# [UNITED STATES] Weatherization Assistance Program

## About the measure

| Policy instrument | Sector | Starting date and status |
|---|---|---|
| **Financial (grants)** | **Residential** | **[1976] – [on-going]** |

U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) was developed by Congress in 1976 under Title IV of the Energy Conservation and Production Act. WAP's current scope and objective 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 quoted in (Tonn, et al., 2014)). Households have to meet one of two **eligibility criteria**: to have an income at 150% of the federal poverty rate, or equal to or less than 60% of the state medium income. The household income threshold increased from 150% in 2008 to 200% of the Poverty Income Guidelines in 2010. Under these requirements, the WAP offers low-income eligible households:

1) a **free energy audit** to identify and prioritize energy-saving actions; 2) **funding for energy efficient actions** to be implemented by registered installers (with a cap on average spending per house at state level)[1], and 3) **on-site verifications** by an inspector that also provides households with energy advice.

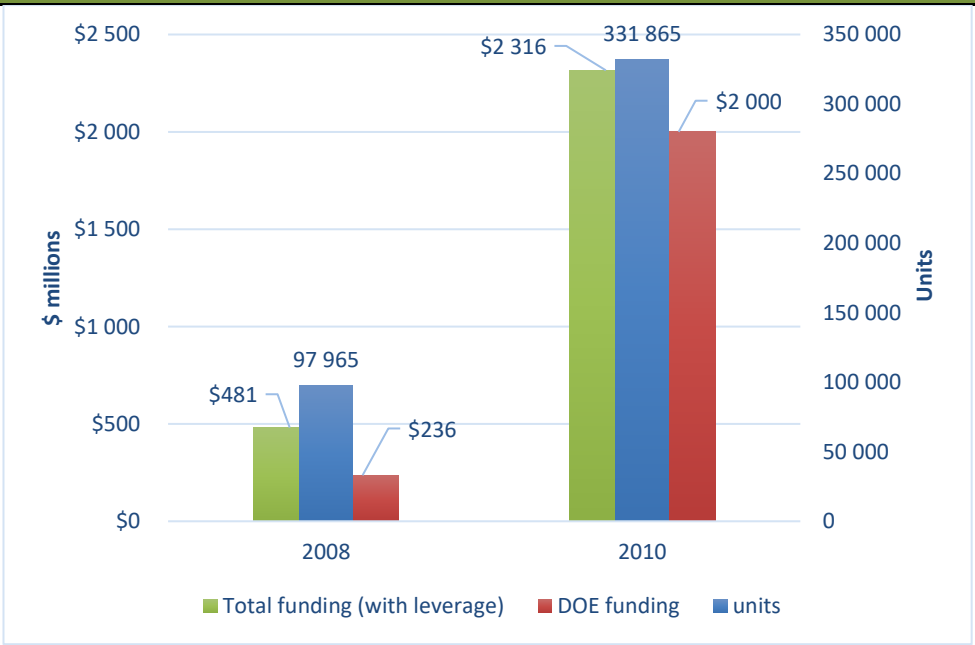
The DOE provides grants to states (**Grantees**), and states provide grants to local weatherization agencies (**Subgrantees**) to weatherize homes occupied by income-eligible households. The **National Association of State Community Services Programs** (NASCSP) supports the Grantees and maintains the **WAP Technical Assistance Center**, which provides up-to-date information about WAP such as training and technical assistance information. In addition, the **National Community Action Foundation** (NCAF) gathers the traditional weatherization Subgrantees (Community Action Agencies). Finally, most of the states and local agencies leverage WAP funding to secure **additional funding** for low-income weatherization from their states, regional utilities, and other sources (Tonn, et al., 2014).

[1] Each state (Grantee) is required to ensure that the overall annual WAP expenses will not exceed a given average spending per house weatherized. In practice, the Grantees then recommend each WAP operator (Subgrantee) to limit their spending to the same average spending per unit. However, Subgrantees might adapt this constraint to take into account differences in weatherization needs. They might for example spend as much as $10,000 on some units and only $2,000 on others.

The EPATEE project has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 746265.

| Expected results | Benchmark |
|---|---|
| There was no official quantitative target set in terms of expected energy savings.<br><br>The objectives are usually expressed in terms of number of dwellings to be weatherized per year.<br><br>During the ARRA (American Reinvestment and Recovery Act) period with the addition of ARRA funding, the expectation was that weatherization activity would exceed 300,000 homes per year (see more details about the ARRA period in the next section). | In general for normal program years, WAP's annual appropriation has been in the range of $200-250 million, supporting the weatherization of approximately 100,000 homes. Approximately 35 million households were eligible for WAP in PY (Programme Year) 2008 or ~30% of all U.S. households. In addition, given the projected population increase, an additional 375,000 low-income homes were anticipated to become eligible for WAP each year until 2050 (Tonn et al., 2014)[2]. Reportedly, the increase would be additional to unmet demand. |

**Means and outputs**




***Source:*** *Based on (Tonn, et al., 2014) (Tonn, et al., 2015). The total number of weatherized units in 2010 excludes a small number of large multifamily units for which no information was collected about, and also weatherized shelters (e.g., mobile homes). For completeness, the total number of weatherized units is 340,158.*

**Figure 1**. Funding (in million dollars) and number of weatherized units in Program Years 2008 and 2010.

[2] This estimate is subject to debates, as the proportion of un-served population is difficult to assess because constantly changing: each year several million households have an increase in income that makes them no longer income-eligible for WAP and several million households have a reduction in income that makes them newly income-eligible for WAP.

Annual WAP funding, and consequently the number of units weatherized per year, has changed significantly over time (for more details, see for example Millhone, 2009). Based on Tonn et al. (2014), it was chosen to present in this case study the data for Programme Year (PY) 2008 and 2010, i.e. respectively one year before and one year after the Recovery Act. The **American Reinvestment and Recovery Act** (**ARRA**) (passed in 2009) provided a **substantial funding increase** in WAP from approximately $230 million per year to $5 billion over a three-year period. WAP during the ARRA period was expected to perform much differently than in previous years.

**Total funding:** refers to the total expenditures on units weatherized that included DOE funding. Most states and agencies leverage DOE WAP funds to acquire additional funds for weatherization from their states, regional utilities and other sources. The total funds spent by the entire national weatherization network are not presented here, as homes weatherized with no DOE funds invested were determined to be beyond the purview of this DOE-funded evaluation. From the PY 2008 total funding, 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. Use of funding is monitored by funding sources (DOE, state, utilities, etc.) and per Grantee and Subgrantee. For PY 2010, the weatherization workforce was greatly expanded, recruited, trained, organized and sent into the field. As a result, the share of spending allowed for training and technical assistance was raised from 1% to 20%. Finally, WAP Grantees and Subgrantees also had to adhere to the provisions of the Davis-Bacon Act with respect to prevailing wages and paperwork reporting. Davis-Bacon requirements increased weatherization costs through increases in wages for weatherization staff and administrative costs for manpower to handle the extra paperwork.

**DOE funding**: refers to the total DOE funds invested in the weatherization of home without leverage. During PY 2008, states and agencies were constrained to spend no more than an average of $2,966 of DOE funds per weatherized home. This average cost ceiling was raised to $6,500 for PY 2010. The increase in available funds was also reflected in the average cost to weatherize a DOE unit that was estimated to amount to $4,695 in PY 2008 (the DOE share was 48%) and was raised to $6,812 in 2010 (the DOE share for investments in units that received some DOE funding was 87%). Lastly, the local programs were allowed to invest a small amount of money to deal with health and safety issues found in homes (maximum average at state level of 15% of funds invested per weatherized unit, with usually many units that do not need any health or safety intervention while others might need up to several thousand dollars). Use of DOE funding is monitored quarterly, with data registered per Grantee and Subgrantee. The evaluation team worked with Grantees and SubGrantees to select a representative sample of participant households served by the program in the respective PYs.

**Units**: includes to the total number of homes weatherized during a given Programme Year. Throughout the evaluations, housing units were categorized into four housing types: i) Single Family houses, ii) Small multi-family houses, iii) Mobile Homes, iv) Large Multi-family houses. Despite the fact that the WAP uses three rather than four categories of housing unit types in its quarterly reporting and other functions, essentially merging single family houses with small multi-family ones into site built homes, these two categories were treated separately in the evaluations. A house or housing unit is considered weatherized once the action installation and the final inspection has been completed. A DOE unit is

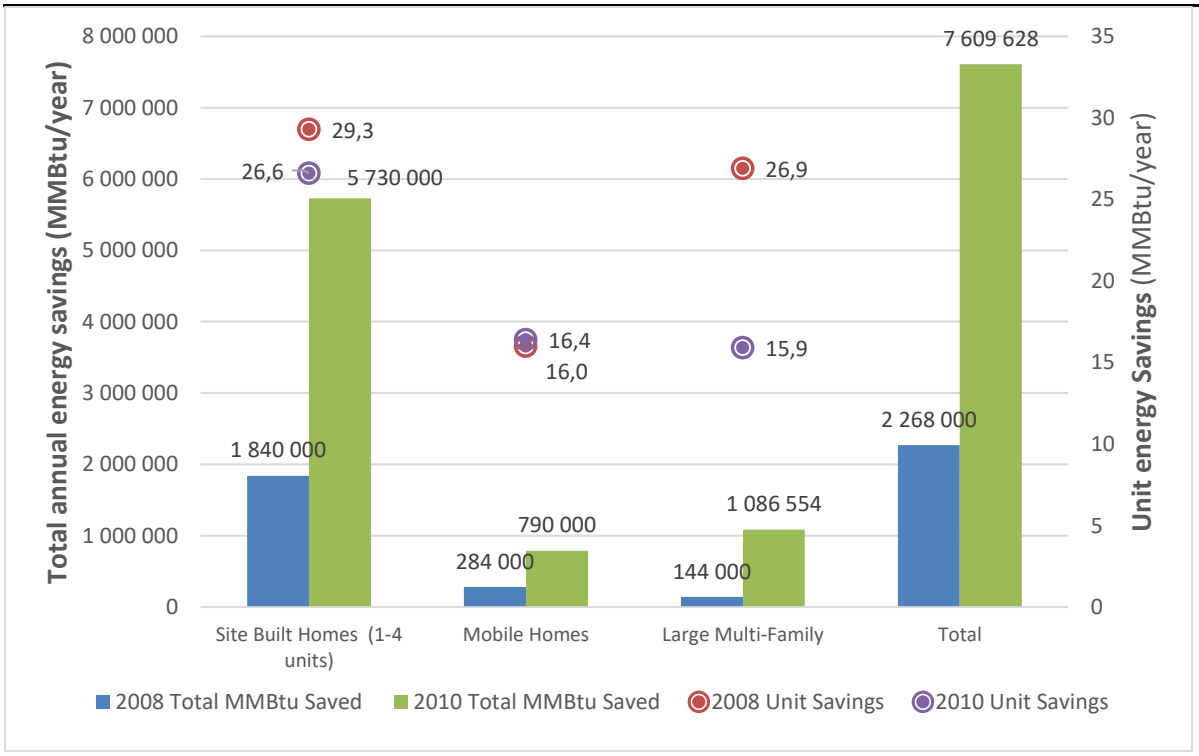
defined as any weatherized home that received at least $1 dollar of DOE funds. The retrospective evaluations (funded by DOE) only addressed energy savings in DOE homes. Data about DOE units are available by climate zone, and include the number of major actions (e.g., air sealing, insulation, furnace replacement) by building type etc. For the rest of this case study, DOE housing units will be referred to as participant-houses or simply units for reasons of simplification.

WAP funds supported the weatherization of 97,965 units in PY 2008. Whereas about 380,000 homes were on the wait list with an average wait of approximately 325 days. Therefore, demand for weatherization eligible homes was much greater than supply.

WAP funds supported the weatherization of 340,158 units in PY 2010, meaning that the objective to exceed 300,000 homes per year was met.

**Data about energy savings**

| Unit | Main source of data |
|---|---|
| Total annual final energy savings achieved from units weatherized by the WAP per year in millions of British thermal units (MMBtu/year). | Evaluation reports done by the Oak Ridge National Laboratory. |




*Source: (Tonn et al., 2014) for 2008 data, and (Tonn, et al., 2015) for 2010 data*
*Note: 1 MMBtu =1.055 GJ = 0.29 MWh = 0.025 toe*

**Figure 2.** Estimated annual final energy savings by house type for PY 2008 and 2010 (in MMBtu/year).

Note: The savings estimates for "large multifamily" in 2008 are all coming from units weatherized in New York City. Based on David Carroll's review of these findings, there are some doubts about possible mistakes in the way

these results were weighted. David Carroll would thus suggest to consider that the energy savings in large multifamily buildings were "undetermined" for 2008.

**Total annual energy savings:** first-year final energy savings for all units who received a WAP funding in each program year. They represent **weather-normalized net** energy savings (estimated by a statistical comparison of a sample of participants with a control group - see more details below).

**Unit energy savings**= represent average annual savings per participant-household. These are first-year final energy savings achieved in a given PY from each housing-unit type weatherized within the PY under evaluation (metered savings). They also represent net energy savings, as they are estimated on the grounds of **weather-normalized net** savings estimates for individual houses and buildings using PRISM model (see more details below). Unit energy savings for each housing-unit are averaged over the sample by the number of units weatherized. For small and large multi-family buildings, building-level energy consumptions and savings calculated were divided by the number of units in the building to calculate unit-level values to facilitate comparison and aggregation with other buildings.

As part of the PY 2008 evaluation report, an Indoor Environmental Quality (IEQ) study about works completed during the ARRA period concluded that there **was no rebound effect relevant to home heating**. Data on indoor temperature for weatherized and control homes were collected for about one month preceding and following weatherization during closed-home conditions[3].

Both evaluation studies assume there is **no free-rider issue** since most of homes in the WAP are low-income with documented problems in paying everyday bills. In other words, the evaluation results support the assumption that none of the households whose homes were weatherized would have undertaken weatherization without WAP. The use of comparison group showed a small reduction in weather normalized usage during the analysis period. That indicates that there might have been "some" actions taken by the comparison group, but to a limited extent. That also shows the importance of using a comparison group in the evaluation.

Available data also include average annual energy savings achieved in 2008 and 2010 in percent and absolute value savings by climate region, housing type, primary space-heating fuel type, and the five participants' types that WAP is specifically instructed to focus on (i.e., the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden). The evaluation studies did not examine energy savings by demographic group so far. But this analysis is under consideration for further research.

[3] Closed-house conditions require that every window and door (that can let outside air enter the home), on every level of the house, be closed during the testing except for normal entering or exiting of the home.

### Sources of uncertainties about energy savings

- Care was taken to limit uncertainties due to sampling (see more details below), as well as selection biases when calculating the total annual energy savings and the average annual per-household savings (e.g. for houses in the hot-climate region for which attrition has been high and statically significant savings have been difficult to measure, with a too small sample for PY2008, which was then improved with a larger sample for PY2010 enabling to get more robust results). Regarding the latter, the ORNL (Oak Ridge National Laboratory) aggregate model was applied as it identifies baseload consumption allowing to estimate uncertainties in parameters and calculation of values with a statistical basis.
- Computerized energy audits conducted do not seem to have been systematically calibrated with actual energy usage for each home-unit (i.e. baseline energy use and amount of energy savings might be overestimated). Some state grantees do require this calibration, whereas other do not. Experience shows that results are much better in states requiring calibration.
- Sensitivity Analysis was foreseen to be undertaken for the PY 2010 retrospective evaluation (Tonn, et al., 2011), to observe how yearly estimates of energy and costs savings may alter due to changes in key driving factors, such as changing demographics in the houses, loss of housing stock, volatile fuel prices, technology evolution, and weather conditions. Sensitivity analysis was also foreseen for determining the impact of key assumptions used in the calculation of Savings-to-Investments Ratio. This approach would allow the assessment of the influence on Savings to Investment Ration (SIR) of uncertainty in key assumptions (e.g. real discount rate, action lifetime, monetary value of non-energy impacts), from probability distributions (Tonn, et al., 2015). However, this analysis was finally not included in the results of the latest retrospective evaluation.

## Evaluation of the energy savings

### Calculation method(s) and key methodological choices

- The **total annual energy savings** and the average annual savings per participant-household (also called "**unit energy savings**", see above) were calculated based on energy bills analysis (= **metered energy savings**, method 2), with and without adjustments for savings in a comparable set of **control homes and buildings**.
- These energy savings were determined with a **bottom-up approach** by starting from estimating weather-normalized savings for samples of individual houses and buildings. **Stratified sampling** of subgrantees (implementing agencies), and subsequently of housing/building units, were done **at states' level**. Annual energy savings achieved in each state in each PY were then estimated by extrapolating the savings in the samples, using **weighting factors**. These factors were based on how the agencies/sub grantees were sampled, the size of the agencies, the number of houses sampled, and the number of houses weatherized in each state. The samples of participant-homes provided by SubGrantees were weighted to account for sampling rates and to adjust for study nonresponse. The weighting process included the calculation of the Base weight (i.e. the inverse of participant's probability of selection) and the State-Level Adjustment. For each state, the weights for each participant house were adjusted to match state's number of weatherized units by housing unit type. Results for each state were finally aggregated to calculate the total annual energy-savings for WAP.

- Two baselines were used when evaluating the total annual energy savings and the average annual savings per households. **Gross energy savings** were evaluated by comparing energy consumption before and after the WAP intervention ("**actual before**" baseline). The evaluation used one year of data before and one year of data after the WAP intervention to determine the baseline consumption. **Net energy savings** were evaluated by comparing changes in energy consumption between the samples of participants and control groups ("**control group**" baseline). This later approach was used to control for changes that would have occurred in the absence of the Program such as occupant behaviour and fuel prices that influence households' energy consumption (for more details see *Focus on method to determine (additional) program savings*). It should be noted that the evaluators assumed that differences in the estimated savings between the control and treatment group should be attributed to factors such as occupant behaviour and fuel prices and not owning to free-ridership. They thus assumed that none of the households whose homes were weatherized would have undertaken weatherization without WAP.
- **Unit energy savings** were established on the basis of the same **billing analysis (metered energy savings, method 2)**. A **quasi-experimental approach** was adopted for the two retrospective evaluations (PY 2008 and PY 2010). A probability proportional-to-size sampling (PPS) was applied (with size measured as agency/sub grantee funding) to subsample 400 sub grantees (out of ~900) for PY 2008 and 450 sub grantees for PY 2010 (for more details about the sampling approach, see appendix O of (Tonn et al., 2011)). Selected sub grantees provided natural gas (NG) and/or electric utility account information for the units they weatherized in PY 2007, 2008 and 2009 (for the Retrospective Study), and 2010, 2011, and 2012 (for the ARRA study) respectively. The required NG and electric utilities were contacted by the evaluation team to gather the billing histories. Sixty months of energy bills were collected from electric and natural gas companies in order to identify usage for periods of 12 months pre-weatherization and 12 months post-weatherization. Energy bills were collected in the same way for the control group. Approximately one-third of housing units[4] from each list submitted by a Subgrantee were selected to be included in the sample for energy analyses. Eventually for PY 2008, a total of 19,496 participant houses were included in the sample, whereas for PY 2010, 35,030 participant houses served by the WAP were sampled. The total usable analysis sample for each PY was further reduced to account for attrition[5] and non-response rates. Most of this attrition was due to too little pre-retrofit data. The utility data collection process and the sample size were determined in a manner so that the nationwide total annual energy savings (and average energy savings per housing unit) attributable to the WAP could be estimated to within ~15% of its actual value at a 90% confidence level after non-response and attrition were taken into account.

[4] Sampling one-third of the units, included in the lists of the sampled subgrantees and weatherized in a targeted program year, yields a treatment sample size of approximately 10,000 units (out of approximately 100,000 WAP weatherized per year pre-ARRA). An equal number of units should be in the control group, to be drawn from homes weatherized during the following program year.

[5] Attrition rate is a calculation of the number of individuals or items that vacate or are removed from a larger, collective group or sample over a specified time frame.

- Using a quasi-experimental approach means that energy savings were evaluated by comparing changes in energy consumption between the sample of participants and a control group over a same period ("**control group**" baseline) (see more details below in *Focus on method to determine (additional) program savings*). Units in the control group were drawn from homes weatherized during the following program year. This choice is reasonable because this group, similar to the treatment group, has self- selected to apply for weatherization and the two groups are likely to be similar in all variables correlated to energy use. Energy consumption were also **normalized to a typical-weather year** when assessing changes in energy consumption for each housing unit.
- **Weather-normalized** savings estimates for the individual housing units and buildings were calculated using the Princeton Scorekeeping Method (PRISM), the ORNL Aggregate Method, other statistical methods or a combination of these based on normalized annual consumptions (NACs) especially for house-cases that cannot be well determined (e.g. the case of electricity use in homes where electricity is not the primary heating fuel or fuel use in homes in hot climates with little heating load, see more details below in *Focus on approach to validate or triangulate program energy saving estimates*).
- An **attribution methodology** was also foreseen in the evaluation plan for the PY 2010 evaluation, categorizing weatherization into a set of activities (program management, outreach and marketing, client selection, audit and action selection, action installation, and training). The influence of these activities on energy savings and cost savings was foreseen to be estimated by a panel of experts and a decision-matrix approach (Tonn, et al., 2015). The results of such a method were not included in the results of the WAP PY 2010 latest evaluation.

## Ex-post verifications and evaluations

According to the World Energy Council (WEC, 2010), WAP is considered an exemplary case in terms of its monitoring and evaluation scheme. First, states/grantees are required to **report quarterly** on their expenses, number of homes weatherized and annually on other performance data. DOE closely monitors grantees performance through the Quarterly Program Report, the Quarterly Financial Status Report, and the Annual Training and Technical Assistance, Monitoring and Leveraging Report (DOE, 2010). This is favored by the use of a **web-based interface** (http://www.ecw.org/weatherization/index.php), where state agencies can directly enter their data and also receive technical support (FAQ, etc.).

DOE also performs weekly, monthly, and quarterly **desktop reviews** as well as site visits on grantees' performance. DOE overview also entails quality assurance (QA) visits. These **quality assurance visits** occur at the Subgrantee level. Grantees are required to conduct comprehensive monitoring of each sub-grantee at least once a year. The comprehensive monitoring must include review of client files and SubGrantees records, as well as **inspection of at least 5 percent of each SubGrantees' DOE-funded completed units**. Finally **tracking of major findings** from Subgrantee monitoring visits is conducted by the Grantee to final resolution. The tracking records usually include success stories, recommended corrective actions, actions taken, and final resolutions and are summarized into an internal monitoring report for consideration and review during **annual planning** (DOE, 2010).

Second, as mentioned above, the **ORNL** is in charge of the **evaluation of the WAP at the national level**. They performed a comprehensive evaluation in the early 1990's (see below), and then have periodically produced meta-evaluation based on the reports done by the states.

The process for conducting the evaluation starts at the request of DOE from the ORNL to develop a national evaluation plan. ORNL developed and published a comprehensive plan in 2007 and 2011 respectively for the two retrospective evaluations (i.e. for PY 2008-2009 and 2010-2011). In turn ORNL organized a National Weatherization Network Committee (i.e. weatherization officials, local weatherization officials, DOE staff, ORNL staff, and independent evaluators) to provide input and data for the retrospective evaluation in 2009. The same process was followed in 2010 and the committee was reconstituted for the WAP ARRA period evaluation. The main components of the evaluation included the Impact Assessment, Process Assessment, Special Technical Studies and a Synthesis study. In turn, the members of the team contacted all the states (i.e. Grantees) that received DOE WAP funding, who then shared their state monitoring weatherization databases with the evaluation team for the evaluations. The mining of these databases was handled by the evaluation team who extracted information from the databases to pre-populate Grantee and Subgrantee surveys and data forms[6]. The DOE WAP managers examines the potential of working with the Grantees to increase the usefulness of their databases for future evaluations.

Reportedly the committee faced a major challenge with the collection of utility bills. Main hurdles related to utility bill waivers that utilities require prior to releasing utility bill information (e.g. Subgrantees forget to ask their weatherization clients to sign waivers, utilities reject the standard waivers used by Subgrantees). In the future, WAP managers might consider working with utilities to develop standards for utility waivers that the program could then adopt for next evaluations. One challenge about this is that each state has its own privacy rules and its own public utility commission. Therefore, what is acceptable in one state may not be acceptable in another. While a national standard approved by DOE, the electric industry, and the natural gas industry could be useful, the waiver language and procedures would thus need to be customized to each state.

It is important to mention that other independent evaluations have been conducted with respect to the WAP impacts and cost effectiveness (Graff Zivin & Novan, 2015), (Fowlie, et al., 2015). (Fowlie, et al., 2015) suggest that the federal WAP upfront investment costs substantially outweigh the actual energy saving benefits, even when accounting for the broader societal benefits derived from emissions reductions. With a similar focus, (Graff Zivin & Novan, 2015) conclude that the actual energy savings achieved by the efficiency upgrades from weatherization programs, when disentangled from behavioral treatments, are substantially smaller than ex-ante engineering predictions. These findings have challenged many past studies as well as the more recent national evaluations conducted by ORNL,

[6] Subgrantees (i.e. agencies) can provide similar information to their respective states. Where possible, the evaluators collected data from the state grantees. However, in most cases, it was needed to get certain data from the subgrantees (i.e. agencies not states) to verify the accuracy and consistency across all states and agencies.

which concluded that WAP energy savings exceed the costs by a factor of 1.4. (see more details in the *Focus on* section further on).

## Other indicators monitored and/or evaluated

| Indicator | Explanations |
|---|---|
| Health related Impacts | Asthma, Thermal Stress-Cold/Heat, Food assistance reduction, Reduction of Missed Days at work, CO poisoning, Improvement in Prescription Adherence, Reduction in use of short-term loans, home fires, Increased productivity at work/home due to improved sleep, Reduction in Low-Birth Weight Babies from Heat-or-Eat Dilemma. They were estimated based on a national survey of occupants (with a comparison group) and data collected on measures installed in homes by WAP. Cost estimates for medical treatment were retrieved from national medical databases. |
| Quantity of Avoided Emissions | Avoided greenhouse gases (GHG), sulfur dioxide, nitrogen oxide and particulate matter emissions associated with the energy usage reductions for each type of energy. Published data sources were used to estimate avoided emissions associated with the energy usage reductions for each type of energy. |
| Value of Avoided Emissions (State-Level) | Dollar value of avoided greenhouse gas emissions was computed using Air Pollution Emission and Policy Analysis Model (APEEP). |
| Macro-economic employment impacts | Average number of direct and indirect jobs created per dollar spent on weatherization |
| Energy Cost Savings, Energy Efficiency Action Costs, and Savings to Investment (SIR) Ratio | The present values of the energy cost savings were calculated based on expected action lifetimes, U.S. Energy Information Administration (EIA) estimates of future energy prices, and Office of Management Budget (OMB) discount rates for 2013. Under WAP, each installed action needs to pass a SIR test, where the present value of the energy cost savings over the life of the action (e.g., 20 years) needs to exceed the present value of its cost (i.e., SIR >= 1.0). These SIR ratio estimates were calculated by dividing the present value of estimated energy cost savings over the lifetimes of the actions by the costs of the installed actions. |

*Source: (Tonn, et al., 2015)*

These indicators have been applied for both the retrospective and the ARRA period impact assessment for PY 2008 and 2010 respectively.

## Other aspects evaluated

The scope of the national evaluations for PY 2008 and 2010 conducted by ORNL also included the following components:

**Process Assessment:** explored how the weatherization network delivers services, evaluated how service delivery under WAP compares to national standards, documented how weatherization staff and clients perceive service delivery. Case studies of weatherization programs in territories were performed.

**Special Technical Studies**: evaluated the performance of the WAP with respect to technical issues such as air sealing, duct sealing, furnace efficiency, and refrigerators (for more details see (Tonn & Goeltz, March 2015), (Pigg, 2015), (Rose, et al., 2015c) and (Tonn, et al., 2015) for an overview of findings).

In addition to these components, the latest national evaluation with respect to PY 2010 done by ORNL also included a **Social Network Study** entitled "Assessing the Potential of Social Networks as a Means for Information Diffusion: The Weatherization Experiences (WE) Project" to explore the potential for WAP recipients and staff to influence energy savings beyond their homes and daily jobs (see (Rose, et al., 2015b) for more details).

A task that also advanced the PY 2008 retrospective evaluation components, was the national weatherization **participant home (i.e., occupant, recipient) survey** (including both a treatment group and a comparison group) which was undertaken as part of the ARRA period evaluation for PY 2010. The survey contained questions about energy end uses, energy consumption behavior, health, household budget issues, and demographics. The report on the occupant survey included in the PY 2010 national evaluation addressed: budget issues faced by WAP participant houses, energy conservation behaviors and use of programmable thermostats. Nevertheless, the WAP evaluation team were unable to match households that answered the **occupant survey** with households for which energy consumption data were collected pre- and post-weatherization.

A **Weatherization Deferral Study** was also conducted as part of the national evaluation report for PY 2010 to provide descriptive statistics for estimated deferral rates and reasons, evaluate interview responses received from a sample of Subgrantees and weatherization recipients describing their experiences with deferrals or 'walk-aways' (for more details see (Rose, et al., 2015a) and (Tonn, et al., 2015) for an overview of findings). The aim was to explore patterns across estimated deferral incidence rates and success with weatherization post-deferral and to highlight strengths and weaknesses within the deferral process[7] at the local agency level from the agency and client perspective and to assess the effects on houses and the overarching WAP objectives.

[7] Situations where agencies decide to postpone weatherization till a later date or ultimately where weatherization services are not provided. Conditions for deferrals vary from state and state, and from agency to agency. Initially a list of deferral conditions posted by the Weatherization Assistance Program Technical Assistance Center (WAPTAC) and additional conditions in regional protocols assist for categorizing the reasons for deferral by evaluators. Additional conditions suggested by weatherization staff or surveyed participants, or from state or agency survey instruments, can also be included.

## Focus on the method used to determine net energy savings

To develop robust estimates of the net energy impacts associated with the services offered by WAP, a **standard pre/post treatment/comparison statistical analysis** (statistical method of **Difference in differences**), using weather normalized utility billing data was performed.

The weather-normalization method was similar to the PRISM model (see further details below) and develops estimates of weather-adjusted **annual energy consumption** for each house-unit based on **monthly usage data** and **daily outdoor temperatures** using a variable degree day base regression analysis.

**Gross energy savings** by housing-unit/building under assessment were estimated comparing pre-weatherization usage (weather-normalized) to the post-weatherization usage (weather- normalized) for homes treated during PY 2008.

Homes weatherized in the following year to the year under assessment were used as a **control group**. This control group was analyzed in a similar manner to identify changes in usage that may not be attributable to the program. Control group usage was determined 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** (i.e. energy savings that can be attributed to WAP) were then estimated as the average gross savings for the treated (i.e. weatherized) houses minus the average savings (i.e. change in usage) found for the untreated houses (control group) (approach similar to the Difference in Differences method).

## Focus on approach to validate or triangulate program energy saving estimates

To validate the normalized energy consumption and savings calculations resulting from the main pre/post treatment/comparison approach, three complementary methods were used to analyze the energy usage data.

1. The core analysis was done with a PRISM type analysis. The PRISM method performs a **pooled fixed effects regression analysis** to estimate net savings. Energy savings for individual housing units were estimated by comparing weather-normalized usage before WAP interventions (pre-WAP) to weather-normalized usage after WAP interventions (post-WAP). Those results for individual housing units were tabulated to characterize overall savings, savings by climate zone, savings by housing unit type, savings by main heating fuel, and savings by Pre-WAP usage. A regression model was then used to attribute savings to individual energy conservation measures. Several model specifications were employed during this analysis. This approach is consistent with past evaluation approaches and is applied to remove house-units that demonstrate models with poor predictive ability (e.g., low $R^2$, high coefficient of variance on the normalized annual consumption estimate, unrealistic balance point temperature) from the analysis. Nevertheless, eliminating such houses (assumed outliers) can introduce a selection bias in the results. These outliers might not be due to errors in the data, but could reflect particular cases that could need to be taken into account or further examined.

The results from the PIRSM analysis were then compared to the results from the Fixed Effects model (method 2) and the Aggregate model (method 3).

2. For the **Fixed Effects model**, all monthly billing data were pooled together across all homes (i.e. all homes for the "participants" sample and all homes for the "control group" sample separately) into a single statistical model applied to elucidate monthly variations in energy use determined as a function of degree day variables (i.e. weather) and program interventions.

3. For housing units that fail to produce reliable savings estimates using the PRISM normalization method (e.g. due to little usage data available), a variation of the PRISM method was developed to avoid high sample attrition rates. An **aggregate version of the pooled model** was applied which aggregates the energy use and weather data for each individual house to a group of houses and statistically analyses this aggregate data-set to determine program energy savings. In this approach, a linear model of energy use vs. heating degree days is fit to a group of houses rather than to individual houses. The aggregate model does not assume that a linear relationship of energy use vs house has to fit each house and produces overall Program (i.e. group) effects rather than house-specific savings estimates. The following table summarizes the key-characteristics for each method.

| Elements | PRISM | ORNL Aggregate model |
|---|---|---|
| Logic | Assumes a linear model of the relationship between energy consumption and heating degree days for each individual house. | Assumes a linear model of the relationship between energy consumption and heating degree days for a group of houses. |
| Model specifications | For each house, energy consumption and heating degree days for multiple billing periods are used to determine the model coefficients for the house. | For the group of houses, energy consumption and heating degree days over one time period for each house are used to determine the model coefficients for the group of houses. |
| | Regression performed for all possible reference temperatures, and reference temperature and subsequent model coefficients chosen that gives the highest model $R^2$. | A fixed reference temperature (e.g., 65°F) is used for all houses to calculate heating degree days. |
| Model predictions | For group of houses, total or average consumption or savings calculated by adding or averaging values for individual houses. | For group of houses, total or average consumption or savings calculated directly from model. |

## Focus on the recent debate about the WAP cost-effectiveness

A working paper released in June 2015 by academics with the E2e Project (Fowlie, et al., 2015) has triggered a debate over the efficiency of the WAP energy saving benefits. The authors' primary objective was to estimate the value of ex post realized energy saving benefits derived from a set of policy-induced efficiency investments. To serve this aim they conducted a randomized encouragement

design experiment (**randomized control trial**) on a sample of over 30,000 Michigan households that were presumptively eligible for participation in WAP. The ORNL ARRA period evaluation was focused on a similar timeframe as the E2e study, based on a somewhat larger (i.e. 35,030 sampled houses) yet more diverse set of weatherized homes across states.

The main differences in the results of the two studies have already been discerned by the DOE Office of Energy Efficiency and Renewable Energy (EERE)[8], which highlights that the E2e study estimates of lower annual energy cost savings per household[9] is due to the fact that their sample of homes use considerably less energy than those typically served by WAP as they are primarily heated by natural gas. The DOE-EERE also points out that cost estimates for energy savings actions in the E2e and ORNL studies would have been about the same if the costs of non-energy benefits such as health and safety actions had been treated separately in the E2e study, as conducted in the ONRL national evaluation. They also stress that, despite the differences in the sample of homes, had the authors adopted more realistic assumptions regarding increasing (instead of constant) energy prices, a lower discount rate (i.e. 2.7% instead 3% consistent with federal protocols) and a weighted average lifetime of 20 years, the benefit-to-cost ratio estimates of the E2e study would have been in agreement with the ONRL evaluation results.

To their defense, (Fowlie, et al., 2015) argue that Michigan's cold winters and the likelihood that the weatherized homes were in poor condition would imply higher returns from energy efficiency investments. They also conclude to another important consideration, that the projected savings are about 2.5 times the actual savings with no evidence of a rebound effect. They consider their findings as a surprise underscoring the necessity for developing credible evidence on the real, rather than projected, cost-effectiveness of energy efficiency investments. Finally, another recent academic study comes to a similar conclusion, presenting evidence that actual energy savings achieved by weatherization efficiency upgrades, are substantially smaller than ex-ante, engineering predictions, when disentangled from behavioral interventions (Graff Zivin & Novan, 2015). The authors used billing data for a much smaller sample of 275 households observing approximately 12 bills per household and conclude that to evaluate the benefits provided by energy efficiency upgrades, it is important to distinguish the impacts of each treatment included in the weatherization programs. Moreover, their study was focused on households living in San Diego, California. This location represents particular climate conditions, usually classified as a Mediterranean climate[10], with low heating or cooling degree days. Most engineering models are not well fitted for this type of climate, which might also explain part of the discrepancies observed in this study.

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[8] https://www.energy.gov/eere/articles/getting-it-right-weatherization-and-energy-efficiency-are-good-investments

[9] One of (Fowlie, et al., 2015) main findings is that WAP energy efficiency investments reduce monthly energy consumption by 10-20% on average per household with annual savings in home energy costs of about $235 per home, which is similar to ORNL estimates of annual energy cost-savings equal to $224 for single family houses. Nevertheless, the E2e study reports on much lower estimates through a second approach that relies on a larger number of weatherized homes, yielding an estimate of about 10 percent and annual savings of $155 per home.

[10] https://en.wikipedia.org/wiki/Climate_of_San_Diego

## Experience feedback from stakeholders

**Interview with David Carroll** (Managing Director APPRISE - lead contractor for the WAP Retrospective and WAP ARRA Period evaluations)

1. **Has an official quantitative target been established for the WAP past or future performance? If not, did this create difficulties for the evaluation?**

At the time that we started the "Retrospective WAP Evaluation," DOE was reporting that the WAP program was saving over 30 MMBtus of home heating energy consumption per home, which was about 35% of home heating usage and 25% of total usage of the home's main heating fuel. The 2008 result for single family homes was about 19 MMBtus of home heating consumption.

One "difficulty" for the evaluation team was that the evaluation findings did not support the savings values that were being reported by DOE. Even though the evaluated estimates of savings documented that the WAP program was a "high performing" energy efficiency program when compared to other low-income and market rate energy efficiency programs. The actual savings simply did not match DOE's reported values. After the evaluation team presented the preliminary "disappointing" results to ORNL and DOE, DOE made the decision that the evaluation team was not allow to present the study findings on energy savings to the broader research community until all of the study reports were complete. That made it difficult for the study authors to gain insights on the findings and potentially improve the reports by hearing from other researchers about how the study findings compared to their own results.

2. **What is the role of evaluation in the management and decision-making about WAP?**

We do not know how the evaluation was used in the management and decision-making about WAP. We conducted the evaluation and prepared reports that were submitted to ORNL. ORNL then discussed the results with DOE. Except in rare instances, we were not included in the management and policy discussions. Our reports included a number of policy recommendations. However, we do not see any evidence that those policy recommendations were implemented.

3. **Is information related to the on-site verifications (post-intervention) and/or to the inspections done for the monitoring of SubGrantees used in some way for the evaluations?**

State grantees conduct monitoring of their sub-grantees. The evaluation protocol did not include collection and analysis of those Subgrantee monitoring reports. As such, they were not used in the evaluation.

4. **Could you give examples of changes that were made to WAP based on evaluation results or recommendations?**

We do not know of any changes that were made to WAP at the national level based on the evaluation results or recommendations. In our work with state grantees, we often communicate the findings of the evaluation and make recommendations to those state grantees on how to design and implement their programs. For example, we recommend that state grantees target the homes with the highest energy usage to achieve the maximum level of savings. We recommend that, in their Subgrantee monitoring, state grantees implement some of the recommendations from the Technical Field Process

Study. However, we do not know whether DOE has adopted any of those recommendations.

### 5. What were the main lessons learnt from the debate due to the studies done by other research teams (e.g. (Fowlie, et al., 2015))?

One lesson learned from the debate comparing the findings from the WAP evaluation to the findings from the Fowlie's study is that both researchers and policymakers had a difficult time understanding that the two evaluations were studying two completely different questions.

The national evaluation was attempting to develop an overall estimate of program savings by collecting and reporting information from all parts of the country, covering all types of fuels, and all types of buildings. The national evaluation showed that there was considerable heterogeneity in the savings estimates among regions, states, and agencies. In one state that we studied in depth, the highest performing agency achieved heating fuel savings of over 300 therms per home while for the lowest performing agency the savings results were not statistically different from 0 therms [1 therm = 105.48 MJ = 29.3 kWh]. The national evaluation also showed that there was considerable heterogeneity by pre-weatherization usage, building type, main heating fuel, and source of funding.

The Fowlie study examined a quite different question. They focused their research on the service territory of one agency in Michigan. And, they asked the question ... "What would happen if you attempted to deliver WAP program services to EVERY income-eligible household in that service territory." Their study was quite good at answering the question that they designed their study to answer. However, their study said next to nothing about the national WAP program.

Here were some of the issues with their study

#1 - Delivery of weatherization services is quite complex. Many studies have found quite different performances among different agencies. The Fowlie study did not document whether the agency that they studied was a high performing, moderate performing, or low performance agency.

#2 - The WAP program targets certain kinds of households, including households with elderly, disabled, and young children, as well as households with high energy burdens and high energy usage. The Fowlie study attempted to recruit and serve households without consideration of how they would be targeted by the WAP program.

#3 - The WAP program serves all types of fuels and all types of end uses. And, the measure installation audit tool is supposed to take local fuel prices into account when energy savings measures are recommended. From the limited details in their report, it appears that the agency that implemented their protocol did not include those prices in their audit tool.

The national WAP evaluation was designed to document the savings from the WAP program as implemented in 2008 and 2010. The Fowlie study was designed to develop a better understanding of the energy savings potential in the entire low-income population, rather than the population targeted by the WAP program. However, somehow, all of that got lost in the discussion that compared the outcomes of those two studies.

### 6. What would be the main lessons learnt in terms of evaluation practices used to assess the impacts of WAP?

The WAP evaluation was quite successful in measuring the overall impact of the WAP program as implemented during a particular program year. In addition, it was effective at showing how the energy savings varied by a number of important factors, including geography, fuel type, housing unit type, and spending per home.

However, the WAP evaluation was not particularly good at looking in detail at how WAP policies, program management practices, and leveraging affected program outcomes. As part of the national evaluation, we conducted a handful of state-level

evaluations for states who requested supplemental data collection and analysis. Those studies furnished much better details about how program design and management can affect program outcomes. In the future, we would recommend that DOE conducts state-level evaluations that compare and contrast outcomes within and between comparable states to get a better understanding of how incremental changes in the program can improve program performance.

7. **In the PY 2010 retrospective evaluation plan (Tonn, et al., 2011), a sensitivity analysis was foreseen. In addition, an attribution methodology was outlined to assess the set of weatherization activities and functions. Were these approaches finally abandoned? Are their results published elsewhere?**

About sensitivity analysis, the reports for each household type examined some different scenarios for looking at discount rates. Other than that, there was not much done in the way of testing the sensitivity of the results to different program assumptions.

About attribution methodology, the idea behind the attribution analysis was to try to assess the contribution of each funding source to the outcomes of the delivery of WAP program services. However, the data collected from the individual agencies did not furnish enough detail on how the funding from each source was used, thereby limiting our ability to attribute savings to specific funding sources.

About Measure Level Savings, the study did examine the contribution of each type of measure to the overall energy savings. The findings from those analyses are included in each of the housing unit type evaluation reports.

8. **What other aspects would you like to highlight about your experience related to the evaluations of the scheme? Or what would you do differently if you had to do the same evaluations again?**

OMB, the US Office of Management and Budget, was correct in suggesting that ORNL would have an apparent conflict of interest in conducting the WAP evaluation. In their work on the Health Benefits of WAP, ORNL rejected use of the standard "difference in difference" analysis approach. Rather, they implemented an alternative approach that attributed much higher health benefits to the WAP program, without furnishing a detailed explanation of why they were rejecting the standard approach. As such, they give the appearance of having a conflict of interest in their research.

As noted above, the state-level program evaluation studies tended to be much richer in terms of the amount of detail that could be developed about program effectiveness.

If procedures are put in place in advance such as ... #1 Development of a good quality tracking database; #2 Ensuring the clients sign utility waivers that have been accepted by the state's utilities (taking into account state's specificities); #3 Making monitoring data accessible for analysis ... state level studies can be done quickly and efficiently to give DOE, the state grantees, and the agencies important information about program performance at a relatively low cost. A number of states ... Iowa, Illinois, and Wisconsin ... have conducted annual program evaluations that are quite informative and lead to program improvements. There is no reason why that should not be standard practice for WAP programs at the state level.

**Interview with Mark Ternes** (Oak Ridge National Laboratory, Program Manager - Weatherization and Intergovernmental Program, evaluation supervisor)

1. **Has an official quantitative target been established for the WAP past or future performance? If not, did this created difficulties for the evaluation?**

A primary performance indicator is the number of houses weatherized per year, with a global objective set at national level and then distributed among the states.

There is also the expectation that the program should operate cost-effectively. This is monitored by the Savings to Investment Ratio (SIR): lifetime energy bill savings divided by the costs, both for actions done in a given year. The programme is deemed cost-effective if SIR > 1. The primary evaluation objective is thus to assess the energy savings then converted into bill savings, and compare them with program costs (see e.g., Tonn et al., 2014 and 2015).
It should be noted that the cost-effectiveness can be assessed according to two scopes, one taking into account the benefits in terms of energy savings only, and the other taking into account also the health benefits. This broader scope gets a higher attention in recent years, as health benefits prove to be important for the program.
There is no energy savings target per se. But the in-depth evaluation of the 1989 program provides a benchmark. ORNL also did meta-evaluations, i.e. reviews of evaluations done at state's level, using evaluations performed between 1993 and 2005. One indicator was to check how the current results compare to these previous results.

2. **What is the role of evaluation in the management and decision-making about WAP?**

WAP has always taken evaluation seriously. There were first small evaluations, and then an in-depth and thorough evaluation of the 1989 program. Then evaluations were done at state's level with periodic meta-evaluation by ORNL to put data together and update the results from the 1989 evaluation. More recently, new national evaluations were done in 2008 and 2011, in connection with the increase in the budget due to ARRA (American Reinvestment and Recovery Act).

DOE-WAP (WAP team of the Department of Energy) sees value in evaluation. Not only how it is important to justify the program, but also to improve it and guide policy decisions.

Other stakeholders are interested as well in the WAP evaluations. For example, the US Congress uses them to see if this is a good program, worth funding. NASCSP (National Association of State Community Services Programs) uses them to see how well the program is working, and as a basis for discussions with its members about possible improvements.

3. **Is information related to the on-site verifications (post-intervention) and/or to the inspections done for the monitoring of SubGrantees used in some way for the evaluations?**

WAP has a strong monitoring component. DOE-WAP supervises the overall monitoring, gathering data from all states. Then each state monitors its Sub-Grantees. Quality insurance is thus implemented at different levels.
The evaluations done in 2008 and 2011 represented an about $20 million effort, which made possible to have a dedicated data collection. One of the objectives was to verify the reliability of the monitoring. That's why it could not be based on monitoring data.
Moreover, these evaluations went beyond the assessment of energy savings and costs, and thus

required additional data collection, particularly for the part of process evaluation)

**4. Could you give examples of changes that were made to WAP based on evaluation results or recommendations?**

There were two big results from the 1989 evaluation:

- Savings in Southern states were found to be lower than in Northern states: it was thus decided to put efforts in better understanding this, which led to promote more baseload measures (e.g., lighting, refrigerators) as well as measures on air conditioning.
- The evaluation recommended that states and Sub-Grantees should use computerized audits instead of predefined lists of actions. There was thus a switch from a generic to a more specific approach. This made that auditors spend more time in the house and thus better see what is really needed.

The results of the latest evaluations have been published in 2014-2015. So their use is still under progress. One result was that radon level was increasing after weatherization. A follow-up study is being done to better understand this phenomenon. Provisions have already been taken about ventilation and quality of works, and especially covering up the ground and foundations (to prevent radon coming from the ground).

It should be noted that WAP was changing while evaluations were done in 2008-2011. For example quality aspects became more important in both, the program and its evaluation. In the ARRA period, Standard Word Specifications (SWS) were introduced as an effort to document the proper way to install each type of measure. Then certifications were required for auditors, crew leaders and quality controllers. In parallel, the evaluation investigated the quality of the works and quality assurance processes. There will soon be a new evaluation to see the impacts of the new provisions about work quality. The results of the previous evaluations will provide the baseline for it.

Another result of the last evaluations was that lower energy savings were found in mobile homes. Then DOE's Building Technologies Office is doing further investigations about retrofitting mobile homes to see how to improve this, for example for attic insulation.

Another point is NEBs (Non-Energy Benefits). They have always been an important topic for WAP. The methodology tested during the last national evaluations is now used by the states for their own evaluation, which should bring more data and evidence about NEBs.

**5. What were the main lessons learnt from the debate due to the studies done by other research teams (e.g. (Fowlie, et al., 2015))?**

There are different ways to conduct studies. It is important to look at these different ways, acknowledging that they might bring different insights about the program. Then when making comparisons, it is essential to be careful to compare things that are comparable. This other study was focused on WAP activities in Michigan and on one fuel type only (natural gas). Whereas the DOE evaluations cover 50 states and several fuels including electricity. So it cannot be compared directly.

**6. What would be the main lessons learnt in terms of evaluation practices used to assess the impacts of WAP?**

NEBs are critical outcomes of WAP. We need to continue the development and improvement of approaches to quantify NEBs. There is still room for improvements in this field.

WAP continues to evolve every year. So one should be careful in using past evaluation results to inform current management of the scheme. When applying evaluation results, changes already

made should be taken into account. For example to see if there is a need to re-evaluate results used for monitoring.

The WAP community is broader than the people working directly on WAP. It is important to keep the whole community informed about ongoing evaluation activity and then about evaluation results.

Numbers alone don't tell the full story. Part of the evaluation was about process evaluation, bringing qualitative aspects that are essential to explain what happened, make sense of the numbers and put them in the right context.

Also, it was important to have an independent evaluation committee. It provided an external look that helped improve evaluation design and also brought a kind of validity stamp that the evaluation was done thoroughly and without bias. This gave legitimacy to the evaluation and helped getting the support from stakeholders.

Another lesson learnt is that one should not overburden with requests the people whose activities are evaluated. Due to ARRA, WAP budget was very largely increased. This made that state agencies and Sub-Grantees were already very busy with growing activities when they were contacted to provide data.

Future evaluations could be done more easily if the data needed would be collected routinely. For example, collecting utility bills afterwards is very difficult and time-consuming. Provisions should be taken at least to include utility waivers that participants would sign when getting WAP benefits.

## To go further

### About the measure

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### How to cite this case study

Spyridaki, N-A., Broc, J-S., 2018. Weatherization Assistance Programme (United States). Case study prepared by IEECP for the EPATEE project, funded by the European Union's Horizon 2020 programme.