Design of the National Impact Evaluation for the DOE Weatherization Assistance Program

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Abstract

The U.S. Department of Energy is undertaking a new national evaluation of its Weatherization Assistance Program. Following the evaluation plan developed by the Oak Ridge National Laboratory, four studies will be performed to evaluate the Program as it was implemented in PY 2006: an impact assessment, a process assessment, special technical studies, and a synthesis study. This paper describes how the evaluation's research questions were identified and discusses the plans for implementing the impact assessment and special technical studies.

Introduction

The U.S. Department of Energy's (DOE's) Weatherization Assistance Program was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the Program is to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential expenditures, and improve their health and safety (Code of Federal Regulations 2007). DOE sponsored a five-part evaluation of the Program in the early 1990's, which was managed by the Oak Ridge National Laboratory (ORNL) and based primarily on data from Program Year (PY) 1989 (Brown, Berry, and Kinney 1994). In more recent years, ORNL has conducted four metaevaluations[1] of the Program's energy savings using studies conducted by individual states between the years 1990–1996 (Berry 1997), 1996–1998 (Schweitzer and Berry 1999), 1993–2002 (Berry and Schweitzer 2003), and 1993-2005 (Schweitzer 2005).

DOE has initiated a new, comprehensive evaluation of the Program because the Program that was evaluated in the early 1990's is vastly different from the Program of today.[2] DOE tasked ORNL with planning the new evaluation in light of its experience in conducting the previous national evaluation and metaevaluations. A preliminary evaluation plan (Ternes et al. 2007) identifies four studies to be performed to evaluate the Program as it was implemented in PY 2006[3]: an impact assessment, a process assessment, special technical studies, and a synthesis study. This paper describes how the evaluation's research questions were identified and discusses the plans for implementing the

[1] Metaevaluations involve the statistical analysis of a collection of analysis results from individual studies for the purpose of integrating the findings. Thus, they are a more rigorous alternative to a narrative discussion of research studies.

[2] For example, the use of computerized audits has increased, cooling and electric baseload (refrigerator and lighting) measures have been added, weatherization approaches tailored to the unique construction characteristics of mobile homes have been developed, the weatherization of large multifamily buildings has expanded and become more sophisticated, and leveraging with utilities, other state programs, and owners of large multifamily buildings has increased considerably.

[3] PY 2006 for the Weatherization Assistance Program extends from April 2006 to December 2007 because the Program year for states can begin in either April, July, or September.

impact assessment and special technical studies. The process assessment and synthesis studies will not be discussed in this paper.[4]

Planning and Identification of Research Questions

The Program evaluation is intended to provide a comprehensive review of Program performance, enable DOE to make any necessary improvements in the direction of the Program for the next decade, and provide information of interest to potential funders in order to support leveraging activities. To expand upon these directives and develop a consensus on the general questions to be addressed by the evaluation, input was solicited from a Network Planning Committee and a formalized planning process was undertaken based on the concept of a program logic model and evaluation design matrix as developed by the W. K. Kellogg Foundation (2001). In addition, a Peer Review Panel was assembled to review the Preliminary Evaluation Plan once it was developed.

Network Planning Committee

ORNL organized a Network Planning Committee comprised of 41 people who represented state weatherization programs, state training centers, local agencies, advocacy organizations for weatherization and local agencies, and DOE. The Network Planning Committee met in March 2005 and provided input on evaluation results that they would find most useful, identified data pertinent to the evaluation that are available at national, regional, state, and local levels, and provided insights into how implementation of the evaluation and specifically data collection could be optimized. Among other things, the committee emphasized the need for the evaluation to examine the following: the energy savings achieved by electric baseload measures (lighting and especially refrigerators); the non-energy impacts that can be credited to the Program; the methods used by states and agencies to implement audits, client education, training, and monitoring; and issues pertinent to the hot climate region.

Logic Model and Design Matrix

A logic model was developed for the Program that systematically identified the resources available to operate the Program, the activities the Program is intended to perform, and the changes or results the Program hopes to accomplish (see Table 1). General research questions that the Program evaluation will address were then developed by examining the Program's logic model and incorporating the input received from the Network Planning Committee.

The evaluation as planned is basically evaluating a snap-shot of the Program's performance as it was implemented in PY 2006. Consequently, the evaluation most directly focuses on the short-term and medium-term outcomes listed in the Program's logic model. Long-term outcomes are also being addressed, in some cases by inferring that short- and medium-term results will have larger community impacts as they are sustained over time. The snap-shot type evaluation being planned does not allow long-term market transformation activity to be evaluated. Although this outcome could be addressed by looking back in time at how the Program helped transform various weatherization products, such an effort is not being planned at this time.

[4] The process assessment will examine how well the weatherization network and Program operated in PY 2006 in delivering weatherization services, if the Program is exploiting leveraging and partnership opportunities, and the approaches used to perform audits, client education, training, and monitoring. The synthesis study will bring all the evaluation results together to address how well the Program is meeting its overall goals, the extent to which the Program is serving the weatherization needs of the low-income community, and how the Program's and weatherization network's performance can be improved.

Table 1. Logic model for the Weatherization Assistance Program

Resources/ Inputs	Roles/Activities	Outputs	Outcomes		
			Short-Term	Medium-Term	Long-Term
Federal authorizing legislation Direct funding from DOE, LIHEAP, PVE, and leveraged sources DOE Program staff State grant administration agencies and related national organizations Local service network of 900 agencies and related national organizations Support network in national laboratories, training centers, and support contractors with special technical skills Utilities and national and state energy organizations	**DOE** - Establish and explain national policy direction - Formulate annual budgets and grant guidance, and make grants - Formulate Program rules and regulations - Initiate and coordinate strategic planning with network - Approve and monitor state plans and their implementation - Create, coordinate, and conduct technical training and assistance to state and local agencies - Develop and maintain core capabilities of the Program including audit tools and standards, evaluations, and assessments - Coordinate Program relations with other Federal agencies, programs, and institutions **States** - Set eligibility requirements and priorities for participants - Contract with local agencies and allocate funding - Establish production goals (number of units weatherized) and schedule - Specify diagnostic, audit, and inspection procedures and allowable measures for local agencies - Determine extent of allowable repair, health, and safety work - Provide training and assistance to local agencies - Establish leveraging programs and expand resources and partnerships - Monitor local agency work **Local Agencies** - Solicit and process applications and select low-income residents to receive weatherization services - Train crew members - Perform home energy diagnostics, audits, and inspections - Determine most cost-effective weatherization measures and other work needed for each home - Purchase, store, and maintain equipment, materials, and supplies - Install measures and perform other specified work - Perform quality assurance work - Meet with clients to review improvements and provide educational materials - Support advocacy and leveraging - Link clients to other programs and services - Track and report client status, expenditures, and funding	Number of low-income homes weatherized Number of priority households weatherized Cost-effective measures installed in weatherized homes Health and safety deficiencies mitigated in weatherized houses Clients receive education on energy savings Number of weatherization staff trained Number of clients referred to social programs Guidance and regulations published Audits developed, improved, and approved Partnerships established	Weatherized homes, particularly those of priority populations, have increased energy efficiency Health and safety of those living in weatherized homes improved Indoor comfort of those living in weatherized homes improved Clients have increased knowledge of energy savings strategies	Reduced energy consumption in weatherized houses Reduced energy bills and burdens for clients Reduced emissions of pollutants and greenhouse gases involved in energy production and consumption Other non-energy benefits for clients, utility rate payers, and society Robust weatherization network Increased Program leveraging	Reduced gap between low-income energy needs and actual consumption of energy services Reduced impact of energy price inflation and market disruptions on low-income communities Improved health and safety for communities Improved local housing stock Workforce enhancement in local communities Creation of sustainable weatherization services market Increased non-energy purchases in low-income communities Transform market for weatherization products

Peer Review Panel

ORNL, in conjunction with DOE, convened a Peer Review Panel to review the preliminary evaluation plan. The Peer Review Panel was comprised of seven members with expertise in weatherization, energy programs, and program evaluation. The committee met for two days in October 2006 to provide their input. The panel made many recommendations that addressed the design and implementation of the evaluation. Two primary outcomes were to expand the billing data analysis methods that will be used in the impact assessment and broaden the scope of the evaluation with regard to non-energy impacts associated with occupant health and safety.

Impact Assessment

The impact portion of the evaluation was divided into the following five studies: Program characterization, energy and cost savings, non-energy impacts, Program cost effectiveness, and explanatory factors. Each of these five studies is discussed in more detail below.

Program Characterization

The impact assessment will collect key data on the Program's implementation and weatherization processes to characterize:

- the low-income population eligible for and in need of the Program and the segments of the national low-income weatherization market that are being served by the Program;
- the weatherization network and its operation, especially the organizations administering the Program at the state and agency level;
- the housing units and households served by the Program, and how they were selected;
- the audit and diagnostic procedures used on the houses;
- the measures installed in the weatherized units;
- other Program services performed on the weatherized houses and how they were delivered; and
- the Program's overall expenditures, expenditures per household, and funding sources.

Data from three national data bases will be used to characterize the eligible low-income population: the Residential Energy Consumption Survey administered by the DOE Energy Information Administration, the Current Population Survey of the Census, and the U.S. Department of Housing and Urban Development's American Housing Survey. In addition, all 50 states and the District of Columbia as well as all ~900 agencies that implement the Program will be surveyed in 2007 to obtain selected information on their PY 2006 activities. More detailed agency-related characterization data will also be collected in 2007 from a subset of 400 agencies, and detailed information will be collected on the housing unit, the household, the diagnostic measurements performed, and the weatherization measures installed for a sample of over 10,000 dwelling units.

Energy and Cost Savings

The two primary foci of this portion of the impact assessment will be to estimate (a) the total annual energy savings (in energy units of MBtu and kWh) achieved by the Program from all units weatherized in PY 2006, and (b) the average annual energy savings achieved per household by the Program in PY 2006 nationally and by climate region, housing type, primary space-heating fuel type,

and the five client groups on which the Program is specifically instructed to focus (i.e., the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden). In addition, the cost savings (in dollars) associated with the above energy savings will be calculated using regionally-dependent fuel costs.

Sampling Plan. To perform the energy analysis, natural gas and electricity billing data for a year before and a year after weatherization will be collected on a sample of single-family houses, mobile homes, and both small and large multifamily housing units weatherized by 400 agencies in PY 2006. The selection of the 400 agencies will be stratified by state (a) to control for differences in geography, climate, housing stock, fuel types, and other factors, (b) to control for the fact that each state administers its program differently, (c) so that each state will have at least one agency included in the sample, and (d) so that data provided by states that wish to contribute resources to extend the survey in their states can be easily incorporated into the analysis.

The number of individual agencies that will be selected from each state will be in proportion to the "size" of the weatherization activity that occurs in each state (i.e., the amount of DOE Program funding received by the state in PY2006). So, for example, if a state received 10% of the Program's available PY 2006 funding, then 40 agencies (10% of 400) would be selected from that state. Agencies will be selected within a state using probability proportion to size (PPS) sampling , rather than simple random sampling (i.e., equal probability sampling), to obtain more accurate estimates. It should be stressed that the evaluation is not interested in comparing states, but that stratification by states is being pursued to improve the sampling randomization and to minimize the sampling error.

For each agency, all units whose primary heating fuel was natural gas or electricity will be sampled if utility account data and other information are stored electronically and can be easily provided by the agency. Otherwise, 33% of such units (with a minimum of 7 housing units) will be randomly selected, resulting in a total sample size of about 10,000 units. If it is determined that additional housing units or buildings are needed to ensure coverage of important subgroups (such as multifamily buildings, rural housing, or housing units from the hot climate states), then additional housing units will be selected from the 400 agencies as needed. The sample size of 400 agencies and ~10,000 housing units was selected so that the nationwide total annual energy savings (and average energy savings per housing unit) attributable to the Program can be estimated to within ~15% of its actual value at a 90% confidence level after non-response and attrition are taken into account.

A control group for the billing data sample will be developed using housing units and buildings weatherized by the same agencies in PY 2007 or that are on the waiting lists of the same agencies during PY 2007. The number of control housing units and buildings selected from each agency will be approximately the same as the number of weatherized units sampled from that agency. Controls will be selected from each agency throughout PY 2007 so that pre- and post-weatherization periods for the control units will be similar to those for the weatherized units.

In addition to the billing data sample, four smaller samples of houses and buildings (both weatherized and controls) heated by either fuel oil or propane will be monitored so that their heating energy savings can be calculated: (a) 128 single-family homes heated by fuel oil from 16 agencies located in states where fuel-oil heated homes are predominantly located, (b) 24 large multifamily buildings heated by fuel oil in four states that weatherize many large multifamily buildings and have substantial fuel oil use, (c) 128 single-family homes heated by propane from 16 agencies in those states

that most frequently weatherize such houses, and (d) 128 mobile homes heated by propane from 16 agencies in states that most frequently weatherize mobile homes.[5]

Houses and buildings heated by fuel oil and propane are an important class of units weatherized by the Program. However, their heating energy savings cannot usually be estimated from delivery records routinely kept by the fuel suppliers. Therefore, submeters will be installed in the above-described sample of houses and buildings so that space-heating fuel use is measured directly, along with indoor and outdoor temperatures. This approach provides accurate data, although it is somewhat costly because of costs associated with purchasing, installing, reading, and removing instrumentation.

Individual Housing Unit or Building Energy Analyses. Energy savings for individual housing units and buildings normalized to a typical weather year will be estimated so that the total annual energy savings or average annual per household energy savings for the Program can be calculated. Electricity savings on all sampled houses will be calculated so that savings from space cooling and baseload energy uses can be included in the total Program energy savings estimate.

Billing data collected on housing units or buildings will be analyzed using the Princeton Scorekeeping Method (PRISM—Fels et al., 1995), the ORNL Aggregate Method (Ternes et al. 2007), and a third method which will be selected after reviewing the state-of-the-art techniques such as Statistically Adjusted Engineering (SAE) models, Analysis of Covariance (ANOVA) models, Conditional Demand Analysis (CDA), and fixed-effect models (Hall, 2006; Hall 2004).

PRISM is an established and well documented analysis method that has been used in energy evaluations for many years and was the primary energy analysis method used in the previous national evaluation of the Program (Brown et al., 1993). The ORNL aggregate method applies the same basic logic of the PRISM approach to billing and weather databases aggregated over many houses to determine an overall program effect. The advantage of the ORNL aggregate method is that few if any houses are excluded from the analysis for not conforming to the linear model.

For submetered energy use data, pre- and post-weatherization energy use models will be developed for each housing unit or building by regressing weekly or daily energy consumption (the dependent variable) versus the temperature difference between indoors and outdoors for each consumption period (the independent variable). Annual, weather-normalized, pre- and post-weatherization energy consumptions and energy savings will then be calculated using the regression models, historical weather for each home or building location, and a standard indoor temperature (e.g., 68 or 70°F) or the actual indoor temperatures.

Annual Program Energy Savings. The total annual energy savings achieved by the Program in PY 2006 will be estimated using (a) the weather-normalized saving estimates for the individual houses and buildings sampled, and (b) a statistical approach that is based on how these houses and buildings were sampled and that considers the energy savings achieved in the control housing units and buildings. The control adjustment will be particularly important considering the changes in energy costs and the public's awareness of energy following Hurricanes Katrina and Rita in August and September 2005. The estimated energy savings for PY 2006 will be compared to results from the 1989 National Evaluation and from the metaevaluations performed using data between 1990 and 2005.

The total annual energy savings achieved by each state in PY 2006 will first be estimated and then these state values will be used to calculate the total annual energy savings estimate for the Program.

[5] For three of the four samples, half of the dwellings will be weatherized units and half will be control (i.e., non-weatherized) units. The only exception is the sample of large multifamily buildings heated by fuel oil, which will consist only of weatherized buildings because of the small sample size and the difficultly in obtaining comparable control buildings. Preferably, the agencies selected for the submetered studies will be from among the 400 used in the billing data sample.

Three separate estimates will be made: one using PRISM results, one using results from the ORNL Aggregate Method, and one using results from the third method chosen.

For all calculations of the Program energy savings, occupancy changes will not cause a house or building to be removed from the analysis. The Program is intended to increase the energy efficiency of low-income housing, and occupancy changes occur naturally in such houses. This is consistent with the approach taken in the 1989 National Evaluation but somewhat atypical of other weatherization evaluations. If desired and deemed necessary, separate analyses with and without occupancy changes will be performed. One concern with automatically dropping such housing units is that large sample attrition may result because low-income housing can have high turnover rates. A second concern is that bias could be introduced because (a) the physical, energy-related characteristics of housing units with occupancy changes may be different from those without occupancy changes, and (b) the characteristics and behaviors of movers could be different from those that don't move.

The average annual energy savings per household achieved by the Program will be estimated in a manner similar to that for the total annual energy savings described above except that savings will be normalized by the number of units weatherized. Average energy savings will be calculated on both an absolute and percent basis, and separately by electricity and all other primary space-heating fuels combined.

Cost Savings. The energy savings estimated above will be converted to cost savings using best available fuel cost data that are based on the actual costs incurred by the weatherized homes used in the above analyses. Average published fuel cost data are unlikely to match the climate regions being used in the evaluation and are likely representative of all households rather than just low-income households.

Attribution of Energy Savings. It is important to properly attribute energy savings and energy cost savings among the set of parties that, along with DOE, contribute financial and in-kind resources to weatherize low-income homes (such as the Low-Income Home Energy Assistance Program, public benefits funds, states, and utilities). This evaluation will use a methodology to attribute energy savings and energy cost savings to the set of parties that is based on well-known concepts found in the field of decision analysis. Weatherization will be categorized into a set of activities and functions (program management, outreach and marketing, client selection, audit and measure selection, measure installation, and training). Contributions of the parties to these activities and functions will be estimated using funding information collected from all the states and the District of Columbia and from all ~900 agencies that implement the Program. Influences of these activities and functions on energy savings and cost savings will be estimated by a panel of experts. Using these two sets of estimates and a decision matrix approach, energy savings and cost savings attributable to DOE and other parties will be determined.

Non-Energy Impacts

As part of the impact assessment, the non-energy impacts attributable to the Program that affect the clients served, utilities and ratepayers, and society will be ascertained. Table 2 lists the primary non-energy impacts that have been identified to date and that will be quantified in this evaluation. Schweitzer and Tonn (2002) identified most of these non-energy impacts as being applicable to the Program and provide a detailed discussion of each. In addition to quantifying the non-energy impacts identified in Table 2, the number of actions taken by weatherization providers to improve health and safety (e.g., fix broken flues, replace cracked heat exchangers) will be reported as part of this evaluation to further document the non-energy impacts produced by the Program.

Table 2. Non-energy impacts to be studied under the evaluation

Utility/Ratepayer Impacts

A. Payment-Related Impacts

1. Rate subsidies avoided—M
2. Lower bad debt write-off—M
3. Reduced carrying costs on arrearages—M
4. Fewer notices and customer calls—M
5. Fewer shutoffs and reconnections for delinquency—M
6. Reduced collection costs for delinquent payments—M

B. Service Provision Impacts

1. Fewer emergency gas service calls—M
2. Transmission and distribution loss reduction—M
3. Insurance savings—M
4. Shifted utility fixed costs—M

Societal Impacts

A. Environmental Impacts

1. Air emissions: carbon dioxide (CO2)—M
2. Air emissions: sulfur oxides (SOx)—M
3. Air emissions: nitrogen oxides (NOx)—M
4. Air emissions: carbon monoxide (CO)—M
5. Air emissions: methane (CH4)—M
6. Air emissions: particulate matter (PM)—M
7. Air emissions: heavy metals—M
8. Fish impingement—M
9. Waste water and sewage in electricity production—M

B. Societal Impacts

1. Avoided unemployment impact—M

C. Economic Impacts

1. Direct and indirect employment—M
2. Lost rental—M
3. National security—M

Impacts to Participating Households

A. Affordable Housing Impacts

1. Water and sewer savings—M
2. Property value impacts—M
3. Avoided shut-offs and reconnections—M
4. Reduced mobility—M
5. Reduced transaction costs—M

B. Safety, Health, and Comfort Impacts

1. Fewer fires—M and NM
2. Changes in frequency of health problems—M and NM
3. Enhanced prevention and treatment of health problems—NM
4. Changes in indoor air quality—NM
5. Changes in household moisture levels—NM
6. Decreased incidence of hypothermia and hyperthermia—M and NM
7. Improved food safety—NM
8. Improved household safety and security—M and NM
9. Change in presence of environmental hazards—NM
10. Improved comfort—NM
11. Improved appearance—NM
12. Reduce noise inside dwelling—NM

M—monetized value
NM—non-monetized value

Table 2 indicates whether each of the primary non-energy impacts will be described by a monetized or non-monetized value. For most of the non-energy impacts, a monetary value (annual dollar value and lifetime net present dollar value) will be calculated nationally (and possibly by climate region) using a computer model or some other mechanism for performing the necessary calculations. The dollar value of each monetized impact is calculated by taking the number of relevant household-level activities reported, multiplying that number by an appropriate performance metric, and multiplying that product by a matching monetized metric. It is important to note that the monetized value will represent the net economic value of the impact because both costs and benefits associated with the impact will be addressed. It is also important to note that monetized values will be calculated for a non-energy impact only when a specific identifiable expense is avoided or incurred, or a monetary impact is clearly obtained. Willingness-to-pay, relative-valuation approaches, and similar subjective techniques will not be used in this evaluation to determine if (a) a non-energy impact produces an avoided or incurred expense or a monetary impact, or (b) the dollar value of a non-energy impact. For a sizable minority of the non-energy impacts, all of which fall under the broad umbrella of "safety, health, and comfort," a non-monetary value will be calculated.

Performance metrics and monetized metrics that are needed to calculate the monetary values of selected non-energy impacts will come from previous research on non-energy impacts (see Schweitzer and Tonn 2002 for values identified from previous research), new data gathered from secondary sources as part of this evaluation, or primary data generated under the evaluation. In addition, household-level data will be collected and analyzed to directly calculate non-monetary values for some of the impacts.

An occupant survey will be used to collect most of the primary data needed. The survey will be administered to ~1000 housing units weatherized in PY 2007 and ~500 non-weatherized control units before weatherization and again a year after weatherization. In addition, direct measurement of the following key factors will be made before and after weatherization in a sample of ~300 housing units weatherized in PY 2007 and 60 control dwellings: carbon monoxide levels, level of airborne mold spores inside and outside the dwelling, level of airborne pollen indoors and outside, indoor humidity level, temperature inside the refrigerator, asbestos and radon levels, and indoor air temperature.

Cost Effectiveness

The impact assessment will determine the cost effectiveness of the Program as implemented in PY 2006 and then compare these results to those from the 1989 National Evaluation and the metaevaluations performed using data between 1990 and 2005. Cost effectiveness will be calculated using the total costs spent on the house from all funding sources, the energy cost savings calculated for the Program, and the monetary values of the non-energy impacts (which may include both benefits and costs). As in the 1989 National Evaluation, cost effectiveness will be determined using savings-to-investment ratio (SIR) and will be examined from three different perspectives:

- **Installation perspective**—savings are limited to energy savings (all heating, cooling, and baseload energy savings combined), and investments (i.e., costs) are limited to installation expenditures (on-site labor and materials),
- **Program perspective**—savings are limited to energy savings, but investments are expanded to include management and overhead costs along with installation expenditures, and
- **Societal perspective**—savings include both energy savings and monetary values for non-energy impacts (which may include both benefits and costs and, therefore, are net economic values), and investments include installation, management, and overhead expenditures.

As part of the cost effectiveness analysis, the impact that alternative per-household investment levels can have on Program cost effectiveness and other key Program metrics such as number of units weatherized and average energy savings will be examined (i.e., the evaluation will examine if there are investment levels that optimize the SIR at an agency or state level and, if so, how this subsequently impacts the number of units weatherized by the agency or state and the average energy savings per weatherized unit). The impact that climate region, housing types, and other factors can have on any optimization approach will be considered in the analysis.

Explanatory Factors

Although average energy and cost savings will be calculated in the previous analyses by climate region, housing type, and primary space-heating fuel type, a full analysis of factors that explain variations in energy savings and cost effectiveness will also be performed. The impact assessment will assess how the energy savings achieved by the Program and the cost-effectiveness of the Program are affected by the various organizational features and operational processes of the Program (including practices that vary among states and agencies), the households the Program serves, the measures

installed, and the environment in which the Program operates. A broad range of potential explanatory variables will be examined using regression analysis. Average savings achieved in houses with and without a single factor will be compared, and the mean value of explanatory factors will be compared between high-saving and low-saving houses; these analyses will be performed nationally and by subgroups (e.g., climate region, primary heating fuel) as needed. Those factors that explain the most variation and are controllable by state and local weatherization agencies will be given the most attention because results in those areas can suggest potentially valuable changes in program implementation. Special emphasis will be placed on identifying variables that explain why the performance in the hot climate region is unique.

In addition, six to ten case studies of high-performing agencies will be conducted to explore factors affecting energy savings and cost effectiveness. High-performing agencies will be defined based on multiple criteria such as high energy savings and high savings-to-investment level, and will be selected from different climates.

Special Technical Studies

Several special technical studies will be performed to determine, to the extent possible, the performance of five individual measures: air sealing, duct sealing, space-heating system tune-ups, space-heating system replacements, and refrigerator replacements. In addition, the overall impact that measures are having on air-conditioning electricity use in the hotter climates will be examined.

Air sealing will be evaluated because it is a fundamental weatherization measure performed on almost all houses addressed by the Program, and there is still large potential for spending money on air sealing that is not effective despite the use of blower doors. Duct sealing will be evaluated because it is a primary weatherization measure with large savings potential that can be implemented relatively inexpensively, especially in mobile homes. The energy benefit of a heating system tune-up will be evaluated because it is an essential element of comprehensive heating system work. The energy benefits of a heating system replacement will be evaluated because it is a measure that is being more frequently performed under the Program, especially when utility partners are involved. Although many feel that replacing a heating system is becoming more cost effective in their climate region, it remains a measure that is often justified for health and safety reasons. The performance of refrigerator replacements will be evaluated because replacing refrigerators is a relatively new measure that is a very important part of the Program's new emphasis on baseload measures, and it is being performed more frequently by agencies, especially in cooperation with electric utilities and state efficiency programs. Finally, air conditioning electricity use is an important energy use in hot climate homes and is becoming more prevalent in moderate and even cold climates, so a better understanding is needed of air conditioning energy use and savings and the factors affecting these.

The studies of the first four individual weatherization measures will be performed using data already being collected by the 400 agencies on the ~10,000 housing units included in the billing data sample. Analysis will focus on determining the direct effect that air sealing, duct sealing, and space-heating system tune-ups and replacements are having (e.g., change in air leakage rate, change in steady-state efficiency); the impact of these measures on energy savings can then be inferred. For space-heating system tune-ups and replacements, only the energy-related benefit due to a change in steady-state efficiency will be evaluated. Levins and Ternes (1994) and Berry and Brown (1994) provide examples of such analyses.

For the refrigerator study, refrigerator energy use will be monitored in 330 housing units divided among 60 agencies. Monitoring will be performed in ~200 housing units that the agencies have determined to need a new refrigerator and ~130 housing units where the existing refrigerator will not be replaced. The annual energy use of the existing and new refrigerators will be estimated by scaling the

monitored electricity use data to a year. These values will be used to determine the savings achieved from refrigerator replacements, the cost effectiveness of the replacements individually and in aggregate, and the missed opportunities in refrigerators that were not replaced.

Although house electricity use and savings are being analyzed under the impact assessment using billing data, air conditioning end use cannot readily be discerned from billing data; therefore, ~130 single-family houses and mobile homes that will be weatherized in the hot climate states will have their air conditioning electricity use submetered. Hourly indoor temperature, outdoor temperature, and humidity/wet bulb temperature will also be monitored in each house. A similar number of control houses will also be monitored. The air conditioning electricity use data will be analyzed to determine pre- and post-weatherization consumptions and savings by regressing weekly or daily consumption versus the temperature difference between the indoors and outdoors for the pre- and post-weatherization periods. Analyses to determine demand impacts are still being contemplated because they would be useful to the electric utilities the Program is interested in partnering with.

Next Steps

The new national evaluation of the Weatherization Assistance Program will provide a comprehensive review of current Program performance and enable DOE to guide the direction of the Program into the next decade. In addition, the evaluation will support Program leveraging activities by providing information of interest to states, utilities, public benefits programs, and other potential funders.

Implementation of the evaluation will begin with the selection of an evaluation contractor in the summer of 2007. Data collection will commence a few months after the contractor is selected and will continue until the end of 2008 or even into 2009 for some data. The bulk of the analyses will be performed in 2009 and final reports will be completed in 2010.

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