National Weatherization Assistance Program Evaluation Methods and Findings for Single Family Homes

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ABSTRACT

The Weatherization Assistance Program combines Department of Energy funding with resources from the federal Low Income Home Energy Assistance Program and other funding sources (e.g., ratepayer funds, state taxpayer funds, and federal Household and Urban Development funding) to deliver comprehensive energy efficiency services to low-income households through a network of grantees and subgrantees. DOE contracted with the Oak Ridge National Laboratory to conduct process and impact evaluations of the national WAP for 2008 and 2010. The project resulted in more than forty published reports that are available on the ORNL website. The purpose of this paper is to review important evaluation findings for single family homes, make policy recommendations based on those findings, and suggest follow-up evaluation objectives and methods. While the study found that WAP measured savings were only about 60 percent of DOE's program savings goals, there are good strategies for increasing the program performance through better targeting of high usage homes and ongoing quality improvement efforts. In addition, DOE would do well to separately track their energy savings performance and their health and safety performance to better document the value of the program.

Introduction

The purpose of this paper is to furnish the reader with a comprehensive understanding of the findings and policy implications for single family homes of the 2008 and 2010 Weatherization Assistance Program (WAP) evaluations. The paper focuses on the energy savings analysis from the 2008 evaluation. The paper also references findings on service delivery quality from the Field Process Study and the Field Study of High and Low Savers, and the non-energy benefits from baseline and follow-up Occupant Surveys.

Background

The Department of Energy (DOE) first implemented WAP in 1976 to deliver weatherization services to low-income households. At the program's inception, WAP focused on insulation and air sealing with the goal of reducing energy used for space heating, space cooling, and water heating. Today, WAP can deliver comprehensive energy efficiency services to address the full range of residential end uses.

In 2006, DOE funded Oak Ridge National Laboratory (ORNL) to work with the network of grantees and subgrantees to develop objectives for a national WAP evaluation and to consult with experts to develop technical specifications for the evaluation. In 2009, DOE funded the 2008 program year evaluation; the Office of Management and Budget (OMB) approved the Information Collection Request (ICR) for the evaluation in 2010. Subsequently, DOE funded a 2010 program year evaluation with the goal of assessing the impact of the expanded funding under ARRA. OMB approved that study in 2012.

Scope

DOE provides funding for WAP to state, territory, and tribal grantees. Those grantees, in turn, fund subgrantees to deliver the program services. In 2008, about 900 local agencies delivered WAP program services to low-income households.

The 2008 WAP evaluation found that many of the service delivery agencies receive funding from both DOE and other funding sources. WAP agencies reported that they received about $850 million in funding and delivered energy efficiency services to 181,301 housing units in 2008. However, the agencies reported that only 97,965 housing units (54%) used DOE funds and were served according to the WAP guidelines. The evaluation specifications developed by ORNL and approved by DOE and OMB restricted the scope of the evaluation to those 97,965 housing units. The evaluation found that 57,518 (59%) of the housing units served in 2008 were single family homes (i.e., a building with one housing unit).

Methodology

The 2008 evaluation included all state grantees and a representative sample of service delivery agencies and housing units. It collected information on the sampled units and installed measures from WAP agencies. It collected consumption records from natural gas and electric utilities. It included a special field metering study for housing units heated with fuel oil. Other sources of data included EIA energy price data, EPA data on emissions, and OMB data on consumer prices and discount rates.

Sample Design and Implementation

ONRL used a multi-stage sampling procedure to develop a representative sample of housing units that were treated in program year 2008. The sample frame development and sampling procedures collected data on 19,496 housing units from 365 agencies, including 10,340 treated single family homes. The sample was designed to give each treated housing unit an equal probability of selection. That approach had the advantage of limiting the amount of weighting that was required. However, at the same time, that approach did not stratify the sample to furnish robust statistics for lower-incidence housing unit types (e.g., mobile homes) or for lower-incidence geographic areas (e.g., the South).

Data Collection

The study collected data from the service delivery agencies for each sampled housing unit on household characteristics, housing unit characteristics, pre-weatherization status, energy efficiency measures, post-weatherization status, treatment costs, and other service delivery information for each treated housing unit. Agencies furnished data for 97% of sampled single family housing units.

The study team collected utility data for housing units with natural gas or electricity main heat. Data was requested from 580 natural gas and electric companies. Data was received from 428 companies covering about 66% of the sampled single family homes that heat with natural gas or electricity.

A randomized control trial (RCT) of 120 oil-heated housing units distributed throughout the Northeast region was used to develop energy savings values for housing units with fuel oil main heat. The finding from that study supplemented the billing analysis findings for natural gas main heat housing units.

Data Processing

The gas and electric savings were analyzed using multiple approaches. The primary analysis approach was a standard pre/post treatment/comparison design using weather-normalized utility billing data. The weather-normalization approach employed was similar to PRISM[1] and produced estimates of weather-adjusted annual energy consumption for each home based on monthly usage data and daily outdoor temperatures using a variable degree day base regression analysis.

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

Gross energy savings for each home were calculated as the difference in the normalized annual consumption between the pre-treatment and post-treatment periods. A comparison group of later program participants was also analyzed to reflect changes in usage, which may have occurred without the program. Comparison group usage was analyzed by subtracting one year from the actual treatment date to create pseudo pre-treatment and post-treatment periods after removing all actual post-treatment usage data. Net program savings were then calculated as the average gross savings for participants minus the average savings (i.e., change in usage) found for the comparison group. The results of the weather normalization analysis were summarized in a variety of ways to address research questions and were further explored using statistical models to estimate savings by measure and the relationship between observed savings and other factors.

Billing Analysis Results

The study furnished estimates of the main heating fuel and electric savings and program cost-effectiveness for single family homes. Subgroup analyses showed the factors that contributed to higher levels of savings and how the program's energy savings impacts and cost-effectiveness could be increased. The analysis found that sample sizes were inadequate to develop savings estimates for some important subgroups, highlighting the need to improve the sample stratification approach in future evaluations.

Energy Savings by Main Heating Fuel

Table 1 shows savings for single family homes that heat with natural gas. Weather-normalized usage for treated housing units fell from 1,020 therms in the year before treatment to 825 therms in the year after treatment, a reduction of 195 therms (19%). However, during that same period, the comparison group reduced their energy usage by an average of 14 therms. Gross program savings were 195 therms (19%) and net program savings were 181 therms (18%). Most of the savings (87%) were attributed to reductions in space heating usage based on analysis of the PRISM model outputs.

Table 1. 2008 WAP energy impacts for single family homes with natural gas main heat, gross and net gas savings (therms/year)

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

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

Figure 1 shows the distribution of the change in natural gas usage for the treatment and comparison groups. This figure clearly documents the way that household energy usage changes year over year even without installation of energy efficiency measures; the change in energy usage is normally distributed with a mode of 0 and with about 85 percent of households having a change of less than +/-12.5 percent of pre-treatment usage. However, some households have much larger changes in their usage. The graph shows that most treatment group households had a reduction in their weather-normalized energy usage. Some of those treatment group households increased their usage after weatherization, but we interpret those increases as being less than the increase that they would have experienced if their home had not been weatherized.

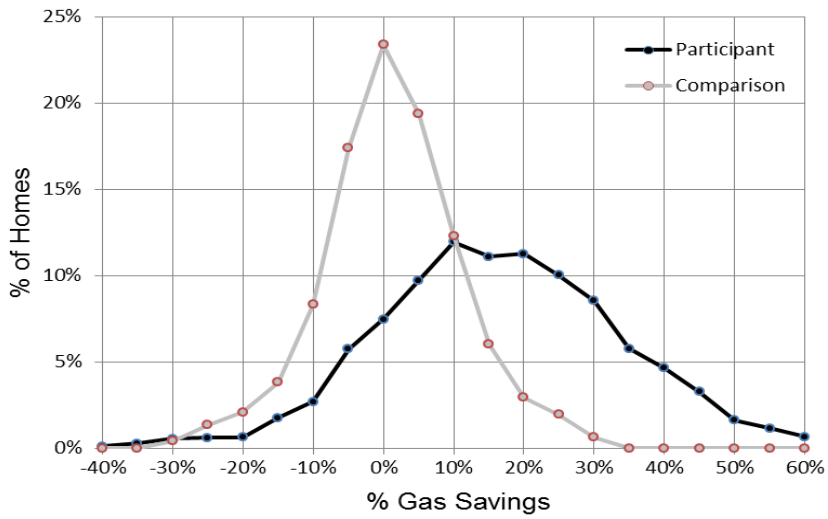

Figure 1. Distribution of gas use reduction percentage for natural gas main heat participants and comparison group

Table 2 shows electric savings for single family homes that heat with natural gas. Weather-normalized usage for treated housing units fell from 9,528 kWh in the year before treatment to 8,792 kWh in the year after treatment, a reduction of 735 kWh (8%). However, during that same period, the comparison group reduced their electric usage by an average of 56 kWh. Gross program savings were 735 kWh (8%) and net program savings were 680 kWh (7%). Most of the savings (75%) were attributed to reduction of baseload usage for lighting and refrigeration based on analysis of the PRISM model outputs.

Table 2. 2008 WAP energy impacts for single family homes with natural gas main heat, gross and net electric savings (kWh/year)

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

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

Table 3 shows that weather-normalized electric usage for treated housing units that heat with electricity fell from 19,994 kWh to 17,999 kWh, a reduction of 1,995 kWh (10%). Gross program savings were 1,995 kWh (10%) and net program savings were 1,804 kWh (9%). Most of the savings (94%) were attributed to reductions in usage for space heating and space cooling based on analysis of the PRISM model outputs.

Table 3. 2008 WAP energy impacts for single family homes with electric main heat, gross and net electric savings (kWh/year)

Group	# Homes	Use Pre-WAP	Use Post-WAP	Gross Savings	Net Savings	% of Pre
Treatment	306	19,994	17,999	1,995 (±381)	1804 (±458)	9.0%(±2.3)
Comparison	248	21,503	21,311	192 (±400)		

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

Table 4 shows savings for single family fuel oil homes. Weather-normalized usage for treatment housing units fell from 116 MMBtu per year in the pre-treatment period to 93 MMBtu per year in the post-treatment period, a reduction of 22.6 MMBTU (19%). The comparison group increased their usage by an average of 2.6 MMBtu. Gross program savings were 22.6 MMBtu (19%) and net program savings were 25.2 MMBtu (23%). All savings were metered reductions in usage for the furnace.

Table 4. 2008 WAP energy impacts for single family homes with fuel oil main heat, gross and net savings (MMBtu/year)

Usage Component	# Homes	Use Pre-WAP	Use Post-WAP	Gross Savings	Net Savings	% of Pre
Total Use	52	116 (±13)	93 (±14)	22.6 (±3.9)	25.2 (±6.3)	22.5 (±6.0%)
Comparison	35	87 (±12)	89 (±13)	- 2.6 (±3.7)		

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

The sample of housing units that heated with fuel oil had average savings that were about 40 percent higher than the energy savings for the sample of housing units with natural gas main heat. However, the fuel oil analysis sample had significantly higher spending per home than the sample of natural gas main heat housing units and the average fuel oil main heat housing units. Regression analysis was used to estimate measure-level savings impacts for natural gas main heat housing units. Applying those measure level savings estimates to the fuel oil study homes yielded a comparable estimate of savings as the metering analysis.

Factors Related to Energy Savings

Based on prior research, DOE was expecting that average energy savings for the program would be about 300 therms per housing unit for single family homes. However, the evaluation estimated that the average savings were about 180 therms, only about 60 percent of the expected value. Subgroup analysis, along with supplemental research studies, furnish insights into the reasons for the realized level of energy savings and the potential for achieving higher savings with changes in policies and procedures.

Number of Energy Efficiency Measures

The study team defined four major measures that were expected to have the greatest impact on energy savings: attic insulation, wall insulation, infiltration reduction of at least 1,000 CFM50, and furnace replacement. Table 5 shows the distribution of single family homes with respect to the number of these major measures installed. The table shows that, for those housing units with three or four of those major measures installed, the energy saving approached and even exceeded 300 therms per year. However, one-third of the single family homes treated by WAP received one major measure and one in ten did not receive any major measures. Housing units that had no major measures installed saved an average of 59 therms per year and those that had one major measure installed saved an average of 118 therms per year.

Housing units that had no major measures installed used only 866 therms per year; most of those homes already had attic insulation and relatively low infiltration rates. Other parts of the evaluation study found that agencies sometimes miss opportunities to install major measures. But, relatively low usage for many treated homes furnishes one explanation for why actual program savings fell short of expectations.

Table 5. 2008 WAP energy impacts for single family homes, gas savings for homes with natural gas main heat by measure combination (therms/year)

Number of Measures	# of Units	% of Units	Gas Use Pre-WAP	Net Savings	% of Pre
No Major Measures	342	11%	866	59 (±16)	6.8 (±1.8)
Any One Major Measure	983	32%	989	118 (±9)	12.0 (±0.9)
Any Two Major Measures	973	31%	1,035	181 (±14)	17.5 (±1.3)
Any Three Major Measures	619	20%	1,146	286 (±19)	25.0 (±1.7)
All Four Major Measures	192	6%	1,220	414 (±28)	33.9 (±2.3)

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

Pre-Weatherization Usage

Table 6 shows these statistics by pre-weatherization natural gas usage. This table shows that the lowest usage homes still had an average of 1.4 major measures installed per home. However, those homes only realized 67 therms of savings per year. Homes with pre-weatherization usage of 1,250 therms or more had an average of about 2 major measures installed per home and achieved savings of over 300 therms per year. In addition, Table 6 shows that housing units with higher pre-weatherization usage had both higher savings and higher percentage savings that those with lower pre-weatherization usage.

Table 6. 2008 WAP energy impacts for single family homes, net gas savings for natural gas main heat by pre-weatherization gas usage (therms/year)

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

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

Table 5 shows that installing more measures results in higher savings. And, it clearly demonstrates that some lower usage homes treated by the program received no major measures because they have fewer opportunities to install measures. However, Table 6 shows that about one-fourth of the homes treated by WAP use less than 750 therms per year, but still receive 1.4 major measures per home and only save 67 therms per year.[2]

Climate Zone Differences

One factor that complicates the analysis of energy usage and energy savings potential is the climate zone factor. Tables 7 shows the natural gas savings by Climate Zone, including the average number of major measures, the average pre-weatherization energy usage, and the net savings. The table shows

[2] For this table, the net savings developed by comparing the gross savings within the energy usage bin for the treatment group to the gross savings in that bin for the comparison group.

that housing units in the Moderate and Hot-Humid Zones have much lower pre-weatherization energy usage and net savings than those in the Very Cold and Cold Zones, but have about the same number of major measures installed. That suggests that the program may be installing too many measures in homes in those warmer zones.

Table 7. 2008 WAP energy impacts for single family built homes, net gas savings for natural gas main heat by climate zone (therms/year)

Climate Zone	# Major Measures	# Homes	Gas Use Pre-WAP	Net Savings	% of Pre
All Clients	1.7	3,498	1,020	181 (±13)	17.8% (±1.2%)
Very Cold	2.1	1,139	1,068	190 (±27)	17.8% (±2.5%)
Cold	1.6	1,909	1,125	209 (±13)	18.5% (±1.2%)
Moderate	1.6	311	868	140 (±47)	16.1% (±5.4%)
Hot-Humid	1.9	83	684	134 (±49)	19.6% (±7.2%)
Hot-Dry	0.2	56	490	26 (± 42)	5.3% (±8.6%)

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

However, Table 8 shows that it is likely that the investment level in the warmer zone is appropriate. Three of the major measures - air sealing, attic insulation, and wall insulation - are likely to have an impact on both space heating and space cooling usage. Table 8 shows that pre-weatherization electric usage is significantly higher in the Moderate and Hot-Humid zones than in the Very Cold and Cold zones, most likely from higher space cooling requirements and from use of electric space heaters. The net savings for the Moderate and Hot-Humid zone have higher point estimates. However, the confidence interval for the net savings values do not allow us to reject the null hypothesis that savings are not different among the Climate Zones. [Note: The 2010 program evaluation had a more robust sample of housing units in the Hot/Humid Climate Zone and found that electric savings in the Hot/Humid Climate Zone were more than twice the electric savings for the Cold Climate Zone.]

Table 8. 2008 WAP energy impacts for single family site-built homes, electric savings for natural gas main heat by climate zone (kwh/year)

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

Source: National WAP Impact Evaluation: Energy Impacts for Single Family Homes, ORNL/TM-2015/13

Policies Affecting Energy Savings

In 2008, WAP had a policy that could make it challenging for a service delivery agency to make decisions with respect to targeting housing units. Each service delivery agency was instructed to limit the average investment per home to a certain amount. For 2008, that value that was about $3,000.

Discussions with individual service providers illustrate how those policies sometimes resulted in suboptimal investment in individual homes. One provider reported that each time he had a home with many measures that qualified for installation, he had to look for a home that needed very few measures so that he could keep his average spending at the right level. Another provider reported that he found it difficult to manage to that average and so he simply treated the limit as a budget for each home. That approach is inconsistent with the WAP policy that instructs the service provider to install all measures with a SIR of 1.0 or greater. But, it is easy to see how that policy could result in a service provider delivering more measures than would be appropriate to lower usage housing units and a suboptimal allocation of WAP resources. [Note: The spending limit is still used by the program. However, it has been increased substantially and may not present the same challenges that it did in 2008.]

Another policy that can affect the average energy savings for the program is the requirement that service delivery agencies target priority households. DOE regulations identify priority households as those with an elderly household member, a disabled household member, or a child. They also allow a state to prioritize households with high energy usage or high energy burden. From Table 6, it appears that targeting high usage households would result in more installed measures, higher savings, and higher percentage savings. However, if a service provider targets a priority household without respect to the household's energy consumption, a service provider who is installing only measures with a SIR of 1.0 or greater will, on average, install fewer measures and have lower average savings.

An important policy that can affect the average energy savings for the program, but potentially increases the value of the program to clients and society, is the extensive amount of health and safety testing that is part of the program protocols. Many low-income households served by the program have problems with their energy systems that can affect the health and safety of household members. While not every low-income housing unit has these problems, the DOE WAP protocol appropriately requires service providers to conduct those tests. The time required to conduct those tests and the cost of remediating identified problems takes away from the resources available for installation of energy savings measures. However, for those households whose housing units have health and safety problems, the non-energy benefits can be significant. [Note: Market rate energy efficiency programs that adopt BPI standards also will conduct these tests and will incur both the costs and benefits of doing so.]

Summary of Findings

It is clear from Tables 5 and 6 above that the WAP can get substantial savings for low-income households by targeting high-usage housing units that need major measures installed. In addition, since there are relatively high fixed costs associated with conducting an in-depth audit of the home that includes an assessment of health and safety issues, it is likely that the most cost-effective approach to the program in terms of energy savings would be to adopt that targeting strategy. However, at this time, DOE has chosen to make the program accessible to all low-income households and to prioritize households based on vulnerability status rather than energy savings potential. While energy savings are not as high as they could be, they are significant given the number of measures that the program is able to install.

Findings from Supplemental Research Studies

Several supplemental research studies furnish additional information on how the program serves single family homes and other benefits delivered by the program, including:

- Process Field Study - In this study, weatherization experts directly observed agency staff conducting intake, performing audits, installing measures, and performance final inspections on homes to assess the quality of the work in the context of WAP best practices.

- Field Investigation of Apparent High and Low Savings Study - In this study, weatherization experts conducted onsite inspections for a sample of high savers and low savers to assess whether there were any systematic practices that led to high savings or low savings.
- Baseline and Follow-Up Occupant Survey - In this study, a treatment group was interviewed prior to weatherization and two years later to understand gross changes from the household's perspective. A comparison group of previously weatherized households was interviewed to control for exogenous factors independent of the program.

Process Field Study

The goal of the Process Field Study was to directly observe WAP agency staff conducting all aspects of WAP service delivery to assess the extent to which intake workers, auditors, field crews, and inspectors delivered program services using best practices. The study involved about 450 direct observations of the work of staff from 19 different agencies conducting audits and installing energy efficiency measures. One important finding from the study was that, for the agencies observed, the staff scored the highest in terms of their professionalism, moderate in terms of their technical performance, and relatively low in terms of their client education.

It is likely that the assessment of the technical performance is the most directly related to the level of energy savings achieved by the program. While the study found that there were certain technical procedures that almost all staff performance correctly, there were some where inconsistent performance could detract from energy savings and still others where the low rate of adoption of certain best practices suggests that there is potential for increased savings from WAP. One example of the range of technical performance is demonstrated by the following findings regarding air sealing and attic insulation:

- Materials - 95% used the proper materials for the specific application
- Gaps or Voids - 88% had no gaps or voids
- Attic Floor Air Sealing - 77% completed attic floor sealing prior to insulation
- Air Sealing Priority - 77% prioritized sealing the top and bottom of the envelope
- Air Sealing Opportunities - 57% sealed all major air sealing opportunities
- Blower Door Guided Air Sealing - 22% used the blower door to guide air sealing

These observations demonstrate that, in most cases, the weatherization crews are doing quality work with respect to the combination of air sealing and attic insulation. However, it also is clear that there is potential for improvement.

The area where program staff received the lowest rating was in terms of client education. While staff received high marks for being courteous and professional with clients, relatively few staff worked collaboratively with the client to maximize the potential for energy savings. For example, relatively few staff reviewed energy bills with clients or discussed the performance of the home in terms of hot or cold areas, drafts, and other indicators that might have been useful in diagnosing the home. That aspect of the program may represent the single greatest area of untapped potential for energy savings.

Field Investigation of High and Low Savers

The goal of the Field Investigation of High and Low Savers Study was to assess whether there were any systematic practices that led to either high or low savings that should either be replicated (high savers) or avoided (low savers) by the program. The study team identified a sample of homes for which measured energy savings were substantially higher than expected or substantially lower than expected given the reported energy efficiency measures that were installed in the home.

While the study focused on homes that had high or low savings relative to the installed measures, the study also examined the homes to assess whether there were measures installed that should not have been installed or measures not installed that should have been installed. The inspections found that about one-half of the low savers had missed opportunities that could have increased savings. However, a surprising finding was that one-fourth of the high savers also had missed opportunities.

The most important finding with respect to low savings in terms of work quality was that about 20 percent of the low savers had measure failures that appeared to be the result of poor work quality. That finding is consistent with the Process Field Study discussed above where there was some potential for increasing quality and thereby increasing savings.

For about one-third of the low savers, it appeared that changes in the use of supplemental heat had an impact on the final saving estimate. The housing unit was using less total energy, but had a large reduction in their electric bills because of reduced use of electric space heaters, and a smaller reduction in their usage of natural gas. This highlights the importance of getting both the main heating fuel and electric bills even if there are relatively few electric baseload measures installed by the program.

Overall, the study found that work quality was one factor in the performance of individual homes. Improving work quality should have an impact of the program's performance. However, while only about 20 percent of low savers were found to have measure failure problems, about 50 percent had missed opportunities. That may be a more important finding from this study.

Pre- and Post-Weatherization Occupant Survey

The goal of the Occupant Survey was to obtain client self-reports that could be used to measure WAP non-energy impacts. The baseline survey was conducted with clients prior to the initial audit of their homes and the follow-up survey was conducted with clients two years later. Clients were not asked to report on changes to their homes. Rather, they were asked about their perceptions about their homes at the time of the survey. The gross treatment change was calculated by comparing the status in the baseline survey to the status in the follow-up survey.

A comparison group of households also was interviewed. Because it was not possible to select a sample of households that would not be treated by WAP, the comparison group was households that had been treated by WAP one year prior to the baseline survey. The assumption was that the comparison households would be affected by exogenous changes in the same way as the treatment households, and that the net change due to the treatment would be the gross change experienced by the treatment households net of any changes to the comparison group. One example of an important change that affected both the treatment and the comparison group was the implementation of the Affordable Care Act (ACA) during the period between the baseline and follow-up surveys. Both groups had an increase in the percent of households with continuous health insurance coverage because of the ACA.

The treatment group had 454 clients who completed both the baseline and follow-up surveys and received weatherization services through WAP. [Note: There were 56 clients who completed both the baseline survey and the follow-up survey but did not receive WAP services.] The comparison group had 430 clients who completed both the baseline and follow-up surveys. Comparisons between the two groups show that the two groups are similar, but certainly not identical in terms of their important geographic and demographic characteristics. The treatment group was more likely to be in the Cold Climate Zone, was less likely to be elderly, and was less likely to be a homeowner.

The occupant survey identified significant changes in the quality of the housing unit from the perspective of the client. Table 9 shows that there were statistically significant changes in the percentage of clients who reported that their home was infested with insects, had a mildew odor, was drafty, was too cold in the winter, and was too hot in the summer. After weatherization, more than 90 percent of households reported that their home was never at an unhealthy or unsafe temperature, an increase of 12 percentage points from their baseline reports. In addition, the survey found that the comparison group reported only small changes on these housing unit conditions, verifying that the treatment group changes were not a result of other exogenous factors.

These improvements in the quality of the housing unit are consistent with the expected impacts of the installation of weatherization measures. They also appear to be a direct result of WAP's attention to details related to moisture in the home. While the program does not eliminate problems, the occupant survey shows that it has a significant impact on these problems.

Table 9. Gross and net changes in client self-reports, baseline (2011) and follow-up surveys (2013) for treatment and comparison group households

	Treatment			Comparison			Net
Problem	**2011 %**	**2013 %**	**Change**	**2011 %**	**2013 %**	**Change**	**Change**
Somewhat or Very Infested	24%	14%	-10%	14%	17%	+3%	-13%*
Mildew Odor/Musty Smell	29%	21%	-8%	15%	16%	+1%	-9%*
Mold Observed	24%	19%	-5%	17%	16%	-1%	-4%
Drafty Most or All of the Time	29%	6%	-23%	8%	5%	-3%	-20%*
Home Cold or Very Cold	39%	16%	-23%	18%	15%	-3%	-20%*
Home Hot or Very Hot	39%	26%	-13%	26%	22%	-4%	-9%*
Home Never at Unsafe Temp	81%	93%	+12%	91%	91%	0%	+12%*

*Source: Unpublished statistics developed by APPRISE, April 2017 (*Statistically significant at 99% confidence level)*

It is more difficult to directly attribute changes in health outcomes to WAP using the occupant survey. Table 10 shows that for general health status questions, the occupant survey demonstrates that clients report statistically significant improvements. For example, clients report a gross change in "no days of poor physical health in the last 30 days" of 5 percentage points; that was a net change of 10 percentage points.

Table 10. Gross and net changes in client self-reports, baseline (2011) and follow-up surveys (2013) for treatment and comparison group households

	Treatment			Comparison			Net
Health Status	**2011 %**	**2013 %**	**Change**	**2011 %**	**2013 %**	**Change**	**Change**
No Days Poor Physical Health	45%	50%	+5%	51%	46%	-5%	+10%*
No Days Poor Mental Health	58%	60%	+2%	58%	63%	+5%	-3%
Able to do Usual Activities	53%	59%	+6%	56%	57%	+1%	+5%*
Has Asthma	15%	17%	+2%	15%	16%	+1%	+1%
Overnight Stay due to Asthma	2.6%	2.0%	-0.7%	1.2%	0.9%	-0.3%	-0.4%
ER Visit due to Asthma	1.8%	2.0%	0.2%	2.6%	2.3%	-0.2%	+0.5%

*Source: Unpublished statistics developed by APPRISE, April 2017 (*Statistically significant at 99% confidence level)*

The analysis of asthma was more challenging. First, survey respondents gave inconsistent responses on whether they had ever had asthma between the two surveys; the project team re-contacted respondents with inconsistent responses to verify their status. Second, the survey found a net increase in clients who reported that they currently have asthma. Finally, only a very small percentage of clients had a "medical event" from asthma; among the 454 survey respondents, only 23 reported a medical event in the baseline survey and only 18 reported a medical event in the follow-up survey. The net change for an overnight stay due to asthma is not statistically significant and rounds to 0%. The net change for an emergency room visit is an increase that is not statistically significant. Moreover, both of these medical events might be affected by the fact that the treatment group had a net increase in the percentage of clients who had insurance coverage for the previous twelve months.

Recommendations

The National Evaluation was successful at measuring the energy savings and other impacts for single family homes. The evaluation found that the program delivered both heating fuel and electric savings. The measured level of energy savings was somewhat lower than DOE had expected from a number of state-level studies that had been conducted prior to the national evaluation. Subgroup analysis found that the lower than expected savings results were due, at least in part, to lower than expected measure installation rates and because the program treated a significant number of homes in cold climate zones that had relatively low pre-weatherization energy usage. Those findings were consistent with the DOE WAP policy that targets households based on vulnerability characteristics rather than energy consumption. Supplemental field studies found that the program also could increase performance by improving the technical quality of service delivery and reducing the number of missed opportunities.

The WAP Occupant survey confirmed that, in addition to energy savings, the WAP treatment protocol delivers non-energy benefits related to improvements in the indoor living environment and, potentially, health benefits to clients. From that perspective, the WAP policy of conducting a detailed audit for each home and treating both energy and energy-related issues in the home seems to be consistent with the program's broader policy objectives. However, a focus on ensuring that the program addresses a client's health and safety issues in not necessarily inconsistent with targeting higher usage homes. Higher usage homes are likely to present greater affordability problems for clients, have a higher level of infestation of pests because poorly sealed homes offer opportunities for entry to the living space, and present more health issues for seniors with circulatory issues because they are colder and draftier.

Conducting a national evaluation of the program implemented by individual states presented expected challenges for data collection and processing, but also presented important challenges for analysis and interpretation. The most important issue for the WAP evaluation was that each state has a different set of funding sources, and a different way of coordinating WAP funding with non-WAP funding. To assess how WAP policies affect program outcomes requires a complete understanding of the decisions that individual agencies are making in response to those policies. That work needs to be done on a state-by-state basis, would require the collection of better detail for individual jobs, and should compare jobs categorized as WAP and non-WAP. For that reason, we would recommend that DOE focus on state-level evaluations for policy assessment and on national-level evaluations for statistics on program impacts.

References

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