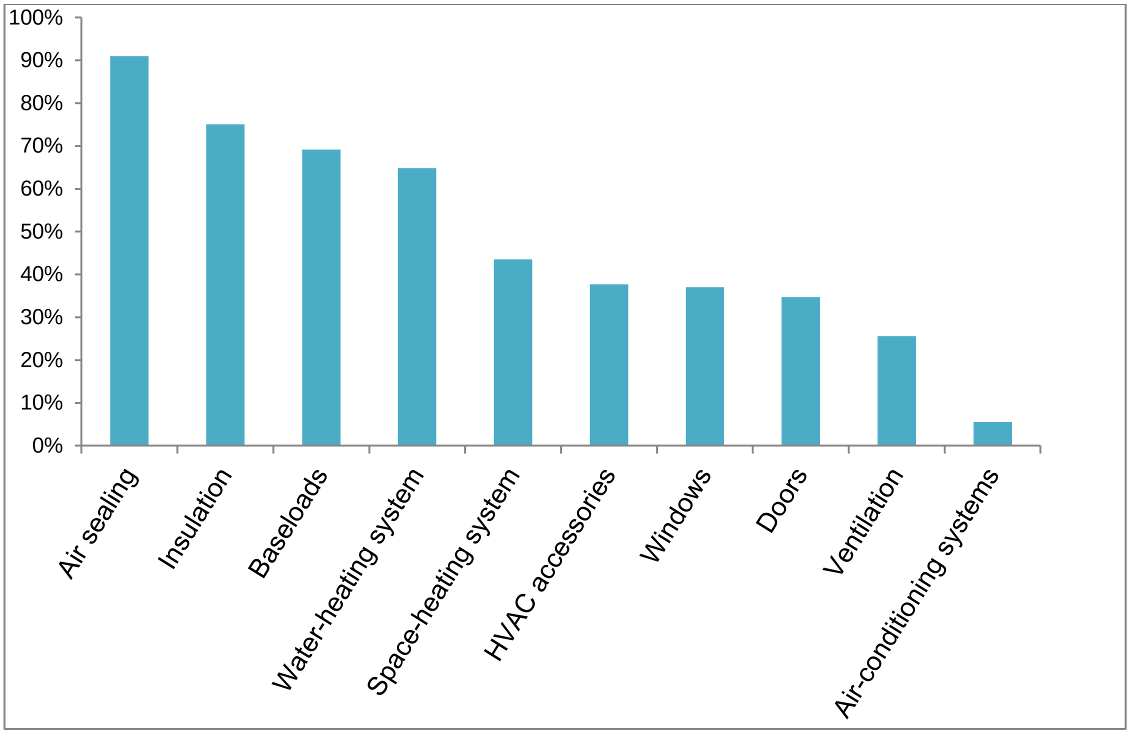


Figure 2.5. Frequency of Measures Installed in Homes in PY2008

2.3 CHARACTERIZATION OF CLIENTS IN PY2008

Overall, in PY 2008, 35 million households were eligible for the WAP program, or ~30% of all U.S. households.[21] In many ways, the population eligible for WAP is quite different demographically from the non-low-income population. Specifically, WAP-eligible households are more likely to:

- Be elderly
- Have a person with a disability present in the home
- Have a child <= 5 years of age
- Be a single parent household
- Be less healthy
- Live in mobile homes

As part of the retrospective evaluation, an extensive survey was administered to a nationally representative, random sample of households that were weatherized in calendar year 2011[22]. A demographic analysis of these households indicates that most of the households fall into one of these three descriptions:

[21] See the Retrospective Evaluation Eligible Population report Carroll et al. (2014d) for a complete discussion of the population eligible for WAP.
[22] See Retrospective Evaluation Occupant Survey – Baseline Results report (Carroll et al. 2014a).

- Household headed by a single female middle-aged parent with health issues who is also likely to be unemployed (~44% of households fall into this general group)

- Single person household headed by an elderly, relatively healthy, retired female (~31%)

- Household composed of a young married couple with children with health issues whose head of household is likely to be employed (~25%)

2.3 SUMMARY

DOE's Weatherization Assistance Program operates in all 50 states plus the District of Columbia and several U.S. territories. Weatherization is accomplished by over 900 Subgrantees. WAP provides the technical framework and training resources to guide low-income weatherization using DOE funds and a large pool of leveraged funds. The program operates in a range of climate zones and encompasses numerous housing types and heating fuels. Compared to the average U.S. household, the households that WAP serves are more likely to be: elderly, have a disabled person, have a young child, be a single parent household, and be less healthy.

3. ENERGY SAVINGS, NON-ENERGY BENEFITS AND COST EFFECTIVENESS

This section of the report describes quantitatively the impacts attributable to WAP. Section 3.1 presents estimates of energy savings attributable to WAP. Data collected as part of a national assessment of the impacts of weatherization on indoor environmental quality (IEQ) indicate that households did not increase their indoor air temperatures post-weatherization, and therefore did not increase their heating energy consumption post-weatherization (Section. 3.2). As such, they accrued maximum energy-cost savings (Section 3.3). Environmental, economic, and health-related non-energy benefits attributable to WAP are presented in Section 3.4. Overall cost-effectiveness estimates of WAP from several perspectives are presented in Section 3.5.

3.1 ENERGY SAVINGS

A major task of the retrospective evaluation was the estimation of energy savings attributable to WAP. Three approaches were followed to estimate energy savings. For single-family attached or detached (SF) units and mobile homes (MH) that were heated using natural gas (NG) or electricity, utility bills were collected for the period of one-year pre-weatherization through one-year post-weatherization. Bills for comparison group homes (i.e., homes weatherized in the following PY) were collected for the same time period. Utility bills were also collected for units located in small multifamily buildings (SMF) that were individually weatherized (i.e., these units typically had their own heating and hot water systems and not all units in the building need to have been weatherized). Well established and industry accepted techniques were used to weather normalize the data and then to estimate energy savings for each home in the sample.[23]

To build a sample of these households, 400 of the approximately 900 Subgrantees operating in PY 2008 were randomly selected to participate in this part of the evaluation. Each of the 400 Subgrantees was asked to provide lists of homes weatherized during PYs 2007, 2008 and PY 2009. One-third of the homes on each list were randomly selected to be in the sample. For these homes, agencies were asked to provide utility billing account numbers for the entire sample and information on measures installed in the homes only for those homes weatherized in PY 2008.[24] The project team ended up contacting over 1300 natural gas and electricity companies for billing histories.

A significant number of homes heat with bulk fuels, such as fuel oil, kerosene and propane. Bills are typically not available or reliable enough to use to estimate changes in fuel consumption for bulk fuels for single family and mobile homes. Therefore, the retrospective evaluation implemented a field study to directly measure fuel oil consumption pre- and post-weatherization (specifically by measuring actual heating system run times). These results were generalized to the WAP population of homes that heat with fuel oil.[25]

Lastly, a special study was conducted to estimate energy savings in weatherized large multifamily buildings (LMF). The challenge with these buildings is that in some buildings heating and hot water is supplied centrally and in others individual units have their own heating and hot water systems. With respect to the former, energy bills are building-level and audits and energy savings are also viewed from the building-level perspective. In either case, evaluating energy savings in large multifamily buildings can be expensive and time-consuming. For the retrospective evaluation, it was decided that it was most cost

[23] These methods generally fall within the rubric of the Princeton Scorekeeping Method (PRISM). http://www.marean.mycpanel.princeton.edu/~marean/

[24] It is very time consuming for the agencies to provide the measure installation information, so it was requested for just one program year.

[25] It was assumed that heating system efficiencies for kerosene and propane were equivalent to those of natural gas.

and time efficient to focus on collecting building-level energy bills for large multifamily buildings weatherized in New York City (NYC).[26]

Table 3.1 presents the total estimated energy savings (heating fuel and electricity source) by housing type in millions of British thermal units (MMBtus).[27] The total savings of just over 2 trillion Btus saved is equivalent to almost 400 thousand barrels of oil.[28] The estimate of 29.3 MMBtus average savings for site built homes (which includes small multifamily in this table) is consistent with expected energy savings for this house type.

Table 3.1. Total Estimated Annual Energy Savings by Housing Type PY 2008

	Total MMBtus Saved	**MMBtus Saved / Unit**
Site Built (1-4 units)*	1,840,000	29.3
Mobile Homes	284,000	16.0
Large Multifamily (NYC only)	144,000	26.9
Total	**2,268,000**	

* Includes single family and small multifamily

Figure 3.1 presents energy savings estimates by house type, climate zone, and main heating fuel (natural gas or electricity). Nationally, for the most common housing type (single family), and the most common heating fuel (natural gas), it is estimated that the average home reduced its natural gas consumption by 17.8% post-weatherization. These same homes reduced their electricity consumption by 7.1%. Nationally, savings in small multifamily buildings were, on average, comparable to those for SF homes. Energy savings in mobile home are less than the other two housing types. Percent savings among electrically heated homes is lower because there are fewer opportunities to improve the efficiency of electric heating systems either through repair or replacement. The total MMBtus saved by the program is an underestimate because only approximately one-third of the units weatherized in large multifamily buildings (those in New York City) were included in this analysis.

[26] In this time period, NYC accounted for approximately one-third of all large multifamily building units weatherized in the United States.
[27] More comprehensive energy savings results for each housing type for PYs 2007, 2008 and 2009 and in-depth descriptions of the sampling and statistical methodologies for the SF, MH, SMF and LMF homes, please see Retrospective Evaluation reports Blasnik et al. (2014a, 2014b, 2014c and 2014d), respectively.
[28] For additional context, the US consumed almost 100 quadrillion of Btus in 2008, with about one-quarter consumed in the residential sector.

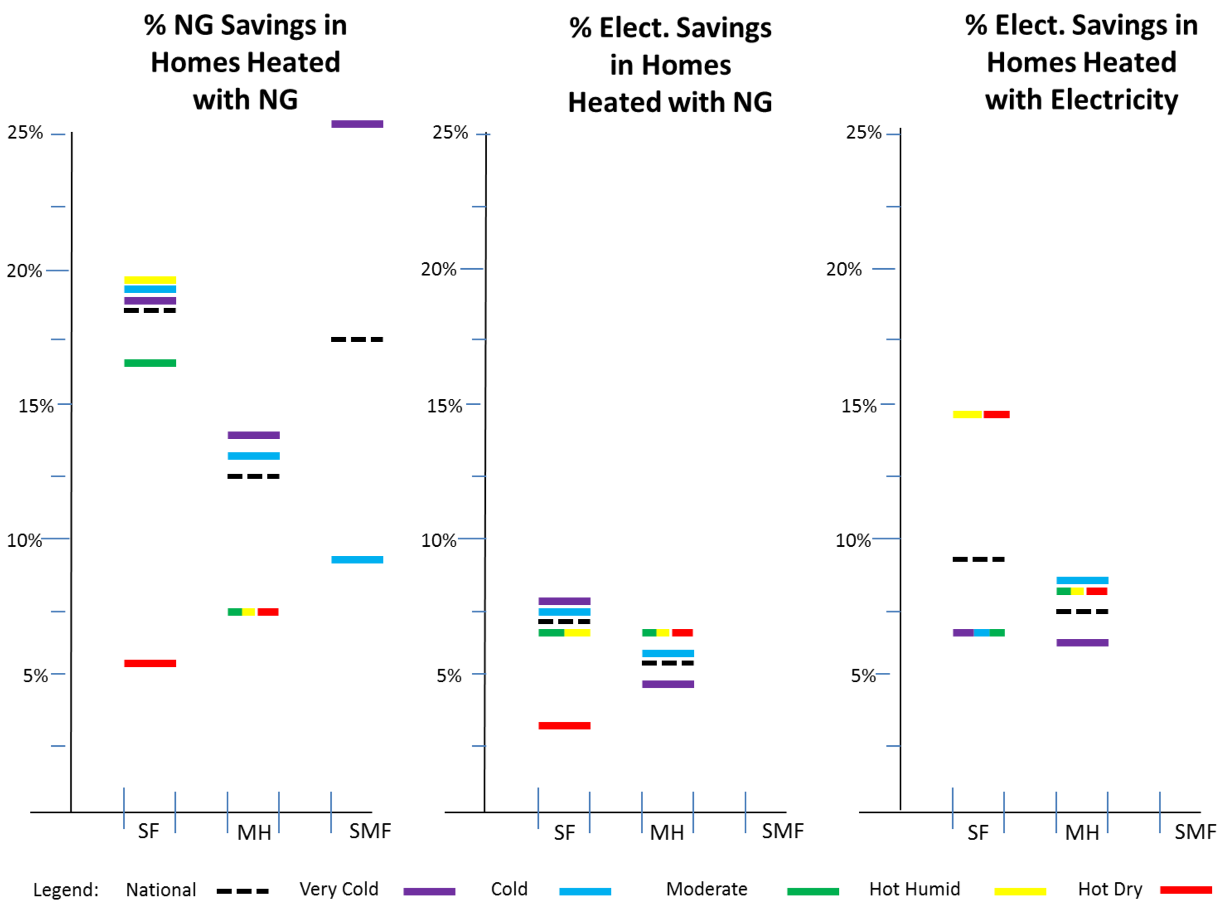


Figure 3.1. Average Percent Energy Savings by Home Type (Single Family, Mobile Home, Small Multifamily), Climate Zone, and Heating Fuel Type for PY 2008

Table 3.2 provides some historical perspectives about these results as compared to results from the PY 1989 evaluation of WAP.[29] It is important to note that over time, natural gas consumed by homes in the program prior to weatherization has dropped considerably from the late 1980s. This is due primarily to the increasing penetration of higher-efficiency furnaces and water heaters in U.S. homes over time as older equipment fails and is replaced. On the other hand, electricity use has increased, as computers and various consumer electronics are finding their ways into all households in the U.S. Despite reduced opportunities for energy savings in the typical home entering the WAP system, the program has effectively increased its percent level of energy savings, though has not increased its per unit energy savings appreciably.

Table 3.2. Comparison of PY2008 Energy Savings to Historical PY 1989 Energy Savings for Single Family Homes

Heating Fuel Type	Pre-Wx Fuel Use: PY 2008	Net Savings: PY 2008	Net Savings: PY 2008 %	Pre-Wx Fuel Use: PY 1989	Net Savings: PY 1989	Net Savings: PY 1989 %
Natural Gas	1020 therms	182	17.8%	1340 therms	174	13.0%
Electricity	19994 kWh	1799 kWh	9.0%	14972 kWh	1826 kWh	12.2%

[29] Brown, Berry and Kinney 1994.

The next table, Table 3.3, provides some insights into the impacts that various measures have on total energy savings. Derived from regression models, the results indicate the overall percentage of average natural gas savings in natural gas heated homes that are attributable to the set of the most common measures installed. For single family homes, air sealing accounts for 28% of the total energy savings, followed by attic and wall insulation and heater replacement. Air sealing and duct sealing are the most influential measures installed in mobile homes. The measures most effective at saving energy are also the most frequently installed measures: air sealing and insulation (see Figure 2.5).[30]

Table 3.3. Percent Total Energy Savings Natural Gas Heated Homes by Measure

	SF	**MH**
Air Sealing	28	45
Duct Sealing	4	20
Heater Replacement	15	15
Floor Insulation	1	12
Attic Insulation	24	9
Setback Thermostat	2	--
Floor Insulation	--	--
Ventilation	-1	--
Wall Insulation	15	--
Other/unattributed	14	0

Figure 3.2 indicates that homes that receive multiple major measures[31] save substantially more energy than homes that receive no major measures (e.g., 33.9% versus 6.8% for site built (SB) homes heated with natural gas).[32] Also as expected, energy savings per major measure are less for SB homes that heat with electricity and mobile homes.

[30] Though this project was not able to measure refrigerator replacement energy savings directly, the Recovery Act Evaluation report by Tonn and Goeltz (2015) presents some descriptive statistics of refrigerators encountered by the project team during the Indoor Environmental Quality study.
[31] Major heating-related measures are generally considered to be: attic insulation, wall insulation, heating system replacement and substantial reduction in air leakage, as measured by pre- and post-weatherization blower-door tests.
[32] It should be noted that it is not unexpected that the number and types of major measures installed in homes will vary considerably. Agencies do not know prior to the completion of energy audits what measures any particular home will need and what measures will also pass the SIR test. Also, at times, agencies will invest more than the average amount in a home (i.e., install more measures) to best address a household's and home's needs. This necessarily means that investments in other homes will be less than average and these homes will on average receive fewer major measures.

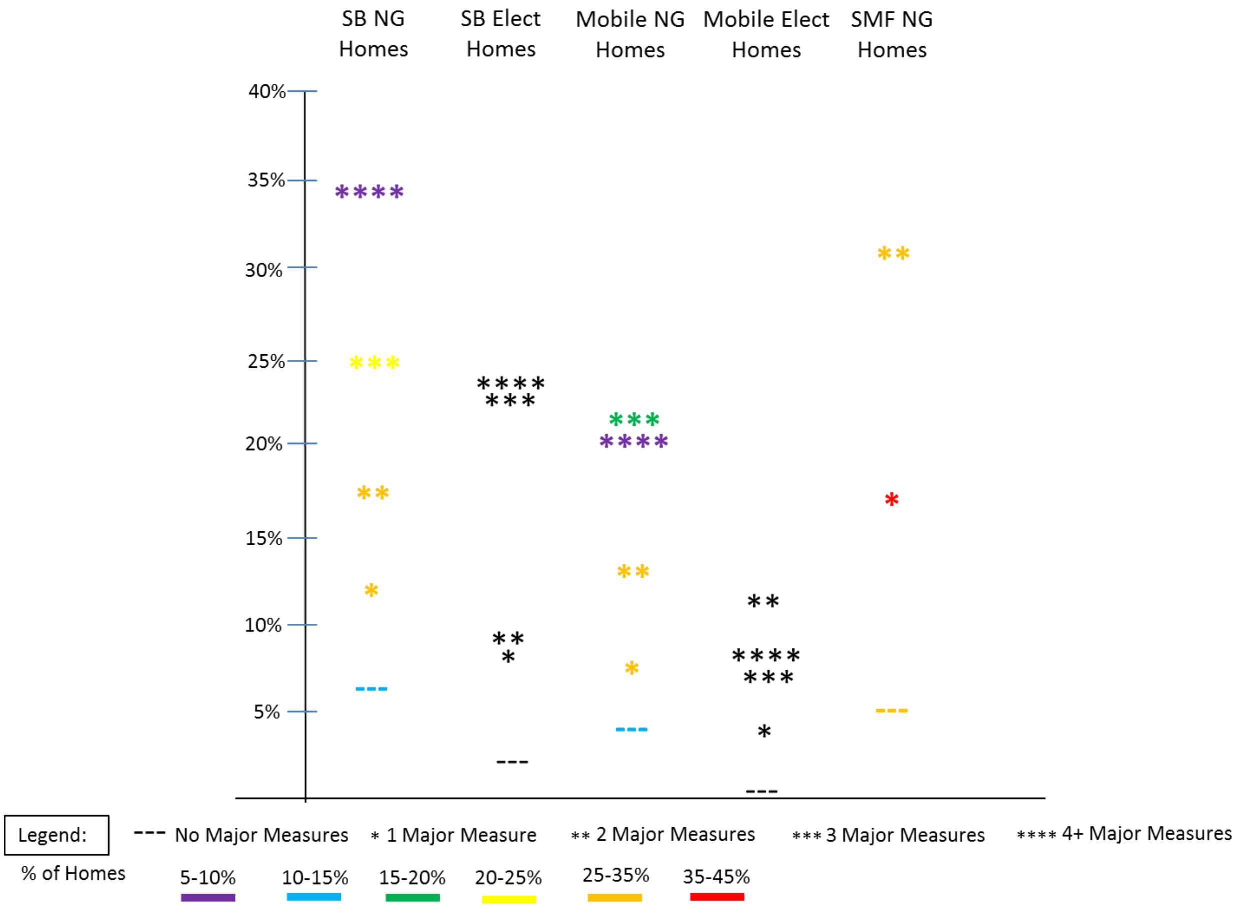


Figure 3.2. Average Percent Energy Savings by Number of Major Measures Installed by Home and Heating Fuel Type for PY 2008

Concluding this subsection, Table 3.4 presents a summary of energy savings in large multifamily (LMF) buildings weatherized during this period. The results indicate substantial energy savings in NYC buildings that are centrally heated with natural gas or fuel oil. Heating fuel savings were largely attributable to central boiler replacements. Electricity savings were largely attributable to light and refrigerator replacements.

Table 3.4. Average Percent Energy Savings in LMF Buildings in New York City

	Heating Fuel Savings	Electricity Savings
Natural Gas Heated	12.4	N/A
Fuel Oil Heated	24.0	N/A
Common Areas Electricity	N/A	6.7
Unit Level Electricity	N/A	23.2

3.2 NO REBOUND EFFECT

A frequent criticism of energy-efficiency programs is that gains made in improving energy efficiency have the potential to be partially or largely offset by corresponding increases in energy consumption. In other words, energy consumption could rebound towards the pre-retrofit levels of energy consumption. This is also referred to as the “take-back” effect.

The retrospective evaluation studied this issue through the Indoor Environmental Quality (IEQ) study (see Section 4.5 for a more detailed description of the study). As part of this study, indoor temperature data for the study homes were obtained from data loggers that were hung from the central thermostat for about one month preceding and following weatherization during closed-home conditions. Indoor temperature was also measured in a set of control homes located in the same local weatherization agency jurisdictions who agreed to have their weatherization delayed for the duration of the study. The temperature data for homes monitored during the heating season showed that:

- Wintertime indoor temperatures in program homes average 70.3 ± 0.5^{o}F, but range from less than 60F to more than 80F.

- The temperature increased post-weatherization in the weatherized homes by 0.14^{o}F and decreased in the comparison homes by 0.13^{o}F, resulting in an estimated increase of 0.27^{o}F.

Thus, for this sample of homes and the time period encompassed by the data collection, one can conclude that there was essentially no rebound effect related to home heating. This means that almost all of the energy cost savings derivable from weatherization were available to these households to spend on non-energy related needs. These findings are consistent those from previous research.[33]

3.3 ENERGY COST SAVINGS

This section presents estimates for energy cost savings attributable to WAP. Tables 3.5 and 3.6 present energy savings estimates for single family site built and mobile homes, respectively, by heating fuel type. The annual first year energy cost estimates were calculated based on what households would have paid for energy one-year post-weatherization had they not been weatherized and multiplying by the average projected price per unit for each state for 2013. Energy prices by fuel type were based upon state-level data provided by the U.S. Energy Information Administration. Overall, energy cost savings average 11.9% for site-built homes[34], or about $264 per year. Savings are considerably higher for fuel oil and propane, which are higher-priced heating fuels per MMBtu. Though annual first year energy costs for mobile homes are comparable, cost savings from the program are lower.

Table 3.5. Single Family Site-Built Homes-Energy Costs and Cost Savings by Main Heating Fuel (2013 Dollars)

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$799	$1,102	$1,901	$142	$65	$208	11.5%
Electricity	-	$1,852	$1,852	-	$192	$192	10.3%
Fuel Oil	$2,606	$1,156	$3,762	$430	$68	$497	13.2%
Propane	$1,968	$1,062	$3,030	$326	$74	$399	13.2%
Other	$925	$967	$1,892	$153	$64	$217	11.5%
All Clients	**$1,027**	**$1,182**	**$2,209**	**$175**	**$88**	**$264**	**11.9%**

[33] For example, see Levins and Ternes (1994) and Greening, Greene, and Difigilo (2000).
[34] To distinguish from mobile homes.

Table 3.6. Mobile Homes-Energy Costs and Cost Savings by Main Heating Fuel (2013 Dollars)

	Annual Energy Costs			Annual Savings (first year)			
Heating Fuel	**Fuel**	**Electric**	**Total$**	**Fuel**	**Electric**	**Total$**	**% Savings**
Natural Gas	$632	$952	$1,584	$77	$37	$115	7.2%
Electricity	-	$2,159	$2,159	-	$145	$145	6.7%
Fuel Oil	$2,066	$1,321	$3,387	$261	$40	$301	8.9%
Propane	$1,728	$1,010	$2,738	$216	$39	$255	9.3%
Other	$930	$1,095	$2,025	$115	$30	$145	7.2%
All Clients	$844	$1,177	$2,021	$105	$53	$157	7.8%

As mentioned above, to help assess the impacts of weatherization on households, the evaluation administered a computer-assisted telephone survey to a nationally representative random sample of weatherized households and a control group. The survey was administered in two phases. In the first phase, one group of homes surveyed was just about to have their home energy audits (pre-weatherization treatment group) and a second group had received weatherization one year earlier (comparison 1 group). The samples sizes for the treatment (pre-weatherization) and comparison homes (one year post-weatherization) were 665 and 802, respectively.[35] The response rate was 70%. The second phase was administered approximately 18 months later to the same households, which are referred to as post-weatherization treatment group and comparison 2 group, respectively, yielding 398 responses from the treatment homes and 430 from the comparison homes.

The results from the national occupant survey presented in Table 3.7 supports the contention that weatherization can reduce the energy burden experienced by low-income homes. Fewer homes found it hard to pay energy bills one-year post-weatherization, although it should be noted that even after weatherization, the majority of households still experienced an energy burden. As noted above, because the rebound effect was negligible, households post-weatherization were likely able to use energy cost savings to purchase food and prescriptions, reduce the probability of having utility service terminated, and avoid high-interest loan arrangements, suppositions all supported by the results in Table 3.7.

"I was having a hard time paying utility bills because the hot water heater and air conditioning were very old. Now I am able to pay the utility bills because the bills are much lower than before I had weatherization and I can be comfortable in the summer and winters." *St. Johns Housing Partnership weatherization client*

[35] For more information on the national occupant survey, see Retrospective Evaluation report Carroll et al. (2014a).

Table 3.7. Percent of Households Experience Energy Bill-Related Affordability Problems

Affordability Problem	Treatment Pre-WX	Treatment Post- WX	Comparison 1	Comparison 2
Hard or Very Hard to Pay Utility Bills	75.1	49.1	59.1	42.1
Every or Every Other Month Did not Pay Energy Bills to Pay Other Utility Bills	9.1	5.0	5.5	5.4
Got a Shutoff Notice Some Months or More	19.3	12.0	13.9	10.7
Electricity or Natural Gas Disconnected	11.2	2.5	10.3	2.1
Every or Every Other Month Did Not Purchase Food to Pay Energy Bills	10.8	5.8	8.1	4.0
Household Member Needed Prescription Medicines but Couldn't Afford	33.0	22.4	23.9	20.7
Needed to See Doctor but Could Not Because of Cost	32.5	23.9	25.0	21.4
Foreclosure on Mortgage Due to Energy Bills	2.7	2.0	2.2	1.9
Moved in with Friends/Family Due to Energy Bills	3.8	1.3	1.6	1.4
Family Separation Due to Energy Bills	1.4	0.8	1.0	0.7
Used Short-term, High-Interest Loans	18.6	12.0	11.7	8.9

3.4 NON-ENERGY BENEFITS

This section addresses non-energy benefits attributable to WAP. Previous studies, including the 1989 WAP evaluation, suggest that the non-energy benefits attributable to low-income weatherization are significant. Figure 3.3 illustrates the framework developed to organize the assessment of non-energy benefits. The framework has three main components: societal benefits, rate payer benefits, and household benefits. Investments in weatherization create direct societal economic benefits (i.e., produce jobs and income multiplier effects). Reductions in energy use resulting from physical changes in the home result in environmental benefits (e.g., reductions in the emissions of harmful air pollutants), which are included in the societal bucket. As mentioned above, weatherization through energy cost savings directly impacts household income. Health and safety measures combined with improvements in disposable income impact the health and well-being of household members (e.g., by reducing instances of thermal stress, reducing asthma symptoms and increasing households' ability to afford prescriptions). Improved health outcomes can lead to societal benefits through decreases in expenses to public and private medical insurance plans. Ratepayers can benefit through decreases in subsidies to percentage of income payment plans (PIPP), for example. The balance of this section addresses: environmental benefits; rate payer benefits, and household health and other household-related benefits.

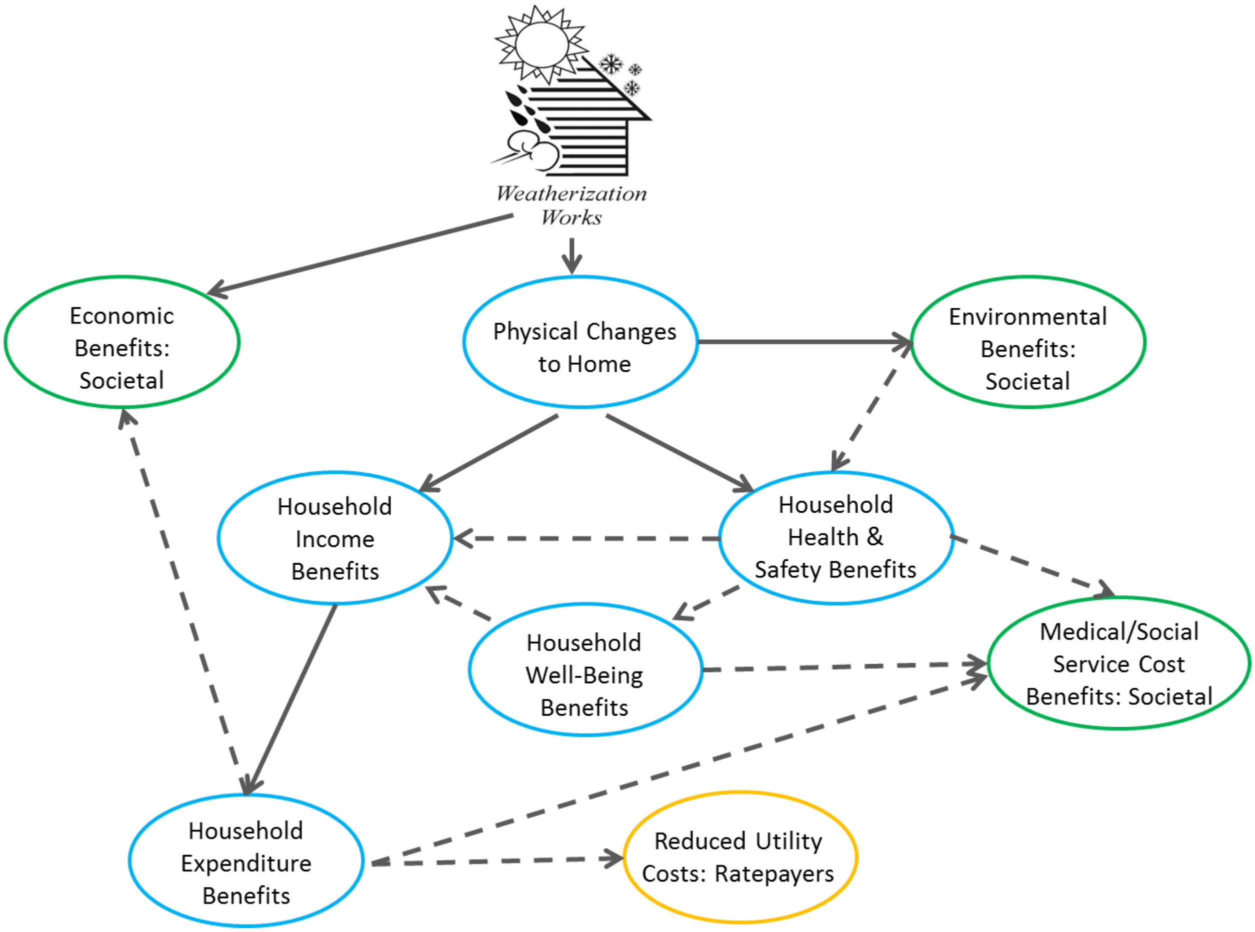


Figure 3.3. Framework for Understanding Non-Energy Benefits

3.1.1 Environmental Benefits

One benefit of WAP is that reducing the amount of energy used in clients' homes reduces the emissions associated with the production and consumption of energy. Values for emissions reductions are estimated for: carbon, particulate matter, sulfur dioxide, nitrogen oxide, and volatile organic compounds. The environmental emissions benefit estimation procedure involves four steps:

1. Energy Usage Reductions (State-Level) – The 2008 program evaluation estimated energy savings per weatherized unit for each type of energy used in clients' homes (e.g., natural gas, electricity) for each building type (i.e., Single Family, Mobile Home, and Multifamily).

2. Quantity of Avoided Emissions (State-Level) – Published data sources were used to estimate the avoided greenhouse gases, sulfur dioxide, nitrogen oxide and particulate matter emissions associated with the energy usage reductions for each type of energy. The analysis developed estimates of the average avoided emissions per housing unit at the state level and the aggregate avoided emissions per state.

3. Value of Avoided Emissions (State-Level) – The dollar value of avoided greenhouse gas emissions was computed using guidance from OMB and sulfur dioxides, nitrogen oxides, particulate matter, and volatile organic compounds was computed using the Air Pollution Emission and Policy Analysis Model (APEEP) as recommended by the National Research

Council (NRC) in their 2010 Report to Congress.[36] The analysis developed estimates of the average emissions benefit per housing unit at the state level and the aggregate emissions benefit per state.

4. National Averages and Aggregates – Using the state-level data, the analysis developed a weighted average avoided emissions and benefits per housing unit served by the program and aggregate avoided emissions and benefits for the overall program. The avoided emissions are expressed as avoided CO2 equivalents in metric tons, and average short tons of avoided for SOx, NOx, PM, and VOCs.

One important reason for developing estimates at the state level in Steps 1 and 2 is because environmental emissions rates for electricity generation vary by region. The valuation procedure done in Step 3 was done at the state level because the APEEP model estimates damages at the county level based on pollution sources and population. In addition, this approach furnishes data that can be useful to states for their own planning purposes. The lifetime CO2 emissions reductions are over 2 million metric tons and over 5 thousand short tons for criteria pollutants.

Figure 3.4 presents the results of monetizing the present value of environmental emissions benefits per unit by emissions type and housing type.[37] The average value for these benefits ranges from over $15,000 per unit for large multifamily buildings in New York City to almost $2500 for single family homes nationally to less than $1500 for mobile homes nationally. It can be seen that the highest monetary return are related to reductions in greenhouse gas and sulfur dioxide emissions and for large multifamily homes in NYC. The present value of these benefits is $251,000,000.

[36] National Research Council, 2010. Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use. The National Academies Press, Washington, DC.
[37] See Retrospective Evaluation Report (Working Paper) Carroll et al. (2014e) for more information on the environmental emissions benefits study.

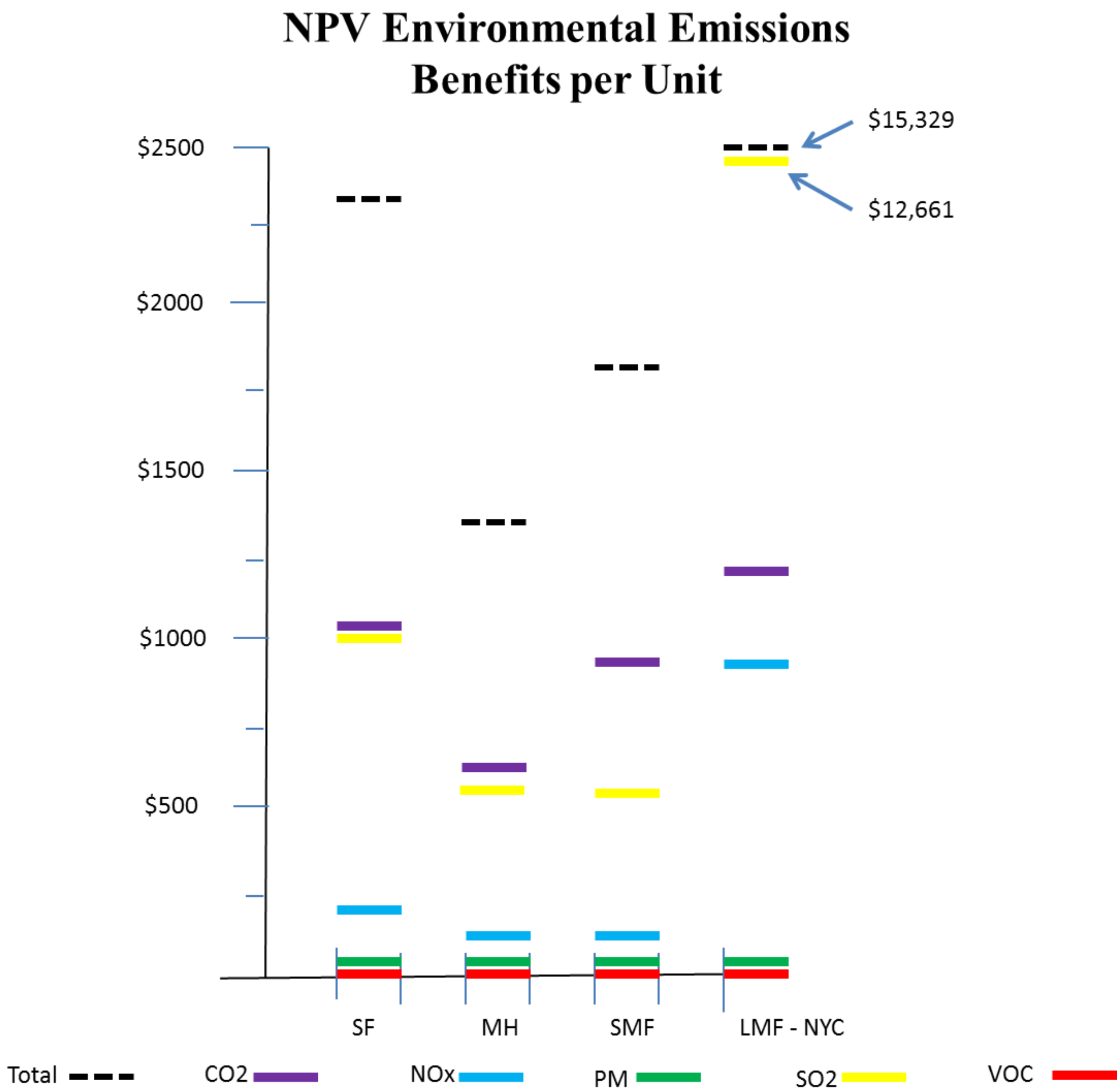


Figure 3.4. Present Value of Environmental Emissions by House and Emission Type for PY 2008

3.1.2 Macroeconomic Benefits

This section summarizes work to estimate the macroeconomic benefits attributable to WAP.[38] It is straightforward to assert that WAP has direct employment impacts. One can also argue that weatherization material and equipment purchases made by WAP at the local and state levels likely have indirect employment impacts. Moreover, the energy cost savings that households experience and are likely to spend on other goods and services may also induce employment benefits.

[38] See Retrospective Evaluation report Burton et al. (2014) for additional details on this study.

To estimate the direct, indirect, and induced employment impacts, the retrospective evaluation team used a sophisticated macroeconomic modeling tool developed by Regional Economic Models, Inc. (REMI). The REMI model is a computable general equilibrium model, meaning that it is capable of simulating the multi-sector U.S. economy year-by-year over multiple decades. The model produces outputs in the form of changes in employment by sector, region, and year as well as changes in gross domestic product by region and year, reaching equilibrium of demand and supply for each modeled year.

The study team focused on estimating the macroeconomic benefits of WAP for PY 2008, including all leveraged funding spent in DOE units. The team apportioned WAP expenditures on energy efficiency measures to over 25 sectors of the U.S. economy, with the resulting impacts touching over 50 sectors.

The findings suggest that:

- Directly and indirectly, WAP was responsible for a combined 8,435 jobs;
- WAP generated $476 million in incomes;
- WAP increased national economic output by $1.22 billion; and
- The national economic multiplier is 2.93.

3.1.3 Health and Household-Related Benefits

This section addresses several non-energy benefits accruable to households following weatherization. Weatherization directly reduces energy costs, improves home comfort, and helps seal the home against outside harm (e.g., outdoor air pollutants, pests). Weatherization agencies also rectify carbon monoxide problems found in homes (see Section 4.5), and as opportunities arise and funding allows, address a large number of health and safety issues, from mold and mildew to infestations.

Comparing the pre-weatherization treatment group to the post-weatherization treatment group and comparison group 1 columns (Table 3.8), the national occupant survey indicates that more clients report having operational heating and cooling systems one year post-weatherization than pre-weatherization. Their homes are less drafty. Their heating solutions make less use of poor quality materials burned, ovens for heat, and portable heaters, which all have implications for improving indoor air quality, occupant health, and home safety.

Table 3.8. Summary of WAP Household Heating and Cooling System Findings (% of Homes)

Indicator	Treatment Pre-Wx	Treatment Post-Wx	Comparison 1	Comparison 2
Heating System Broken	14.9	6.8	8.5	9.1
Central Cooling System Broken	9.9	5.0	5.5	6.5
Home is Cold or Very Cold in Winter	39.4	15.1	19.7	15.2
Home is Hot or Very Hot in Summer	41.0	24.9	26.6	22.3
Home Drafty Most or All of the Time	29.5	5.8	8.9	4.9
Use Portable Heater (Main)	2.4	NA	1.7	NA
Use Portable Heater (Other)	33.1	NA	26.8	NA
Use Oven for Heat	11.5	6.3	7.3	6.0
Poor Quality Materials Burned	4.6	3.4	1.8	2.1

Consequently, the survey results suggest that one year after weatherization respondents and other household members experienced a wide range of health and well-being benefits. For example, with respect to well-being, the survey results indicated that:

- respondents experienced less bad days of rest and sleep the previous month
- respondents felt healthier and full of energy more days the previous month
- household members experienced fewer allergy symptoms, fewer instances of the flu, and fewer instances of persistent cold symptoms over the past year
- household members suffered fewer headaches over the past year
- respondents with asthma reported being hospitalized less and visiting the emergency department less after weatherization
- respondents who were asthma sufferers reported missing fewer days of work the previous 12 months (a decrease from 8.5 days missed to 6.8)
- respondents reported fewer incidences where they paid their utility bill instead of buying food
- respondents reported a decrease in worry that household members would not have nutritious food (in the past 4 weeks)
- respondents reported being better able to afford prescriptions
- fewer households needed food assistance after weatherization
- households used fewer short-term high-interest loans after weatherization

"Less dust and mold – less coughing and congestion than before. Fewer respiratory problems." *St. Johns Housing Partnership weatherization client*

"I don't have to choose between the gas bill and my medicine." *Corporation for Ohio Appalachian Development weatherization client*

It was reported that household members suffered:

- Fewer food poisonings;
- Fewer burns from hot water;
- Fewer instances of thermal stress from being too cold or too hot; and
- Fewer missed days of school in the previous 12 months for the child most absent from school living in the home (7.6 days versus 6.8).

The homes experienced:

- Less intrusion of outdoor noise into their homes;
- Less cockroach infestation;
- Less rodent infestations;
- Less standing water;
- Less mold; and
- Less mildew or musty smells.

The homes are safer because of:

- Reduced exposure to carbon monoxide
  - Working CO monitors installed in homes increased from 46% to 76%
- Reduced risk of fire-related injuries
  - Working smoke detectors installed in homes increased from 88% to 96%

As seen above, the list of potential non-energy benefits of low-income weatherization is quite extensive. As noted above, weatherization can directly increase household disposable income through decreases in energy burden. In some homes, measures such as low-flow showerheads are installed, which can reduce water bills. It is also important to note that weatherization can also positively impact household disposable income in many other ways. For example, fewer illnesses in the household may allow employed household members to miss fewer days at work, which provides a direct income benefit because most low-income jobs do not provide sick leave. These incremental increases in income, along with reductions in energy costs, may allow households to avoid using costly short-term loans, which can then save households the cost of the interest on the loan. They also may be better able to afford prescriptions and food, which have both household and societal benefits. These and additional income relationships with weatherization are captured in Figure 3.5.

Monetization of the benefits provides a way to combine these benefits with the energy cost savings and emissions benefits to develop a fuller picture of the total benefits versus costs of WAP. Twelve categories of health and household-related benefits were monetized as part of this evaluation. Methodologies used to generate the monetary estimates listed in Table 3.10 can be found in Tonn et al. (2014). Here are several points to be considered with respect to these estimates:

- Household benefits are limited to financial benefits accruable directly to the households;

- Financial benefits due to improved health, for instance, that benefit health insurance plans are accrued to society in this framework;

- Value of saving lives benefits are consider societal; and

- The present values are calculated over a ten-year time frame using the 2013 discount rate published by the Office of Management and Budget.

Table 3.9 presents the estimates of the monetary value for these twelve non-energy benefits for households residing in single family and mobile homes.[39] These estimates are grouped into three tiers according to the strength of the methodologies and data underlying the estimates. Tier 1 estimates can be considered to have the least amount of uncertainty, followed by the Tier 2 and Tier 3 estimates.

The highest benefit accrues from preventing instances of thermal stress from being too cold. This benefit has a high value because in a few cases, thermal stress can lead to death and preventing a death was valued at $7.5 million in this analysis. Preventing deaths also weighed heavily in the benefits estimated for preventing instances of thermal stress from being too hot, CO poisoning, and home fires.

[39] Small multifamily and large multifamily homes were not included in these analyses because clients living in these types of homes were not included as part of the national occupant survey and because weatherization of large multifamily buildings focuses more on central heating and water heating systems and common areas and less on individual units, which is hypothesized to have a very different impact on health and household-related non-energy benefits.

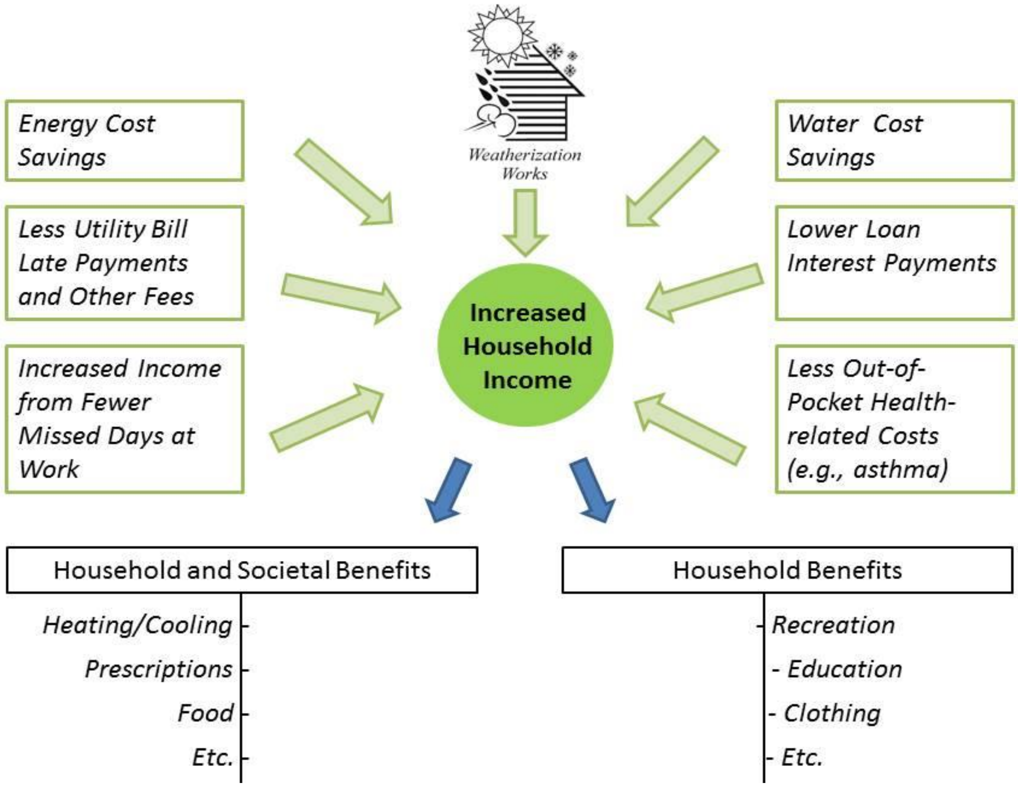


Figure 3.5. Potential Impacts of Weatherization on Household Disposable Income

Table 3.9. Present Value of Per Unit and WAP Program Health-Related Benefits of Weatherization

	Total	Total (Value of Life Excluded)	Tier 1		Tier 2		Tier 3	
			Societal	Household	Societal	Household	Societal	Household
Asthma	$2,009	-	$1,852	$157				
Thermal Stress-Cold	$3,911	$172	$3,892	$19				
Thermal Stress-Heat	$870	$85	$855	$15				
Food Assistance Reduction	$832	-	$832					
Reduction in Missed Days at Work	$201	-	$40	$161				
CO poisoning	$154	$7			$153	$1		
Improvement in Prescription Adherence	$1,929	-			$1,929	-		
Reduction in Use of Short-Term Loans	$71	-			-	$71		
Home Fires	$831	$175					$768	$63
Increased Productivity at Work Due to Improved Sleep	$1,813	-					$1,813	-
Increased Productivity at Home Due to Improved Sleep	$1,329	-					-	$1,329
Reduction in Low-Birth Weight Babies from Heat-or-Eat Dilemma	$198	-					$198	-
Total by Tiers (Present Value Per Unit)	$14,148	-	$7,471	$352	$2,082	$72	$2,779	$1,392
			$7,823		$2,154		$4,171	
Total by Tiers (Present Value WAP Program)	$1,136,883,221	-	$600,333,094	$28,295,957	$167,310,541	$5,766,863.04	$223,324,724.16	$111,878,910.72
			$628,629,051		$173,077,404		$335,176,766	

The benefits associated with reducing asthma symptoms are also appreciable. This is because it appears that weatherization can substantially reduce asthma-related hospitalizations and emergency department visits. Benefits also accrue to improving the use of prescriptions and helping pregnant women avoid the heat or eat choice, which may lead to low-birth weight babies. It should be noted that the grand total presented in Table 3.9 is likely to be an underestimate of the monetary value of weatherization to households and society with respect to health-related issues. The estimate only includes weatherized single family and mobile homes. Several additional health-related benefits were not monetized, such as the prevention of trips and falls and the replacement of refrigerators, which may prevent food poisoning. Additionally, no attempt was made to monetize the subjective benefits of: increased comfort experienced by households; improved mental and physical health; and less infested households. On the other hand, there are a number of uncertainties associated with these estimates, which are explained in detail in Tonn et al. (2014b).

3.5 COST-EFFECTIVENESS

This section addresses the cost effectiveness of WAP. The section begins with cost effectiveness defined with respect to measure costs and energy cost savings. Savings-to-investment ratio savings are estimated by house type, fuel type, and climate zone.[40]

3.5.1 Measure Costs and Energy Savings Only

Table 3.10 presents a summary of energy cost savings, energy efficiency measures costs, benefits, and the estimated SIR for each building type and for the program overall, by house type. These estimates were calculated by dividing the present value of estimated energy cost savings over the lifetimes of the measures by the costs of the installed energy conservation measures (ECMs). Estimated costs savings were calculated using U.S. Energy Information Administration fuel price forecasts and discount rate guidance published by the U.S. Office of Management and Budget.[41] The savings-to-investment ratio for the most-weatherized type of home, single family site-built is 1.72. As shown, SIRs range from 1.03 for mobile homes to 1.82 for large multifamily units weatherized in New York City.

Table 3.10. Energy Cost Savings, Efficiency Measure Costs, and Cost-Effectiveness by Building and Fuel Type (2013 Dollars)

	Energy Cost Savings (present value of lifetime savings)			Costs & Cost-Effectiveness		
Building Type	**Fuel**	**Electric**	**Total**	**Measure Costs**	**Net Benefits**	**Savings/ Investment Ratio**
Single Family	$4,161	$1,176	$5,337	$3,096	$2,240	1.72
Mobile Home	$2,107	$946	$3,053	$2,961	$92	1.03
Small Multifamily	$3,401	$1,217	$4,618	$2,878	$1,741	1.60
Large Multifamily	$5,237	$1,222	$6,460	$3,336	$3,142	1.82
All Types	**$3,757**	**$1,134**	**$4,890**	**$3,070**	**$1,820**	**1.59**

[40] The energy savings, energy cost savings, and cost effectiveness estimates presented in this subsection are drawn from Blasnik et al. 2014a, 2014b, 2014c, and 2014d.
[41] Energy cost savings and non-energy benefits reported herein were discounted using OMB Circular A-4, Appendix C 2013 real interest rates on Treasury Notes and Bonds of Specified Maturities. These rates are typically used on cost-effectiveness analyses.

Figure 3.6 breaks down SIRs by climate zone, funding source and number of measures installed based on 2008 dollars. These results suggest that the most cost effective investments are made in homes located in cold climates, followed by homes in very cold climates. Homes weatherized only with DOE funds achieve higher cost effectiveness than homes weatherized with DOE and other, leveraged funds. Lastly, it appears that the while installing more measures in homes will certainly save more energy (see Figure 3.2), adding more measures is not necessarily more cost effective, at least with respect to single family housing.

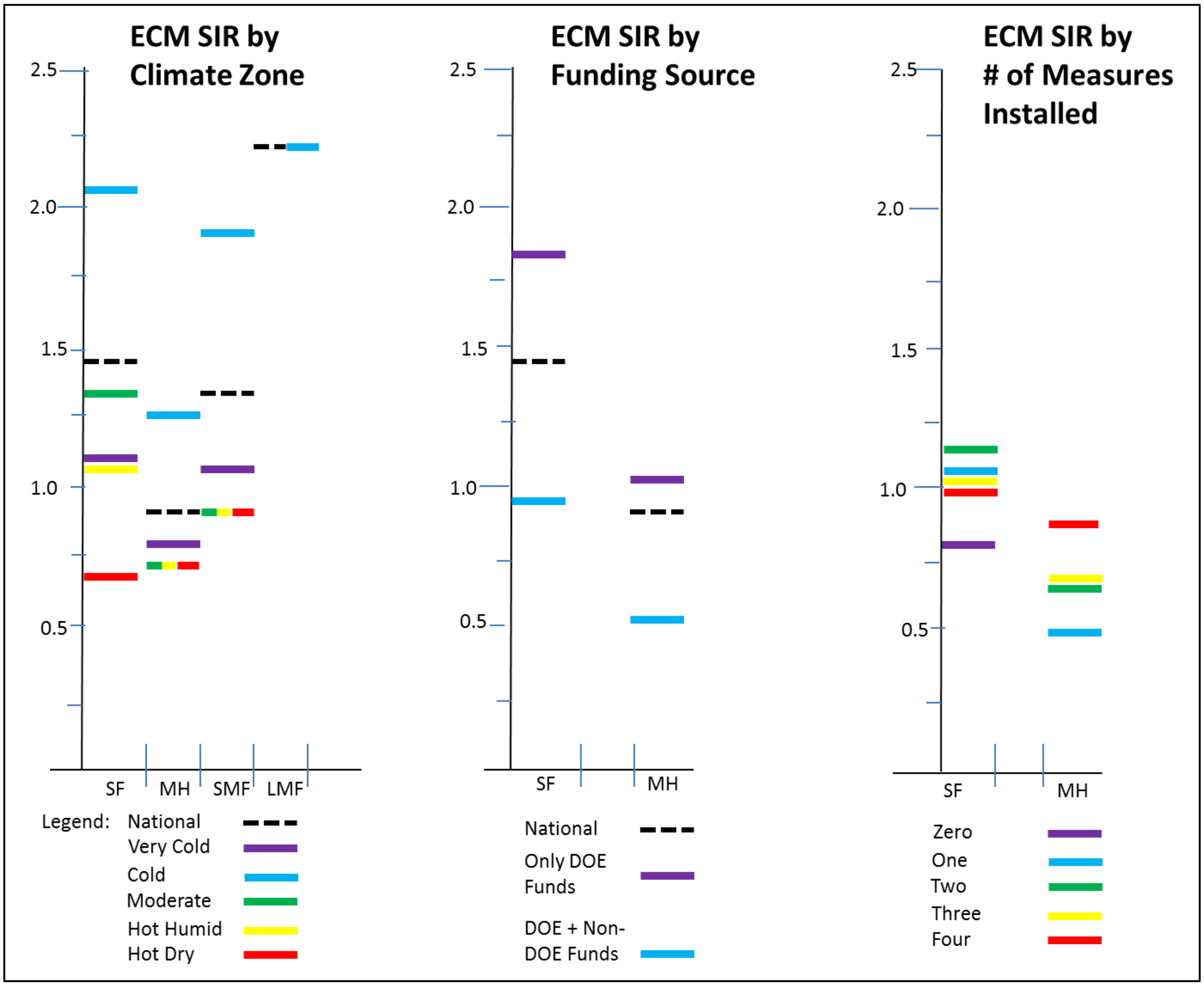


Figure 3.6. Cost Effectiveness by Climate Zone, Funding Source and Number of Measures Installed for PY 2008 (2008 dollars)

Table 3.11 presents the SIR by fuel type based on 2013 dollars. As expected, SIRs are much greater for the expensive delivered bulk fuels – fuel oil and propane – than for homes heated with natural gas or electricity.

Table 3.11. Cost Effectiveness by Fuel Type per Housing Type (2013 dollars)

Building Type	ECM Savings/ Investment Ratio					
	Natural Gas	Electricity	Fuel Oil	Propane	Other	National
Single Family	1.39	1.23	2.85	2.50	1.42	1.72
Mobile Home	.82	.70	2.36	1.84	1.10	1.03
Small Multifamily	1.34	1.26	4.58	3.15	1.88	1.60
Large Multifamily NYC	1.27		4.64			1.82

3.5.2 Total Costs and Benefits

Table 3.11 presents a summary of the total program benefits and costs for WAP for PY 2008 for all weatherized units except for large multifamily buildings located outside of New York City.[42] The average cost per unit weatherized is $4,695.[43] The average energy cost savings is $4890. Because numerous households whose homes were weatherized participate in utility administered Percentage of Income Payment Programs (PIPP) that are subsidized by ratepayers, approximately 22% of the energy cost savings accrue to ratepayers. The combined present value of the energy and non-energy benefits per unit is approximately $22,000. [44] Accounting for the units weatherized in PY 2008, the total present value of the benefits exceeds $1.8 billion. It should be noted that there are uncertainties in all of these estimates. However, the total estimates are conservative in several manners. First, the health and household-related benefits do not take into account subjective benefits enjoyed by households with respect to comfort, improved health and other factors. Second, these non-benefits were not estimated for the large multifamily component of WAP. Third, the energy savings benefits only account for one-third of the large multifamily buildings weatherized in PY 2008.

Lastly, numerous other non-energy benefits were not monetized by the evaluation, including potential health impacts of refrigerator replacement, increased home value resulting from the value of the weatherization investments, interest payments on late payments of utility bills, reduced forced mobility, reduced emissions of heavy metals, improvements in national security, and the value of free training provided to weatherization staff. Ratepayer benefits not addressed include: lower bad debt write-off, reduced carrying costs on arrearages, fewer notices and customer calls, fewer emergency gas service calls, reduced transmission and distribution costs, and reduced peak electricity demands.

[42] For more information on total program cost effectiveness, see Retrospective Evaluation report Carroll et al. (2014e).
[43] This cost estimate encompasses total program funding, DOE and leveraged funds spent on measures, administration, etc.
[44] This study assumes there is no free-rider issue. In other words, none of the households whose homes were weatherized would have undertaken weatherization without WAP. This assumption is justified given that all homes in the program are low-income and the national occupant survey documents problems these households have in paying everyday bills. It should be noted that these estimates also do not include spillover benefits, despite the fact that spillover was documented by the Social Network Study (See Recovery Act report Rose et al. (2015b)).

Table 3.12. Total Benefits and Costs for WAP PY2008 (2013 Dollars)

	Present Value Per Unit	Present Value Program
Energy Cost Savings	$4,890	$420,000,000
Accrued to Households	$3,814	$327,800,000
Accrued to Ratepayers	$1,075	$92,000,000
Environmental & Water Benefits[1]	$3,118	$266,945,000
Emissions Tier 1	$2,932	$252,000,000
Water Savings[45] Tier 3	$186	$14,945,000
Health & Household-related Benefits[2]	$14,148	$1,166,000,000
Tier 1	$7,823	$657,000,000
Tier 2	$2,154	$174,000,000
Tier 3	$4,171	$335,000,000
Total Benefits	$22,156	$1,852,945,000
Total Costs[1]	$4,695	$481,000,000
DOE	$2,295	$236,000,000
Leveraged Funds	$2,400	$245,000,000

1 – Excludes LMF outside of NYC
2 – Excludes LMF

3.6 COST EFFECTIVENESS: COMPARISON OF APPROACHES[46]

Energy cost savings, non-energy benefit results, and cost effectiveness calculations are sensitive to what year the analysis is focused on. Results presented in Section 3 of this report for PY 2008 are based on 2013 as the analysis year to facilitate comparison with results from the ARRA period. As the retrospective evaluation unfolded, it was decided to evaluate WAP during a year during the ARRA period. This decision was made, in part, in order to compare program performance during the last program year before the ARRA period with a program year during the ARRA period in order to better judge changes made in the program during the ARRA period. In order to allow a straightforward comparison between these two years, it was decided that a common analysis year should be chosen. The common analysis year chosen was 2013 because that was the year when it was expected that both evaluations were to be completed. Thus, the energy, benefit, and cost-effectiveness estimates in various tables in Section 3 are based on OMB published discount rates for 2013 (~0.8% for benefits over 20 years) and energy price forecasts that begin in that year. In this way, differences seen in program cost effectiveness between PY 2008 and the ARRA period will be due primarily to estimated energy savings, not on financial and forecast assumptions. The choice of OMB discount rates for these estimates is consistent with choices made by other major evaluations, including evaluations of the State Energy Program and the Energy Efficiency and Conservation Block Grant Program.

Others can argue, with merit, that it is important to present results related to energy savings and cost-effectiveness using the financial assumptions for the year under study. Thus, with respect to the retrospective evaluation, the year under study was PY 2008. The single family, mobile home, small multifamily, and large multifamily impact reports all contain energy savings and cost effectiveness estimates tethered to 2008 OMB discount rates (~2.7%) and energy price forecasts made at that time. The impact of using 2013 as the analysis year rather than 2008 can be demonstrated by examining the WAP

45 For a description of the water savings non-energy benefit, see Carroll et al. (2014e).
46 This subsection was added to this report in August 2015 to discuss how using different sets of assumptions can yield different cost effectiveness estimates, with reference to a fact sheet developed by the Office of Weatherization and Intergovernmental Programs (see http://weatherization.ornl.gov/WAP_NationalEvaluation_WxWorks_v14_blue_8%205%2015.pdf).

energy savings. As shown in Table 3.13, the present value of the energy savings for WAP is estimated to be $340 million using PY 2008 energy savings results and discount rate and energy price forecast assumptions for that time period, This estimate is lower than the estimate of $420 million using 2013 dollars primarily because the OMB discount rates for 2013 were historically low.

The results presented in Table 3.13 for the program also illustrate different ways of using the results from this evaluation to produce cost effectiveness estimates and how cost effectiveness estimates are sensitive to what benefits and costs are included in the numerator and denominator of the SIR calculations. For example, one could divide energy cost savings by energy measure costs to produce a "measure" SIR. This results in a measure SIR of 1.59 using 2013 dollars and about 1.4 using PY 2008 dollars. A "program" SIR could also be calculated by dividing total benefits (i.e., energy savings and non-energy benefits) by total costs. Using 2013 dollars, this results in a program SIR of 4.72, where all the non-energy benefits as summarized in Table 3.12 were included in the total benefits and the total cost includes all administrative costs and H&S costs in addition to energy measure costs. In the 2008 dollars column, a program SIR of 4.1 is calculated by adding the energy cost savings to just a subset of the health-related benefits (for a total benefit of $13,550) and dividing by the average measure costs plus an additional 15% to account for average health & safety investments in homes.

Similarly, Table 3.14 addresses single family cost effectiveness specifically. The lower OMB discount rates for 2013 yield a higher present value of energy cost savings per single family weatherized, though the natural gas price forecasts for 2013 were lower than in 2008, which resulted in a lower annual energy cost savings estimate. The two approaches yield similar measure SIRs: 1.72 using PY 2013 dollars and 1.47 using PY 2008 dollars.

Table 3.13. Total (Program) Benefits and Costs for WAP PY 2008: Comparison of Approaches

	2013 Dollars	2008 Dollars
Program Energy Cost Savings		
Total (present value)	$420 million[1]	$340 Million
Per Unit (present value)	$4,890[1,2]	$4,243
Total Program Benefits Per Unit (energy costs savings plus non-energy benefits)	$22,156[1]	$13,550
Costs		
Total per Unit	$4,695[1]	$4,695
Energy Measure Costs Per Unit	$3,070[2]	$2,846
Cost Effectiveness – SIR		
Measure (energy savings only)	1.59[2]	1.4
Program	4.72	4.1

[1]From Table 3.12.
[2]From Table 3.10.

Table 3.12. Single Family Benefits and Costs for WAP PY 2008: Comparison of Approaches

	2013 Dollars	2008 Dollars
Annual Energy Costs Per Unit	$2209[1]	$2279
Energy Cost Savings		
Annual per unit	$264[1]	$283
Present value per unit	$5,337[2]	$4,196
Energy Measure Costs per Unit	$3,096[2]	$2,846
Measure Cost Effectiveness	1.72[2]	1.47

[1]From Table 3.5.
[2]From Table 3.10.

3.7 SUMMARY

The results presented in this section demonstrate in numerous ways the effectiveness of the Weatherization Assistance Program. Specifically,

- The magnitude and percent of energy savings are significant

- The magnitude of the non-energy benefits – environmental, rate payer, and health and home-related – is also quite significant

- The present value of total program benefits exceeds the total program costs for PY 2008.

These high level results do, however, mask variability and uncertainty in the impacts. For example, energy savings and ECM SIR results vary considerably by climate zone, fuel type, house type, and number of major measures installed. The monetary estimates for the twelve categories of health and home-related benefits also vary widely, based primarily on whether weatherization is thought to prevent hospitalizations and deaths. There are several areas of uncertainty with respect to the health-benefits that need to be addressed through future research.

4. PROCESS EVALUATION AND FIELD STUDIES

This section describes in more depth how WAP was implemented in the field in PY 2008. Section 4.1 describes the complexity of low-income weatherization. Section 4.2 provides information on the wide range of training resources available to the national weatherization community. A Field Process Study was conducted that entailed observations and assessments of weatherization activities implemented by nineteen local WAP agencies around the country. The results from this study, presented in Section 4.3, found that weatherization is carried out competently but identifies areas for improvement. Section 4.4 summarizes the results from a study that addressed reasons for variation in energy savings amongst homes. This followed by a summary of an extensive and comprehensive assessment of the impact of weatherization on indoor environmental quality. Lastly, it is a testament to the program that its clients and its workers are very satisfied with their service and jobs, respectively (see Section 4.6).

4.1 PROGRAM COMPLEXITY

Let's return to Figure 2.3, which graphically illustrates the complexity of the weatherization process. To elaborate upon this figure, at any point in time, a local weatherization agency has numerous homes in various stages of the weatherization queue. Households are often referred to the weatherization program from other agency programs, such as their LIHEAP or other social service programs.[47] The program also generates positive communication amongst recipients and their social networks, which results in applications being generated by strong word-of-mouth phenomena. After it is determined that a household is eligible for WAP, the household is placed on the waiting list for an energy audit. The length of time on the waiting is dependent upon the length of the list, weatherization resources available, and whether the household falls into a priority category (e.g., elderly) and/or faces an emergency situation (e.g., inoperable furnace in the dead of winter).

Weatherization auditors need to have a basic understanding of building science, and the technical know-how to carry out over a dozen different diagnostic procedures. All in all, the auditors' job can be broken down into 30 different work categories and over 300 actions (see Figure 4.1). It should also be noted that audits and the weatherization work need to be appropriate for the specific climate zone, house type and fuel type, of which there over 60 potential combinations.[48] The results of the audit are used to develop a work order for the weatherization crew. The scope of work is based not only upon the list of cost-effective measures needed by the home but also must take advantage of leveraged resources available to the agency for weatherization. In addition, how agencies braid together DOE and leveraged funds is an art, given that these funding streams often have separate spending rules and reporting requirements. In some instances, the auditor may determine that weatherization needs to be deferred until the household can rectify structural and/or health and safety issues associated with their home.

After the audit, the agency addresses the logistics of scheduling the weatherization work, assigning crews, and equipping trucks to go out into the field. Many agencies also stock and maintain their own warehouses. Weatherization crew members need to have the capabilities to install a very large range of weatherization measures, such as: air sealing; attic, wall, duct and floor insulation; mobile home skirting and belly insulation; installation of new windows and doors, pipe insulation, low-flow shower heads; and installation of energy-efficient lights and refrigerators. Crew leaders also need to be able to manage the subcontractors that typically replace and tune up heating and cooling systems and install new water heaters.

[47] Approximately 50% of households that participated in the national occupant survey received LIHEAP the previous year.
[48] No agency deals with all 60+ combinations but the national program needs to develop tools and training materials to deal with all of the combinations.

Crews also implement a wide range of health and safety measures, including: installation of smoke alarms and CO monitors; ventilation measures such as installation and repair of kitchen and bathroom fans; and repairs to ceilings, walls, foundations, roofs, stairs and plumbing. If the home is built before 1978 and/or diagnostics reveal that lead is present in the home, crews need to implement Lead Safe Weatherization practices. Overall, weatherization crews need to master 60 work categories and successfully accomplish over 450 different actions.

Lastly, inspectors have a lengthy list of actions they must do to properly inspect homes following the installation of weatherization measures. Inspectors' responsibilities can be grouped into 12 different work categories and over 100 actions. If inspectors find issues with the weatherization job, crews are instructed to fix the problems. States and DOE also conduct random quality assurance (QA) inspections of homes. Once the home passes inspection, the job is closed. According to DOE regulations, agencies are not allowed to return to homes. Agencies are only allowed to re-weatherize homes that were weatherized before 1994.

Finally, it should be mentioned that the program stresses professionalism and respect for the household members. As observed by the evaluation team in the field, time is taken to explain the weatherization process at each stage in the process.[49] Crews are instructed to protect households' belongings and to leave the home as clean as they found it. Many auditors are trained to refer households to other social service programs because oftentimes the weatherization program is the only local program that has the opportunity to interact with the clients in their homes. The Process Field Study observed a very high level of professionalism displayed by auditors, crews, and inspectors.[50]

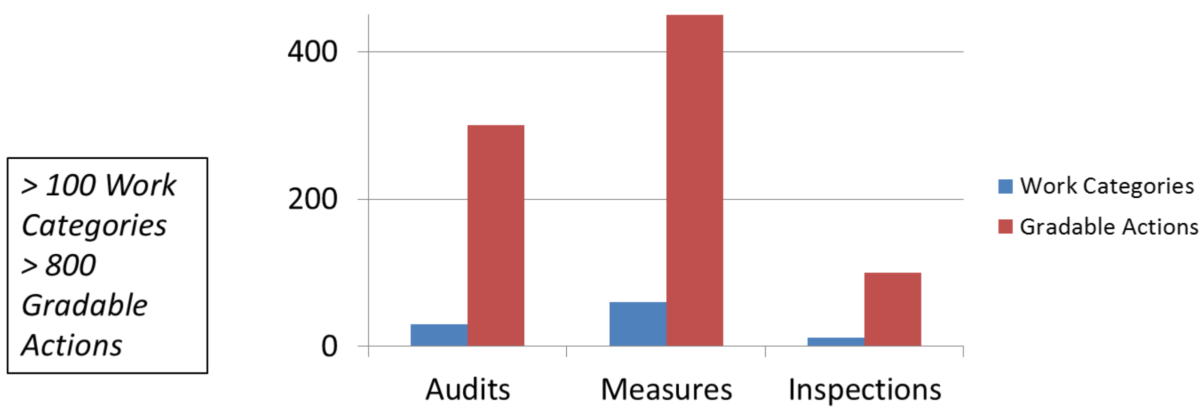


Figure 4.1. Complexity of the Weatherization Knowledge Base[51]

[49] On the other hand, as discussed in Section 4.3, true client energy education is not routinely conducted.
[50] See retrospective report Berger et al. (2014)
[51] Drawn from Retrospective Evaluation report Berger et al. (2014)

4.2 PROGRAM TRAINING

To equip staff to handle the aforementioned complexities, the national weatherization network provides a wide range of training alternatives on a wide variety of topics. A substantial majority of auditors, crew chiefs and crew members received classroom training at a training center within the five years previous to the survey (see Table 4.1).[52] Weatherization staff also attend state-level and national training conferences and receive training at their agency. Only a small number of weatherization staff did not receive training in the time period covered.

Oftentimes, special training is provided by housing type and/or health and safety topics. For example:

- 84% of auditors, 76% of crew chiefs, and 71% of crew members received infiltration/air sealing training with respect to single family homes;
- 62% of auditors, 64% of crew chiefs, and 61% of crew members received insulation training with respect to mobile homes;
- 35% of auditors, 21% of crew chiefs, and 22% of crew members received base load measure training with respect to multifamily buildings; and
- 87% of auditors, 96% of crew chiefs, and 85% of crew members received Lead Safe Weatherization training.

A survey of over 800 trainees who attended classes at DOE-supported weatherization training centers found high satisfaction with the training offered.[53] For example:

- 97% found the training useful;
- 95% found the technical quality of the training to be high; and
- 95% stated they would recommend the training to others in the weatherization field.

"I don't have to worry about stepping on heater grate that is hot. I could use the both/shower without fear of electrocution from small space heater that I used to warm my bathroom (that was always a big concern to me)." *Housing Resources of Western Colorado weatherization client.*

[52] These statistics are derived from a survey of weatherization auditors, crew chiefs and crew members implemented in Spring 2011. See Retrospective Evaluation Weatherization Staff report Carroll et al. (2014c) for complete results of the weatherization staff survey.
[53] For more information on the results of the trainee survey, see Retrospective Evaluation report Hawkins et al. (2014).

Table 4.1. Formal Training Attendance in Last Five Years

Which of the following types of formal training have you attended in the last five years? (Select all that apply)			
	Auditors	**Crew Chiefs**	**Crew Members**
Classroom Training at a Training Center	86%	78%	70%
Classroom Training at Agency	60%	58%	51%
State's Weatherization Conference	43%	27%	20%
National Weatherization Training Conference	42%	31%	23%
Webcast	40%	15%	9%
Regional Weatherization Conference	34%	23%	12%
Affordable Comfort Conference	33%	13%	4%
BPI Certification Training [Volunteered]	5%	3%	2%
Health and Safety	0%	6%	4%
Other	9%	6%	3%
None of These	1%	3%	9%

Table 4.2 indicates that the majority of weatherization staff is trained to conduct Lead-Safe Weatherization. Building Performance Institute (BPI) certification is higher amongst auditors than crew chiefs and crew members. It should be noted that BPI, Lead safe work practices and other certification standards are increasingly required of weatherization staff.

Table 4.2. National Professional Certifications Received

What national professional certifications do you have? (Select all that apply)			
	Auditors	**Crew Chiefs**	**Crew Members**
Number of Respondents	**350**	**268**	**264**
Lead-Safe Weatherization[54]	63%	74%	62%
Lead Certified Renovator	59%	72%	50%
BPI Building Analyst	51%	19%	12%
BPI Envelope	18%	9%	5%
BPI Heating	14%	4%	3%
BPI Manufactured Housing	8%	4%	3%
Residential Building Envelope Whole House Air Leakage Control Crew Chief	6%	10%	3%
HERS	5%	2%	<1%
BPI Multifamily	4%	1%	0%
BPI Residential Building Envelope Accessible Areas Air Leakage Control Installer	3%	5%	3%
Leadership in Energy & Environmental Design	2%	1%	2%
BPI Air Conditioning and Heat Pump	1%	1%	1%
National Association of Home Builders Green Building	1%	<1%	0%
None of These	7%	7%	21%
No Answer	<1%	<1%	2%

Lastly, it should be noted that the national pool of weatherization staff has a high level of experience. Over 30% of auditors reported working in low-income weatherization for more than 10 years. Almost as many auditors and crew chiefs reported working for their current weatherization employer for more than 10 years.[55]

4.3 PROCESS FIELD STUDY

The retrospective evaluation supported a comprehensive Process Field Study of weatherization services delivery. In addition to identifying work subcategories and actions encompassed by each, weatherization technical experts and social scientists were sent into the field to observe audits, measure installation, and final inspections. On-site observations of 155 audits, 159 measure-installation periods, and 128 final inspections were conducted at 19 Subgrantees across the country. The experts were trained to observe work in the field, not to interfere or to provide their own advice.[56] The weatherization technical experts documented when specific work subcategory actions were applicable and if applicable, whether they were carried out.

[54] It should be noted that Lead Safe Weatherization is technically not a national certification; however, within this industry it appears that weatherization staff perceive that infield training on lead safe weatherization is considered equivalent to a certification.

[55] The weatherization staff survey was conducted during the ARRA period and thus encompassed many individuals new to weatherization. However, the case study visits to local weatherization agencies revealed that the core staff at many agencies had three or more decades of experience in low-income weatherization (see Section 5).

[56] However, the experts were told to intervene if the health and safety of anyone was at risk.

Table 4.3 summarizes the very detailed and comprehensive findings of the Process Field Study.[57] The results are presented by the three main weatherization activities: audits, measure installation, and final inspections. Technical experts graded work observed on technical quality, professionalism, and client education. Overall, the technical quality of the work observed was competent. Auditors, weatherization crews, and inspectors were getting the job done. Auditors and inspectors could make better use of some diagnostics (see Tables 4.4 and 4.5, respectively)[58]. Crews install measures well but frequently miss opportunities for additional air sealing.

Table 4.3. Summary of Findings from the Field Process Study

	Audits	Measure Installation	Final Inspections
Technical Quality	Audits are comprehensive; blower tests done regularly; work orders are generally well done Use of additional diagnostics could be improved	Most installation work observed was high quality (e.g., insulation, ventilation, doors, windows, air sealing) Opportunities for additional air sealing frequently missed	Final inspections are comprehensive, generally based on visual inspection; blower door test-outs are done regularly Use of additional diagnostics could be improved
Professionalism	Auditors treat household members with respect	Crews treat household members with respect, protect household belongings, and clean up after themselves	Auditors treat household members with respect
Client Education	Auditors explain the auditing and weatherization process well Auditors do not often engage household members in discussion about energy, bills, home conditions	Crews explain their work well Crews often do not engage household members about why certain measures are being installed	Inspectors explain their responsibilities well Inspectors often do not engage household members in discussions about energy use, health & safety issues, expected energy savings and energy cost savings

The field process evaluation team gave high marks for professionalism to auditors, crew, and inspectors they observed in the field. Staff members generally gave the appearance of being dedicated to their work and taking pride in it. Crews seemed to work well together and collectively solved problems encountered in homes.

On the other hand, the assessment found that auditors, crews and inspectors could engage households in more discussions about energy use, the performance of the home, utility bills, and the expected benefits of weatherization. It should be noted though that client education was not a DOE reimbursable expense/measure, so agencies did not have a strong incentive to invest personnel time in this activity. Also, it should be noted that in discussions with agencies held during the case study visits (see Section 5), weatherization staff tended to shy away from giving energy savings and energy cost savings predictions to households because they can vary so much from home to home due to factors outside of the control of the weatherization agency (see Section 4.4).

[57] Please see Retrospective Evaluation report Berger et al. (2014) for more details about the study and results.
[58] Results presented in these tables are drawn from surveys of Grantees and Subgrantees.

Table 4.4. Diagnostic Procedures Used by Weatherization Auditors

Diagnostic procedure	Percentage of agencies that performed in PY 2008
Blower door (house air leakage rate)	99%
CO measurements in flues (space heating system)	91%
CO measurements in flues (water heating system)	88%
Flue gas analysis (space heating system steady-state eff. test)	83%
Cooking stove	82%
Draft/spillage (space heating system, normal operation)	78%
CO measurements in living areas	78%
Draft/spillage (water heating system, normal operation)	77%
Flue gas analysis (water heating steady-state eff. test)	72%
CO measurements in equipment rooms	69%
Worst case draft/spillage (CAZ)	63%
Refrigerator energy use	63%
Duct pressure pan measurements	59%
Zonal pressure measurements	58%
Heat rise measurements (space heating system)	55%
Infrared scanning (camera)	51%

Table 4.5. Post-weatherization Inspections Performed by Grantees and Subgrantees in PY2008

Type of post-weatherization inspection	Percentage of Grantees that perform	Percentage of Subgrantees that perform
Visual inspection of installed measures	100%	99%
Assessment of quality of measures installed	100%	88%
Discussion with occupants	98%	89%
Verification of operation of measures installed	94%	89%
Identification of unresolved health and safety issues	92%	68%
Verification of insulation depths/quantities	92%	92%
Identification of needed measures that were not installed	92%	73%
Blower door test	87%	95%
Carbon monoxide (CO) monitoring	83%	N/A
Draft/spillage tests of heating systems	64%	N/A
Heating system efficiency test (flue gas analysis)	51%	N/A
Infrared scanning	51%	N/A
Other diagnostic tests	N/A	95%

4.4 PERFORMANCE STUDY

The retrospective evaluation investigated a small number of apparent low and high energy savers among single family homes treated by WAP in PY2008. This special study sought to better understand the factors leading to unusually high variations in energy savings that derived from analysis of pre- and post-weatherization utility consumption histories for homes heated with natural gas or electricity.[59]

To implement the study, a geographically diverse sample of 19 locations in 17 states was selected from among geographies represented in a much larger sample of homes included in the impact evaluation of the PY 2008 program. Individual homes within each sampled location were then randomly selected from among those determined to have unusually low or high apparent savings relative to the major heating-related measures installed in the home. A total of 105 homes were included in the final sample, of which 71 had lower-than-expected apparent savings and 34 had higher-than-expected savings. The analysis revealed a rich set of explanatory factors for apparent low or high savings among the study sites, some of which were household-driven factors unrelated to the program, and some of which were program related.

Household factors

- Household change – About one in four study participants experienced a change in household composition or schedule that could be considered a primary or contributing factor to apparent low or high energy savings. These occurred with about equal incidence among apparent low- and high-savers.

- Change in use of supplemental heating – About one in three participants changed how they used supplemental heating sources (mainly electric space heaters). On balance, these households were somewhat less likely to use supplemental sources following weatherization. Since supplemental heating offsets the need for primary heat to some degree, decreased use of sources like space heaters reduces savings for the primary heating fuel (for which utility bills were collected and analyzed to estimate energy savings) relative to what would be seen if no supplementary fuels were used.

- Change in thermostat settings – About one in ten households reported a change in thermostat-setting practices following weatherization. These were more likely to involve lower settings during the heating season than higher settings. There is thus little evidence for "rebound" of heating energy savings following weatherization.

- Idiosyncratic consumption – Some households (particularly in warmer climates) used their heating system irregularly, such that estimated annual consumption—and savings—was particularly uncertain. This was identified as an important factor for about one in ten cases with low apparent savings, but was rarer among apparent high savers.

Program factors

- Atypical measure application – About one in three or four apparent low savers had wall or ceiling insulation treatments that were in fact minor applications involving a limited area. Since the program typically treats most or all of the wall or ceiling area when these areas are addressed, this would explain lower-than-expected savings relative to more typical jobs where the treatments were more extensive. Conversely, about one in seven apparent high savers received ceiling insulation in spaces with little or no existing insulation: this would explain higher-than-average savings in these cases, because most homes that receive additional ceiling insulation have some existing insulation in place.

[59] See Retrospective Evaluation report Pigg (2014c) for more information on the performance study. The text in this section was drawn from the Executive Summary of this report.

- Issue with existing heating system – A small number of apparent low savers had a heating system that was non-functional or malfunctioning prior to weatherization. Repair or replacement of this system as part of the weatherization package meant that usage of the primary heating fuel increased following weatherization, leading to negative apparent savings. In other cases, functional heating systems were replaced for health-and-safety reasons with new units that had about the same efficiency level as the existing unit: savings from these would be expected to be less than for energy-efficiency replacements, which generally involved high-efficiency, condensing equipment.

- Measure persistence – A small number of apparent low savers experienced premature failure of an installed measure. For example, in one case, animals largely destroyed belly insulation work under a mobile home.

- Work quality – Issues with the quality of the weatherization work were deemed to be a primary or contributing factor to apparent low savings in about one in five cases. These mostly had to do with the quality of insulation work in ceiling spaces and missed cavities for wall insulation.

- Additional measures – About half of the apparent high savers received measures such as duct sealing or foundation insulation that would help explain higher-than-average savings relative to the more limited set of measures used to establish expected savings for each site. A small number of apparent low savers had health and safety related measures installed that might plausibly increase heating energy consumption: in one case, for example, a home with forced-air heat had a supply register added to a crawlspace, presumably to help deal with moisture issues.

The study also identified missed energy-saving opportunities in addition to explanatory factors for apparent low or high energy savings. Missed opportunities for wall or ceiling insulation, duct sealing or air leakage reduction were identified for about half of the apparent low savers and about a quarter of apparent high savers, suggesting that there is potential for additional savings from the program.

4.5 INDOOR ENVIRONMENTAL QUALITY[60]

The retrospective evaluation conducted a comprehensive study of the relationships between weatherization and indoor environmental quality. Seventy-seven local weatherization agencies from 35 states were selected to participate in the study. Each agency provided lists of homes in the weatherization queue. Homes were randomly selected from these lists to be treatment and control homes. Over 500 were enrolled in the study. Control group homes were provided a small incentive to delay weatherization until after the study period.

The homes were monitored under closed-home conditions during winter 2010-2011 for homes in cold weather states and summer 2011 for a small number of homes in hot climates. The homes were monitored for: carbon monoxide, radon, formaldehyde, temperature (as mentioned in Section 3.2), and humidity and moisture. Complete descriptions of the monitoring protocols, devices, and statistical results can be found in Pigg et al. (2014). What follows is a summary of the results from the IEQ study.

[60] The text in this section was drawn from the Executive Summary of Retrospective Evaluation report Pigg et al. (2014a).

4.5.1 Carbon Monoxide Production by Combustion Appliances

Study technicians measured carbon monoxide (CO) production by fuel-fired appliances before and after weatherization. Generally, low incidence rates of actionable CO were found among combustion appliances in the study (see below). However, given the deadly nature of CO, this does not imply that current combustion-safety practices are unnecessary, or that changes should be made to the program. A summary of findings for the three key combustion-safety related appliances in most homes follows:

- **Heating systems:**
  - About three quarters of homes have a central, fuel-fired heating system and about 40% of these are atmospherically vented, which are of the most concern in terms of combustion safety. Only two of 114 naturally vented systems in the study were found to have inadequate draft.
  - An incidence rate of 9 ± 6% was found of natural-draft systems that produced hazardous levels of carbon monoxide (>400ppm) prior to weatherization.
- **Water heaters:**
  - Testing for the study revealed a 15 ± 4% incidence of fuel-fired natural-draft water heaters with inadequate draft (per BPI guidelines), suggesting that water heaters represent a somewhat greater combustion-spillage risk in homes. Following weatherization, none of the remaining natural-draft water heaters failed a draft test.
  - Carbon monoxide production above 400 ppm was found at only about a one in 200 incidence among fuel-fired water heaters in the study.
- **Ovens and ranges:**
  - The study data suggest that prior to weatherization roughly 10 to 20% of fuel-fired ovens (but only about 2% of cooktop burners) in homes produce carbon monoxide above the 800 ppm (air-free) level that is the federal standard for new ranges.

4.5.2 Indoor Ambient Carbon Monoxide Levels

Carbon monoxide data loggers recorded ambient CO levels in a single central location in the study homes at 1- or 5-minute intervals for approximately one month before and after weatherization. The data show that:

- Ambient CO levels never exceeded 5 ppm for about two-thirds of homes.
- About one in ten homes had one or more episodes of CO elevation that peaked at 20 ppm or higher prior to weatherization (the highest was 90 ppm).
- About one in 25 program homes had an indoor CO level that exceeded 5 ppm for 10% of the time or more, but only about one in one hundred exceeded this threshold regularly.

These proportions remained substantially unchanged following weatherization for both treated and control homes. A more detailed review of all sites with recorded (persistent or episodic) elevated CO revealed some cases with likely sources such as an attached garage or operation of a furnace or cookstove.

4.5.3 Radon

Study technicians deployed 7-day, activated-charcoal canisters to measure radon levels in foundation spaces and first-floor living spaces before and after weatherization. These tests were conducted during the heating season under closed-home conditions. These short-term tests are thus not reflective of expected annual average radon levels in weatherization homes. Key findings for radon follow:

- The study data indicate that the average single-family home in the program has a heating-season indoor radon level of 1.9 ± 0.1 pCi/L.[61]
- Pre-weatherization radon levels are correlated with pre-weatherization air tightness: tighter homes tend to have higher radon levels.
- The study confirms that elevated radon is relatively rare in mobile homes across the country and in site-built homes in counties identified by EPA as having low radon potential.
- The data from the study suggest that weatherization results in a slight (in absolute terms) increase in indoor radon levels. Nationally, the study data suggest an average increase of 0.4 ±0.2 pCi/L.[62]
- The impact of weatherization on radon appears to be generally proportional to pre-weatherization levels: homes with low pre-existing radon levels – which constitute the majority of program homes – experience only a slight increase in radon levels on average, while homes with pre-existing elevated radon experience a larger average increase following weatherization. On average, the radon impact is thus largest among site-built homes in EPA high-radon-potential counties, and lowest among mobile homes and homes in low-radon potential counties.
- Changes in measured air-leakage rates due to air-sealing efforts — which are intended to reduce air infiltration and yield energy savings were found to be statistically correlated with changes in radon levels in study homes.
- The study provides some evidence that the installation of continuous mechanical ventilation reduces radon levels in homes.

A follow-up study was conducted to explore the impacts that ventilation might have on indoor radon levels.[63] Specifically, the study sought to assess the impact of exhaust-only ventilation on indoor radon and humidity in 18 single-family homes in Colorado, Iowa, Minnesota and Ohio that were part of the national study and had been shown to have moderately elevated radon levels.

For the study, exhaust-only ventilation that was compliant with ASHRAE Standard 62.2-2010, "Ventilation, and Acceptable Indoor Air Quality in Low-Rise Residential Buildings," was installed in each home to provide continuous background ventilation. The impact of the ventilation on radon and humidity was assessed with an experimental protocol that involved using a timer in each home to disable the installed ventilation on alternate weeks, thus allowing an examination of the difference in radon and humidity levels with and without the ventilation operating. Radon levels were monitored continuously on

[61] It should be noted that all homes that tested over the EPA threshold level of 4.0 pCi/L received radon remediation if the households agreed to have their homes remediated.
[62] While this study was able to statistically discern an average change in radon levels post-weatherization, it is not possible to determine with certainty with respect to any specific home baseline radon levels the impact of weatherization on radon levels due to many sources of uncertainty, including seasonality, weather conditions, and measurement variability.
[63] For more information on this ventilation study, see Retrospective Evaluation report Pigg (2014b).

the lowest occupied level of the home, and humidity was tracked at the main thermostat. Key results are as follows:

- Radon levels declined or remained about the same for all homes in the study when the ventilation was operated. On average, the installed ventilation reduced radon levels by 12 ±7%.

- No homes experienced any practically-significant increase in radon with operation of the ventilation—though statistical uncertainty for individual sites does not preclude that possibility. This suggests that in most cases, the dilution effect of exhaust-only ventilation outweighs any tendency to increase the radon entry rate by depressurizing foundation spaces.

- Six homes showed a larger (and more regular) decline in radon with operation of the ventilation than the other sites. These included all three sites where the exhaust ventilation was located in a basement, as well as the single site with slab-on-grade construction.

- Sites with higher ventilation flow rates relative to their estimated seasonal natural ventilation rate also tended to show a larger impact from the ventilation.

4.5.4 Formaldehyde

Formaldehyde levels were measured on the first floor above grade for a sub-sample of 131 homes in the study using commercial test badges that were exposed for an average of eight days before and after weatherization. The results indicate the following:

- The average program home has a pre-weatherization indoor formaldehyde concentration of 14 ± 1 ppb, which is consistent with formaldehyde levels observed for older homes in other studies. Most homes tested below 30 ppb prior to weatherization.

- Weatherization resulted in a net 1.6 ± 1.1 ppb increase in formaldehyde levels.

- Formaldehyde levels (and changes in formaldehyde levels) were correlated with indoor humidity (and changes in humidity): higher formaldehyde levels were observed in homes with higher indoor humidity.

- Mobile homes may have higher formaldehyde levels than site-built homes, and weatherization may have a larger impact on these levels, but the available sample precludes solid conclusions.

4.5.5 Humidity and Moisture

The data loggers that recorded indoor temperature also provided data on humidity levels in the study homes. In addition technicians made a visual inspection for signs of indoor moisture before and after weatherization. The results for the homes monitored during the heating season follow:

- Prior to weatherization, program homes tend to be on the dry side during the heating season: nearly half (44 ± 5%) have wintertime relative humidity below 30%, but 6 ± 4% have relative humidity above 50%.

- Weatherization was associated with a small but statistically significant (1.1 ± 0.6%) increase in winter relative humidity.

- About 35% of foundations and 40% of above-grade spaces had observed moisture problems.

- Water stains were the most common observed moisture problem in both foundations and above-grade spaces.

The follow-on ventilation study discussed above also collected data to study the relationship between ventilation and indoor humidity. The study found:

- On average, relative humidity was reduced by a statistically significant 1.7 ± 1.2% points by the ventilation. All but one site experienced a decline in relative humidity associated with operation of the ventilation

- No relationship was observed between the ventilation's impact on relative humidity and general humidity level in the home

4.6 PROGRAM SATISFACTION

Indicators that WAP is a competently run program are high client satisfaction as well as the satisfaction of those that are actually delivering the weatherization services – the staff and crew members. These two groups and their level of satisfaction are addressed in Sections 4.4.1 and 4.4.2, respectively.

4.6.1 Client Satisfaction Survey

Participants in the national occupant survey were surveyed a short time after their homes were weatherized. Table 4.10 indicates that 94% of the clients were overall very satisfied or satisfied with the weatherization program. Well over 90% of respondents were very satisfied or satisfied with the work performed in the home and the final conditions left inside and outside of the home by the weatherization crews. Satisfaction was less (83%) for the length of time between the client's request to have their homes weatherized and when the work was done.[64]

[64] For more information about the client satisfaction survey, see Retrospective Evaluation report Carroll et al. (2014b).

Table 4.10. Overall Client Satisfaction with the Weatherization Program

Rate your overall satisfaction with the weatherization program.	
Very satisfied	63%
Satisfied	31%
Neither satisfied nor dissatisfied	4%
Dissatisfied	1%
Very dissatisfied	<1%

4.6.2 Weatherization Staff Satisfaction

The majorities of auditors, crew chiefs, and crew members are very satisfied or satisfied with most aspects of their jobs (see Table 4.11).[65] For example, a substantial majority of staff gives their jobs high marks for providing steady work. The enjoy interacting with clients and their co-workers.[66] Even their bosses get high marks. Pay and health and retirement benefits are issues that the respondents are much less satisfied with. Lastly, approximately 40% of weatherization staff indicated at the time of the survey that they believed they would have been unemployed without their weatherization job.

Table 4.11. Summary of Job Satisfaction Ratings of Very Satisfactory or Satisfactory

How satisfactory are these aspects of your job weatherizing low-income houses?			
Job Aspect	**Very Satisfactory or Satisfactory**		
	Auditors	**Crew Chiefs**	**Crew Members**
Steady Work	91%	88%	91%
Interactions with Clients	90%	90%	89%
Dress Code	88%	91%	89%
Paid Time Off Policy	86%	74%	82%
Co-workers	84%	84%	84%
Flexibility of Work Schedule	82%	83%	89%
Job Safety	81%	79%	80%
Boss/ Supervisor(s)	79%	83%	79%
Health Benefits	57%	49%	48%
Retirement Benefits	55%	49%	47%
Pay	49%	59%	55%

[65] At mentioned earlier, these statistics are derived from a survey of weatherization auditors, crew chiefs and crew members implemented in Spring 2011. See Retrospective Evaluation report Carroll et al. (2014c).

[66] Conversations had with weatherization staff during site visits conducted by ORNL evaluators support this statement. It was mentioned frequently that crew feel their job working in low-income weatherization is rewarding and that most clients are very appreciative.

> “My home has been completed. It was such a fast and easy process, and I am so grateful!”
> *St. Johns Housing Partnership weatherization client*

4.7 SUMMARY

This section described a program that is technically complex as multiple actions within each phase of weatherization may need to be taken to achieve the full cost-effective energy savings potential in a home. The program supports a comprehensive set of training options through training centers and several yearly national conferences to ensure the program follows the same path towards continuous quality improvement and innovation.

The national weatherization program is implemented in a diversity of contexts across the country, ranging from extremely cold climates to extremely hot and dry and humid climates. The program serves clients in the most urban of areas living in large-multifamily buildings, such as in Manhattan, and in most rural of areas where local programs spread over service areas that stretch for hundreds of miles, such as in the Arizona desert. Auditors and weatherization crews work on a wide variety of housing types and vintage that varies considerably by condition and encounter repair needs and situations requiring clever and innovative solutions. The results from studies as mentioned in this section show that the work performed in the field is professionally and technically competent. These studies also note opportunities to improve the overall quality of the program.

The performance study found that household factors are significant contributors to the wide variations often seen in energy savings post-weatherization. Weatherization has a differential impact on indoor environmental quality: CO issues are effectively dealt with whereas air sealing can result in slight increases in radon and formaldehyde levels. A follow-on study suggests that ventilation installed by the program can help mitigate the former.

Overall, findings show that clients are quite satisfied with the weatherization services received and weatherization staff is satisfied with almost all aspects of their careers in low-income weatherization.

5. WEATHERIZATION “BEYOND THE NUMBERS”

This section summarizes the findings from a set of local weatherization agency case studies. [67] This effort afforded the research team the opportunity to visit over a dozen local agencies, talk with managers and crew, tour their facilities, observe representative and notable weatherization jobs, and visit the homes and talk with clients of their programs. The cases document the day-to-day operations of these agencies and provide the opportunity for those involved in the program to talk about weatherization outside of the context of surveys and energy savings metrics. Thus, the case studies go ‘beyond the numbers’ in describing agency operations, philosophies, challenges faced and met, and prospects for the future. The main theme that runs through the case studies is that the local weatherization agencies are quite focused in their mission of helping low-income families through weatherization and other social services.

Agencies were chosen for case study development to exemplify the types of challenges and situations faced by local weatherization agencies, fundamental differences in management approaches, and innovative practices. More specifically the set of fourteen agencies chosen for case studies includes:

- A range of climates (e.g., cold versus hot-dry)
- A range of housing contexts (e.g., rural, urban, large multifamily)
- A range of management approaches (e.g., in-house crews vs. contractors)
- A range of organizational types (e.g., classic community action agencies versus housing programs)
- Agencies known for high energy savings and effective management
- Agencies known for success at leveraging non-DOE funding for weatherization
- Agencies known for innovative practices
- Several agencies that operate weatherization training centers

The agencies included in the case study project are listed in Table 5.1.[68] Two-person research teams visited the agencies during the period between May 2011 and July 2012. The teams spent approximately two-days on site, with one day spent conducting interviews discussing the agency’s philosophy, choice of weatherization model and approach (e.g., in-house crews versus contractor crews), ARRA period ramp-up and ramp-down[69], operational successes and challenges and agency wish lists and views of the future.

[67] See Tonn, Rose and Hawkins (2014a), Weatherization Beyond the Numbers: Case Studies of Fifteen High-Performing Weatherization Agencies.

[68] It should be noted that this list includes a fifteenth entry, Lindsay Park. The research team visited this housing development on Long Island as part of another task and found its weatherization story so interesting and compelling, that it is mentioned in this section and fully described in the case study report.

[69] The case study task was originally included in the retrospective evaluation. At the time when the evaluation plan was done, in 2006/2007, there were no indications that WAP would significantly change in the near-term, so it was felt that case studies done a couple of years after the year of focus of the energy savings tasks would not be a methodological issue. As it happened, the evaluation was delayed, the Recovery Act came into being, and WAP did change during the ARRA period, when these case studies were conducted. As such, it was felt important to take the opportunity to address the ARRA ramp-up and ramp-down experiences of our case study agencies in addition to less time-sensitive issues related to agency program philosophies.

Table 5.1. Case Studies

- Puerto Rico
- Housing Resources of Western Colorado – Grand Junction, Colorado
- Community Action - Lewiston, Idaho
- Salish and Kootenai Housing Authority – Polson, Montana
- HELP of Southern Nevada – Las Vegas, Nevada
- Community Action Human Resources Agency – Eloy, Arizona
- Opportunity Council – Bellingham, Washington
- Central Vermont Community Action Council – Barre, Vermont
- Corporation for Ohio Appalachian Development – Athens, Ohio
- St. Johns Housing Partnership – St. Augustine, Florida
- Social Development Commission – Milwaukee, Wisconsin
- Association for Energy Affordability – Bronx, New York
- Northern Manhattan Improvement Corporation – Manhattan, New York City
- Community Action – Minot, North Dakota
- Lindsay Park - Long Island City, New York

Section 5.1 summarizes what was learned about local agency program philosophies and approaches to low-income weatherization. The mission-orientation of the agencies underlies all of these findings. Section 5.2 presents several additional observations related to program operations.

5.1 LOCAL WEATHERIZATION OPERATIONAL PHILOSOPHIES

The material presented above and found in the case studies themselves depicts a program that is implemented in many manners at the local level by a very diverse set of local agencies. There is no one best staffing model (e.g., all in-house crews vs. all contractor crews) for a weatherization agency; it was found that agencies shape themselves to best operate within their local contexts. In addition, it was found that various other aspects of agencies' operational models are quite diverse, for example with respect to the auditing tools used by an agency (computer vs. general priority lists), the housing stock that it serves (single-family, mobile home, or large multifamily), and the typical weatherization measures it installs (wall and ceiling insulation in cold climates like Colorado vs. rooftop solar hot-water heaters in hot and humid climates like Puerto Rico).

Instead of continuing to describe differences among agencies, the purpose of this subsection is to discuss the commonalities among the agencies. These commonalities provide the foundation upon which successful programs flourish regardless of their distinct characteristics. The observations presented below are motivated and organized around important themes put forth by Peter Drucker in his seminal book, *Managing the Nonprofit Organization: Principles and Practices*. Drucker outlines several general categories in which successful nonprofit organizations excel: mission, commitment, respect, quality, innovation, and resilience.

Mission – All of the agencies visited as part of the retrospective evaluation have a strong sense of mission. However, the philosophies underlying those missions vary. For example, the Lewiston, Idaho agency's mission is stenciled on its trucks emphasizes a sense of community (See Figure 5.1). Central Vermont Community Action Council bills itself as promoters of "weatherization, efficiency and innovation" in that order. Regardless of the mission statements, or even each agency's understanding of what the larger view of its work is, the work of weatherization infuses every day's shared effort.

Figure 5.1 Mission Statement on a Lewiston Community Action Partnership Truck

***Commitment* –** Weatherization staff were found to be deeply committed to their jobs, and the agencies were, in turn, strongly committed to and supportive of their staff members. Clear evidence of this commitment was seen in the fact that a substantial majority of the core weatherization staff at all of the agencies have been at their jobs for decades. Despite being able to provide only relatively low wages to their staffs, agencies work hard to provide such benefits as they can, and a collegial and comfortable working environment was characteristic of the agencies observed.

The agencies were found to be very committed to their local communities as well. In discussions with the agencies, their concerns about community economic development, job training, and community stability were repeatedly expressed. Weatherization agencies often provide individuals with new career paths, give troubled youth second chances, and give local contractors the training needed to perform home retrofitting work beyond the immediate low-income weatherization.

In another example, the historic flood faced by the Minot, South Dakota agency in summer 2001 (See Figure 5.2) challenged it to respond to the community's needs while staff was also trying to take care of

Figure 5.2 The Flooding of the Souris River in Minot, summer 2011.

their own flooded homes and maintain program services. Showing a similar spirit of helping neighbors, staffs at the Social Development Corporation (SDC), Northern Manhattan Improvement Corporation (NMIC), Housing Resources of Western Colorado, and St. John's Housing Partnership (SJHP) regularly volunteer their time to causes and activities that range far beyond day-to-day weatherization. It is not uncommon for these weatherization staff members to continue helping clients in their off hours, to prepare their homes for winter, for example. Personal commitment was found to be a defining characteristic of the weatherization network.

Respect – The organizational cultures witnessed were infused with respect for the clients served by the weatherization agencies. Weatherization personnel are acutely cognizant that there are many paths into poverty and that there are many barriers to rising out of poverty. Many of the homes they work with are in poor physical condition, and many households struggle to survive from day-to-day. The case study team, as well as social scientists employed through the Process Field Study, observed weatherization staff interactions with clients in hundreds of households. Clients and household members were uniformly treated with respect. For example, auditors are the first personnel to visit a home. None were observed to be judgmental or condescending; in fact, the team was told repeatedly that those auditors who express disrespect toward the clients quickly leave the field or are encouraged to leave. The crews were respectful of household property, as well, cleaning up after the completion of the work. The hundreds of grateful letters sent to agencies by clients attest to the respectful treatment given them.

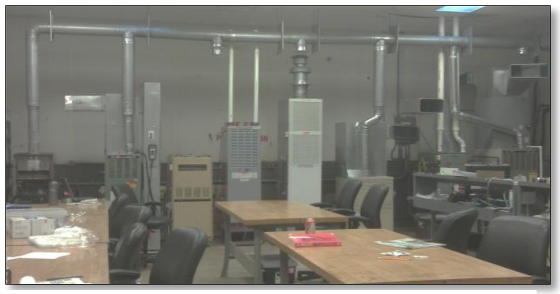
> "Workers are polite, friendly, very professional, prompt. Willing to answer any and all questions. Neat and clean. I feed them lunch everyday – coffee break snack and I did all cleanup of stuff when they were done to save them a trip here and time so that they could go on to next job to help someone else as much as they helped me. Felt like they were family by the time they left here. They are my 'EARTH ANGELS!'" *Central Vermont Community Action Council weatherization client*

It was also clear that agencies respect their staff; this can be seen in how staff is empowered in various ways; auditors are empowered to develop weatherization job plans that will best meet the needs of households. They also deal with challenging home construction, and work both within budget constraints and with the opportunities afforded by leveraged funding. In most cases, the crew chiefs are empowered to revise job plans in the field when complicated conditions in the homes are revealed. The crew members, too, are trusted to do their work and empowered to make appropriate decisions. New crewmembers receive active management and mentoring, but veteran crews and crewmembers, upon entering a home on the first day of the job, quickly fan out through the house to work on their assignments without having to be micro-managed.

Quality – The weatherization agencies' sense of their mission, their commitment to their work and staff, and the mutual respect given their employers combine to facilitate a culture of high-quality work. A great deal of pride in the quality of agency employees' work among the long-term weatherization auditors, crew chiefs, and crew members was witnessed.

WAP policy requires agencies to inspect all homes following weatherization and for states to inspect a sample of weatherized homes. It was found that agencies are careful to assign auditing (pre-weatherization) and inspection (post-weatherization) tasks to different individuals in order to avoid conflict of interest issues.

A plethora of training opportunities (see Section 4.2), mentoring, and on-the-job training are available to support high quality work. We visited three organizations with their own state-of-the-art weatherization training facilities: Opportunity Council in Bellingham, WA, Corporation for Ohio Appalachian Development (COAD), and Association for Energy Affordability (AEA) in NYC. Figure 5.3 presents views of COAD's training center. Each was well-designed, well maintained, and in high demand.



Training center- various heating systems

Training center- model home

Training center- classroom

Figure 5.3. COAD Training center

***Innovation* –** Because they are constantly dealing with unforeseen situations as they enter a wide variety of homes in a wide variety of conditions, agencies need to be both innovative and creative, technically and organizationally, to deal with these situations. Over the longer term, several agencies have developed innovative approaches to and techniques for weatherizing homes. For example, a type of perimeter insulation for mobile home bellies, the "burrito", was developed by Housing Resources of Western

Colorado (Fig. 5.4). Great pride is taken in innovations related to outfitting and packing-up the trucks the agencies take to job sites. St. Johns Housing Partnership is experimenting with new air-conditioning technology, and the Association for Energy Affordability has launched a distance-learning program. These programs highlight the energy and creativity that many agencies are bringing to the field at large and to their jobs in particular.

Figure 5.4. "Belly burrito" Insulation Roll

Organizational innovation and creativity are also brought to bear in "braiding" or combining leveraged funds to meet client needs. Creativity and innovation also underpinned the ambitious plans made by COAD to weatherize the entire town of Murray City, Ohio, and by several local weatherization agencies to collaborate with shareholders to weatherize the seven building twenty-two story, 2702 unit Lindsay Park housing development in New York City (Fig. 5.5). Agencies are also exploring innovative approaches to

Figure 5.5. Lindsay Park Development

synthesizing program services and cross-program referrals. Some, such as the Opportunity Council, are experimenting with fee-for-service programs. The diversity of program operational models is a strong indicator of this innovation and creativity found within the national weatherization network.

Resilience – The agencies we visited exhibit the characteristic described by Drucker as resilience. That is, they find ways to survive year after year despite constrained and uncertain budgets, uncertainty about when funds will be available for expenditure, and often frustrating, confusing, and duplicative regulatory requirements. Many agencies were founded during the Johnson Administration, during the War on Poverty, and have been operating weatherization programs since the late 1970s. They have survived because they have built strong relationships with their key supporters – state weatherization offices, other state offices, utility companies, other community organizations, and multifamily building owners and because their management practices have adapted to fit changing circumstances.

The ARRA period's relatively rapid ramping-up and ramping-down periods tested the weatherization agencies. The case study team visited several agencies during the ARRA period's ramp-up and ramp-down stages. During the ramp-up, agency managers were under an enormous amount of stress to grow their staffs and meet production numbers. An element of the ARRA legislation, the Davis-Bacon pay-scale requirements[70], at first delayed production and then produced numerous reporting difficulties. However, the agencies visited persevered, largely without complaints, despite difficulties and the increased oversight implemented under ARRA. As ARRA approached its end, many agencies needed to shrink, not just to pre-ARRA levels, but to even lower levels of staffing because of anticipated cuts in federal weatherization funding. In response, agencies were forced to lay off staff and crew members; in fact, many of the individuals interviewed during the case-study visits no longer work at their agencies.

5.2 OTHER OBSERVATIONS

Many local conditions prevent a one-size-fits-all approach for the implementation of weatherization programs. For example, programs that weatherize relatively few units per year cannot afford full-time, year round in-house crews. Some local economic situations are more conducive to using contractors than others. The typical suite of measures installed may also lead a program to choose an in-house model, a contracting model or a hybrid model.

Another observation is that the national weatherization network does not get the credit it deserves for dealing with the diversity of conditions it faces in the field. It was mentioned above that the local programs can adjust to different climates, housing stock, fuel types, and demographics. The network also can adapt to their particular leveraging opportunities, be they related to healthy homes or weatherizing entire communities.

Energy education has the potential to be effective as it relates to its impact on energy consumption at a household level. The best models witnessed included having a separate energy educator who either accompanied the auditor or visited the home pre-audit. Client agreements also seem to work well (e.g., before weatherization measures are installed, the household signs an agreement to improve their energy uses in specified manners). Auditors and crew members can provide energy education if given the time, although this time was in short supply during the ARRA period. The intense focus on production limited the amount of time any agency staff could spend with households.

After witnessing how programs ramped up and then down again during the ARRA period and listening to their travails during this period of time, one can conclude that more appreciation is due the national weatherization network for how it dealt with the ARRA funding and Davis-Bacon regulations, which mandated the levels at which local contractors and local agency staff had to be recompensed.

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[70] Davis-Bacon is a law passed in the 1930s that requires federal construction projects to pay prevailing wages. These wages are determined by the Department of Labor (DoL). The Recovery Act required weatherization agencies to pay Davis-Bacon wages for the first time. It took many months for DoL to determine what those wages would be and imposed significant new paperwork and accounting requirements on the agencies.

Even with the added ARRA funding, the number of homes eligible for weatherization is far greater than available resources can serve. Many agencies have long waiting lists; many others do not advertise their programs in an attempt to keep waiting lists manageable. When asked, most estimated that it would take many decades to serve the number of eligible homes given current funding.

It was observed that increased funding during the ARRA period allowed DOE to pass more money down to the states and agencies for training and technical assistance (T&TA). This additional money afforded by a larger program led to more training opportunities and increased quality assurance in the field. The larger program also allowed DOE to experiment with the installation of renewable energy and energy efficient measures not currently allowed by standard program rules. The several agencies visited that received Sustainable Energy Resources for Consumers (SERC) grants had no problems incorporating these new measures into their programs; most clients reported they were thrilled to be recipients of these measures.

6. ISSUES MOVING FORWARD

The Weatherization Assistance Program has many opportunities and challenges moving forward. This section addresses some of the more important issues with respect to program operations, health and safety, the role of weatherization in the national home retrofit marketplace, and dealing with future trends in demographics, energy prices, and technology.

6.1 PROGRAM OPERATIONS

An important question has arisen concerning the weatherization program: What is its optimal size? Those within the WAP network are beginning to compare the program pre-ARRA to the program it evolved into during the ARRA period. For many years, WAP's annual appropriated funding fluctuated in the $200 - $250 million dollar range. This amount of funding supported a certain level of training and technical assistance, and fairly stable set of local weatherization programs of approximately 900 agencies. Most people familiar with the program believe this level of funding is close to the minimum needed to maintain a viable national low-income weatherization program that funds enough jobs for the various agencies to maintain a program and to fund the required training and technical assistance.

Then, ARRA funding considerably increased the size of WAP from PY 2009 thru PY 2012. The ARRA funding allowed WAP to dramatically increase training and technical assistance (e.g., the number of weatherization training centers increased from 8 to 34), afford increased in-field quality assurance inspections, and allowed many agencies to increase weatherization activities to new levels. It can be argued that economies of scale of the larger program could actually improve in-field work quality (e.g., by funding more training centers, increasing quality assurance inspections, allowing Subgrantees to increase pay and benefits, increasing work proficiency by increasing in-field work experiences) as well as serve more homes, resulting in synergistically higher energy savings and non-energy benefits (e.g., macro-economic impacts, occupant health, reductions in greenhouse gas emissions). One goal of the Recovery Act evaluation of WAP will be to produce data and information for policy makers to assess the optimal size question.

6.2 HEALTH & SAFETY

Both health and safety are important issues to WAP and countless others who work in affordable housing and healthy homes programs. By-and-large, the results presented above strongly suggest that weatherization services improve health and safety. Still, weatherization is deferred for many homes because financial resources required to address more than minor health and safety issues are often minimal or altogether absent. Additionally, DOE funds are not available to address specific health issues such as asthma in homes. Ways that WAP and its Grantees and Subgrantees can collaborate with health-based organizations and/or leverage other federal, state-level and even non-governmental funds to more comprehensively address health and safety issues in homes that WAP touches need to be identified.

6.3 ROLE OF WEATHERIZATION IN THE HOME RETROFIT MARKETPLACE

A theme running through the two subsections immediately above is WAP's relationships within the larger housing and health communities. For example, if WAP were able to maintain its full complement of training centers, then one could imagine that the centers could train workers not only for low-income weatherization but also for the larger non-low-income home retrofit sector (e.g., through collaborations with the Home Performance with Energy Star Program). One could even imagine that the WAP programs themselves could provide internships and mentorships for individuals seeking to work in the larger home retrofit sector.[71] Through its training centers and DOE rules and recommendations for home energy auditing, measure installation, and post-weatherization inspections, WAP could provide national technical and training leadership with respect to improving home energy efficiency.

6.4. FOCUS ON THE FUTURE

The purpose of this section is to identify major trends in society that could increase or decrease poverty in the United States generally and the need and demand for low-income weatherization services more specifically. It is organized around three questions:

1. How might the population eligible for weatherization change over time?

2. How might the number of homes needing weatherization change over time? and

3. How might energy affordability change over time?

The U.S. population is forecast to increase from 320 million to 439 million by 2050. This is a population increase of almost 40% from today. If poverty rates remain stable, then the pool of WAP eligible homes would naturally increase from approximately 35 million to 50 million. Given this projected population increase, one could expect an additional 375,000 additional low-income homes to be eligible for WAP each year. This increase would be in addition to unmet demand. For example, in PY 2008, for the reporting agencies (~65%), there were about 380,000 homes on the wait list with an average wait of approximately 325 days. Therefore, demand was much greater than supply (~97K were weatherized in PY2008). The Subgrantee respondents indicated it would take on average two or more decades to meet demand at that level of production.

It should be noted that household size has dropped considerably in the U.S. over the past 100 years, from 4.6 persons per household in 1900, to 3.38 in 1950, to 2.63 in 1990, to 2.59 over the past decade or so. If the average household size continues to shrink, then the number of homes per capita will continue to increase, thereby further increasing the pool of households potentially eligible for low-income weatherization.

Currently, according to WAP rules, only homes weatherized before 1994 are eligible for re-weatherization. If we operated under the assumption that this cut-off date automatically increases one year every year, each year a new cohort of past-weatherized homes is added to the larger pool of homes that could receive weatherization services. Let's assume that this pool is around 100,000 homes per year. Again, assuming poverty rates stay stable, the overall increase in homes that may qualify for weatherization through this channel may increase by this number per year.

Discussions in previous sections suggest that WAP households are, on average, smaller and have more health issues and disabilities than the U.S. population in general and the typical low-income household. Demographic trends imply that the pool of the U.S. population fitting the WAP demographic is going to increase substantially over the next several decades. For example, the population of persons 65 years old and over is estimated to increase from 40 million in 2010 to over 88 million in 2050 (from 13% to 20% of the U.S. population). The population 85 years and over is forecast to increase from 5.7 million in 2010 to 19 million in 2050.

The number and percentage of Americans diagnosed with diabetes is expected to increase from 11 million to 29 million, and from 4% to about 7% of the population, respectively, between the years 2000 and 2050.

[71] One ARRA period Weatherization Innovation Pilot Program grantee, YouthBuild International, is testing such a program. This project will be evaluated as part of the WAP ARRA period evaluation.

Rates for various cardiovascular diseases are also expected to increase between 2010 and 2030. For example, rates for hypertension are expected to increase from 33.9% to 37.3%, coronary artery disease from 8% to about 9%, heart failure from about 3% to about 4%, and stroke from about 3% to about 4%. Costs for treating cardiovascular diseases are expected to double by 2030, exceeding $1 trillion. Unfortunately, these and other trends suggest that the future U.S. population is likely to be much less healthy, thereby impacting their ability to maintain adequate employment and income. Based on these trends, one could argue that more than 50 million households could be eligible for WAP in 2050 and the number of homes that could experience the health benefits found to be attributable to weatherization could significantly increase.

Elderly households and those with health issues tend to depend on fixed incomes and/or government benefits to make ends meet. A New York Times article published on February 11, 2012 discussing government benefits suggests that an increasing number of Americans are dependent on the federal government for an increasing percentage of their income. Government benefits accounted for 17.6% of personal income in 2009, with the following breakdown:

- Social security – 5.6%
- Medicare – 4.1%
- Medicaid – 3.1%
- Income support (e.g., food stamps, disability payments) – 1.9%
- Veterans benefits – 0.4%
- Unemployment insurance – 1.1%

For various reasons, many Americans are heavily dependent upon Social Security. "For more than half (55 %) of elderly beneficiaries, Social Security provides the majority of their cash income. For one-quarter (26 %), it provides nearly all (more than 90 %) of their income. For 15% of elderly beneficiaries, Social Security is the sole source of retirement income (See Figure 6.1)."[72] Energy costs are only one of many serious economic issues being confronted by households dependent upon Social Security.

[72] See http://www.cbpp.org/cms/index.cfm?fa=view&id=3261 (Accessed February 15, 2012)

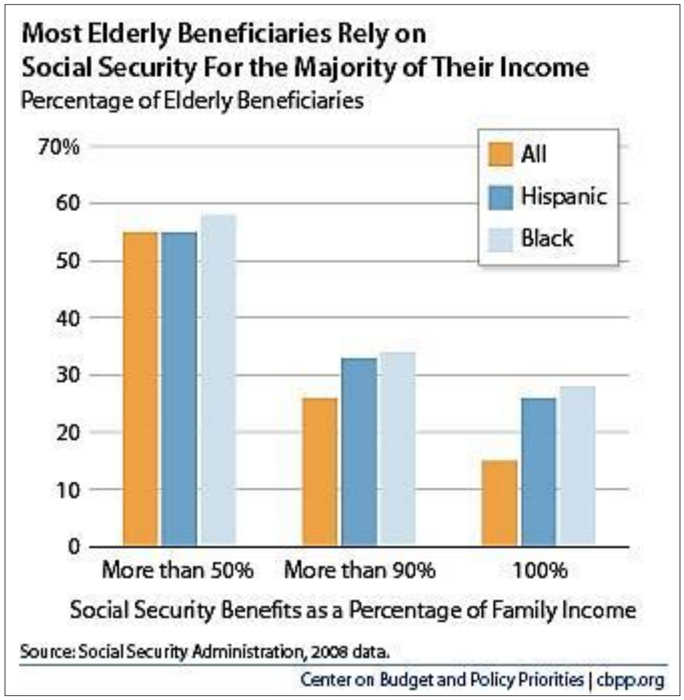

Figure 6.1. Social Security Incomes as a Percentage of Family Income

The trends mentioned above describe a future U.S. population with more households in poverty simply by virtue of population growth, and the pool of typical WAP clients increasing even more due to societal aging and the increase of individuals afflicted with serious health issues. It should also be noted that various studies suggest that social mobility in the United States has stalled. For example, one study estimates that 40% of men in the U.S. raised in the bottom quintile of households ranked by income will end up in that same income bracket through their lives.[73] This finding suggests that poverty could become even more chronic in the U.S. in the future, limiting households' ability to rise out of poverty for periods of time long enough to have the financial resources to deal with their housing and home-based energy efficiency challenges.

The reduction in household sizes mentioned above also means that the number of households with multiple income earners will continue to decrease. For example, the percent of one-parent families rose from 27% in the year 2000 to nearly 30% in 2008. The percent of one-person families has also risen from approximately 26% in 2000 to nearly 28% in 2008. One could argue that smaller households have fewer sources of income, on average, and thus could be at more risk of falling into poverty if not already in poverty. These households would also have relatively less resources to invest in energy efficiency.

System shocks (e.g., extreme weather events and other natural disasters, recessions, private sector bankruptcies and loss of investments and pensions) can be expected to increase in frequency and magnitude. For example, extreme weather events can damage homes and cause electricity outages that could ruin costly refrigerated food supplies. These catastrophes could compound daily struggles experienced by low-income households on a regular basis: a large utility bill due to an energy price increase; temporary loss of employment and income; large out-of-pocket medical costs; and emergency

[73] See http://www.nytimes.com/2012/01/05/us/harder-for-americans-to-rise-from-lower-rungs.html?_r=1&hp

home repairs. These unanticipated events have significant negative impacts on households that are already in need and can cause additional households to fall into poverty and experience extreme energy burdens.

In addition to shrinking household sizes, globalization can be expected to continue to put pressure on wages in the United States. For example, the loss of manufacturing jobs, from just over 20 million in 1980 to approximately 13 million in 2008, has effectly reduced the rolls of the middle class in the U.S. The service jobs that have increased during this period of time tend to be part-time providing lower incomes and fewer benefits. There are few signs that globalization will alter these trends any time in the future.

Thus, there are many pressures on the incomes of tens of millions of households in the U.S. What are the trends with respect to the prices of consumer goods and services? Unfortunately, the Consumer Price Index is forecast to annually increase approximately 3% between now and 2020, further straining the resources of households with limited incomes and on fixed budgets.

What about energy prices? It is widely understood that energy prices are volatile and difficult to forecast. The U.S. Energy Information Administration recently published its 2013 Annual Energy Outlook (See Table 6.1). The price forecasts are quite sensitive to assumptions. For example, if a carbon tax were implemented and the price of carbon averaged around $25 per ton from now until 2040, electricity prices would be significantly higher than in the reference case. Conversely, if new energy demand technologies are continually adopted reducing energy demand, prices could fall from the base case in the year 2040. However, from the viewpoint of a low-income household, the real prices of both natural gas and electricity are forecasted to increase over time. It should also be kept in mind that elderly households consume more energy per capita than other households because they spend more time in their homes and tend to be more sensitive to cold conditions, which makes prospective increases in energy prices particularly problematic.[74]

One piece of good news is that the energy efficiency of appliances and HVAC systems are expected to continue to improve. The table below (Table 6.2) was drawn from projections also made by the Energy Information Administration. The projections were made for nine geographic regions and forecast the average efficiency of the stock in the field in 2030 compared to the actual efficiencies in 2010. The range in the table represents the lowest and highest projections across the nine regions. These forecasts suggest that programs like WAP that fund the acquisition of new, more energy-efficiency technologies can continue to provide increasing energy cost benefits to low-income households. To take advantage of these dramatic improvements, one could reduce the time WAP must wait, due to DOE requirements, to revisit previously weatherized homes.

[74] See Tonn, B. and Eisenberg, J. (2007)

Table 6.1. Forecasted Energy Prices in 2011($) per Unit*

	2012		2026		2040	
	Nat Gas ($/MMBtu)	Elect. (Cents/kWh)	Nat Gas ($/MMBtu)	Elect. (Cents/kWh)	Nat Gas ($/MMBtu)	Elect. (Cents/kWh)
Reference Case	2.62	9.4	5.02	9.5	7.83	10.8
Carbon $25	2.62	9.4	6.06	12.4	7.77	13.6
High Oil Price	2.62	9.4	5.33	9.8	8.96	11.3
Best Available Demand Technology	2.62	9.4	4.15	9.1	7.16	9.9

*See http://eia.doe.gov

Table 6.2. Trends in the Efficiency of Selected Residential Energy End-Use Technologies

	2010	2030	Avg. % Change
Single Family			
Average Natural Gas Furnace Efficiency (AFUE)	0.83 – 0.84	0.85 – 0.93	6.4%
Average Cooling Efficiency (COP)	12.3 – 12.5	14.1 – 14.8	16.5%
Average Water Heating Efficiency (EF)	0.54 – 0.63	0.54 – 0.66	2.3%
Average Refrigerator Efficiency (kWh/year)	611.5 – 614.9	534.7 – 541.3	12.3%
Multifamily			
Average Natural Gas Furnace Efficiency (AFUE)	0.83 - 0.84	0.84 – 0.92	5.6%
Average Cooling Efficiency (COP)	12.4 – 13.1	14.1 – 14.3	11.3%
Average Water Heating Efficiency (EF)	0.54 – 0.59	0.54 – 0.66	6.1%
Average Refrigerator Efficiency (kWh/year)	612.0 - 614.9	534.7 – 540.9	12.3%

6.5 SUMMARY

Like any governmental program, WAP has its own issues and challenges to deal with. These issues fall into the categories of: program operations, health and safety, and interactions with the larger home retrofit market. Major demographic and economic trends suggest that demand for low-income weatherization will substantially increase in the future.

7. CONCLUSIONS

In PY 2008, DOE's WAP supported the weatherization of approximately 100,000 homes. Based on the evaluation of WAP during this time period, one can support the conclusions that the program:

- Is Effective
    - Natural gas consumption was reduced by almost 18% in the most common type of home weatherized by WAP – single family heated with natural gas
    - Similar energy savings were estimated for other categories of single family homes (e.g., heated with fuel oil), units in small multifamily buildings, and centrally heated large multifamily buildings in NYC
    - There is little evidence that energy savings were 'taken back' by households through increased energy use post-weatherization
    - Numerous measures suggest that households' health and well-being increased post-weatherization
    - The program supported 8,500 jobs
    - Significant reductions in GHG and other environmental pollutants can be attributable to the program
    - Overall, when considering energy cost savings and measure costs, the program is cost-effective
- Is Competent
    - The national weatherization network offered a comprehensive range of training and technical assistance programs to the weatherization community
    - Clients were extremely satisfied with the weatherization services they received
    - Weatherization staff were observed to be professional and exceedingly respectful as they delivered weatherization services
- Is Mission-oriented
    - Agencies have adopted sound non-profit management principles such as successful leveraging and partnering to help them achieve their missions
    - Numerous agencies go to extraordinary lengths to help their clients

Although the program has proven itself to be effective and competent across many categories, like most programs, there is always opportunity for growth and improvement. Areas identified for on-going improvement include:

- Increasing energy costs savings to measure cost ratios (i.e., SIRs)

- Improving the quality of work completed in the field

- Increasing the ability to address serious health and safety issues the program encounters upon engaging clients in the home environment

- Improving collaboration with players in the larger home retrofit market

- Positioning itself to meet challenges related to increasing demands and opportunities for low-income weatherization in the future

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APPENDIX A. SUMMARY OF RETROSPECTIVE EVALUATION DATA COLLECTION ACTIVITIES

APPENDIX A. SUMMARY OF RETROSPECTIVE EVALUATION DATA COLLECTION ACTIVITIES

The Retrospective Evaluation of the U.S. Department of Energy's Weatherization Assistance Program entailed a large and comprehensive data collection effort. Table A.1 lists the major data collection activities that were national in scope. Table A.2 lists the data collection activities undertaken by the numerous field studies. Details about the sample selection methodologies can be found in Ternes et al. (2007). Details about response rates and other issues related to the administration of the information collection instruments and methods are contained in the individual reports.

Table A.1. Major Data Collection Activities

Designation	Name	Description
S1	Grantees Program Information Survey	All Grantees were asked to complete this web-based survey about program finances, leveraging, program procedures and training.
S2	Subgrantees Program Information Survey	All Subgrantees were asked to complete this web-based survey about program finances, and leveraging.
S3	Subgrantees Detailed Program Information Survey	Four hundred Subgrantees were randomly selected to complete a detailed, web-based survey about audit procedures, diagnostics and training. These agencies were also asked to provide information for DF2, DF3 and DF4 as well as assist with the S4 and S5 surveys.
S4	Occupant Survey	A random sample of homes about to be weatherized and weatherized one year previously were selected for this phone survey that contained questions on energy behavior, health and safety, demographics and satisfaction with weatherization services delivered. These homes were surveyed again approximately eighteen months later.
S5	Weatherization Staff Survey	A random sample of weatherization auditors, crew chiefs, and crew were selected for this phone survey that contained questions on their careers in weatherization, job satisfaction, training, and in-field experiences. The respondents were surveyed approximately eighteen months later to track their career paths.
DF2	Housing Unit Information Data Form	A random sample of single family and mobile homes weatherized by the four hundred Subgrantees during PY2008 were selected for the Subgrantees to provide details about what diagnostic procedures were used, what measures were installed, and job costs.
DF3	Building Information Data Form	Subgrantees provided for a random sample of small multifamily and large multifamily buildings and all the large multifamily buildings in the special New York City study information on diagnostic procedures, what measures were installed, and job costs for the selected jobs.
DF4	Subgrantee Utility Bills Data Form	For each home and multifamily building heated with natural gas or electricity that the Subgrantees provided DF2 and DF3 data, the Subgrantees were also asked to provide information utility account information.
DF5	Utility Information Data Form	For each home and building included in DF4, the correct utilities were asked to complete this data form to provide up to 60 months of billing histories.

Table A.2. Field Study Data Collection Activities

Field Study	Description
Indoor Environmental Quality	This study monitored over 500 randomly select homes (treatment and control groups) pre- and post-weatherization with respect to carbon monoxide, radon, formaldehyde, temperature and humidity.
Field Process	This study assigned weatherization experts and social scientists to observe in the field approximately 450 home audits, weatherization jobs, and final inspections in 19 different Subgrantees agencies.
Subgrantee Case Studies	Visits were made to fourteen different Subgrantees for in-person discussions and field visits about their program operations
Performance Study	This study revisited approximately 100 homes weatherized in PY2008 to assess reasons why the homes achieved more or less energy savings than predicted by regression models.
62.2 Radon Study	A small number of homes (approximately 18) that tested above the EPA threshold for radon were equipped with ventilation packages that met the new ASHRAE 62.2 standards and monitored for radon levels post-weatherization.
Weatherization Training Center Trainee Survey	The Department of Energy's Weatherization Training Centers asked their trainees to complete a survey post-training about what training the received and their satisfaction with the training. The trainees were re-contacted approximately eighteen months later to collection information on career paths.