STATE-LEVEL EVALUATIONS OF THE WEATHERIZATION ASSISTANCE PROGRAM IN 1990-1996: A METAEVALUATION THAT ESTIMATES NATIONAL SAVINGS

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Introduction

The U.S. Department of Energy's (DOE) Low-Income Weatherization Assistance Program (the Program) is implemented in all fifty states. The Program strives to increase the energy efficiency of dwellings occupied by low-income persons in order to reduce their energy consumption, lower their fuel bills, increase the comfort of their homes, and safeguard their health. It targets vulnerable groups including the elderly, people with disabilities, and families with children.

The most recent comprehensive National Evaluation of the Program was based on an analysis of changes in pre- and post-weatherization energy consumption for homes weatherized in 1989. The National Evaluation (Brown, Berry, Balzer, and Faby, 1993), which used a representative national sample of several thousand dwellings, estimated average savings for several fuel types. For dwellings that heated primarily with natural gas, which made up over 50% of the sample, average savings per dwelling were 17.3 MBtu, which was 18.3% of space heating consumption, or 13.0% of the total consumption of natural gas for all end uses.

If another national evaluation were conducted today, for homes weatherized in 1996, it is very likely that the savings would be significantly higher than they were in 1989. There are a number of reasons to believe that current savings would be higher than those estimated for 1989. First, the Program has made significant advances in its weatherization procedures. One important advance is the post-1989 introduction, and now the widespread use of advanced audits. In 1989, the Program was not yet using advanced audits. Today 37 states use them. Two studies, one in New York and one in North Carolina, demonstrated the superior energy savings achieved with the use of advanced audit procedures (New York State Energy Research and Development Authority and New York State Department of State, 1993; Sharp, 1994). In North Carolina the introduction of an advanced audit increased heating energy savings from 18% to 23%. In New York, savings increased from 25% to 34%.

Another important advance is the increased use of blower-door directed air sealing. In 1989 only a few states used this technology; now most do. With the use of blower doors to guide air sealing, investments in air infiltration reduction will produce higher savings.

Another reason to expect higher savings today is that more weatherization agencies now target high energy consumers. Many studies have shown that high pre-weatherization consumption is the best predictor of high energy savings (Brown et al., 1993; Columbia Gas of Ohio, 1995; Pennsylvania Public Utility Commission, 1994). Additional reasons to expect higher energy savings today relate to the implementation of new Program regulations designed to capture opportunities for improvement. Among the new DOE regulations implemented in 1994 are changes that promote the use of advanced audits, and permit the use of cooling efficiency measures such as air conditioner replacements, ventilation equipment, and screening and shading devices.

Need for an Updated Estimate of National Savings

Because everyone familiar with the Program expected that its performance was likely to have improved during the last seven years, the Department of Energy asked Oak Ridge National Laboratory (ORNL) to develop proposed approaches to obtaining an updated estimate of national Program savings. The proposed approaches were to include both high and low budget options and to discuss the tradeoffs between study costs and accuracy.

ORNL suggested three general classes of methods that could be used to update the estimates of Program energy savings:

- billing analyses,
- engineering analyses, and
- metaevaluation.

Both the engineering and billing analyses options would involve extensive data collection, processing, and analysis activities. Such efforts would require a large staff of workers, just as the National Evaluation of 1989 did, to conduct large-scale agency and utility telephone and mail contacts, follow-up data collection activities, data entry, data processing, and statistical analyses. In addition, a billing analysis option would require several years to complete, as would a well-validated engineering analysis of Program savings.

The third option, a metaevaluation, which would involve locating, assembling, and summarizing the results of all state-level evaluations of the Program that have become available since 1990, was by far the lowest cost and quickest approach. While this approach would not produce as comparable or detailed a picture of Program performance as the other two approaches, the DOE preferred it because it could be completed much more quickly and inexpen-

sively. ORNL had completed a similar task in preparation for the National Evaluation. That task was a literature review (which was completed in 1990 and is presented in Section 1.4 of Brown, et al.(1993).

The 1990 literature review concluded that the evaluations available at that time (covering the years of 1981-1989) showed that energy savings of between 12% and 16% (as a percentage of the total consumption of the primary heating fuel for all end uses) were typical, with a range of 6% to 23% savings in various locations. The 1990 literature review also concluded that a number of demonstration projects indicated that the Program could potentially achieve much greater savings (25% to 40%). The similarity in findings from that literature review (i.e., expected average savings of 12% to 16%) and the results of the National Evaluation (13% savings as a percentage of the total consumption of natural gas for all end uses in homes that use natural gas as the primary heating fuel) led to confidence that a review of the evaluations conducted between 1990 and 1995 would also yield a reasonably accurate current estimate of typical savings. In addition, the fact that previous metaevaluations (Schlegel and Pigg, 1990; Cohen and Goldman, 1991) had shown an improvement in Program performance between 1980 and 1989, suggested that a new, more up-to-date metaevaluation, might also reveal continuing improvements between 1990 and 1995.

All of the savings estimates that are presented in this paper are for dwellings that heat primarily with natural gas. Both the savings estimates taken from the National Evaluation and those based upon the state-level evaluations are for gas-heated homes. This focus on natural gas was chosen because all of the state-level evaluations conducted between 1990 and 1995 studied homes that heat primarily with natural gas. A few of the state-level evaluations also examined homes heating with other fuel types, but natural gas was the only fuel type included in all the studies.

Methods

The first step in the metaevaluation was to locate and obtain copies of all of the state-level evaluations of the DOE Program that had been completed since 1990. A survey form was mailed to every state weatherization office and follow-up telephone conversations were conducted. Using these methods, eleven published state-level evaluations were obtained from nine states (Fig. 1). The states with published evaluations and the dates of weatherization for the houses included in each study were as follows:

- Colorado (1993-95),
- Indiana (1991-92),
- Iowa, (1992-93),
- New York (1990),
- North Carolina (1990),
- North Dakota (1990-92),
- Ohio (1990-91 and 1993-94),
- Texas (1991-92), and
- Vermont (1992-93 and 1993-94).

In both Ohio and Vermont, two separate evaluations of Program energy savings were conducted and published between 1990 and 1995 (Columbia Gas of Ohio, 1993; Columbia Gas of Ohio, 1995; Vermont State Office of Economic Opportunity, 1993; Vermont State Office of Economic Opportunity, 1995).
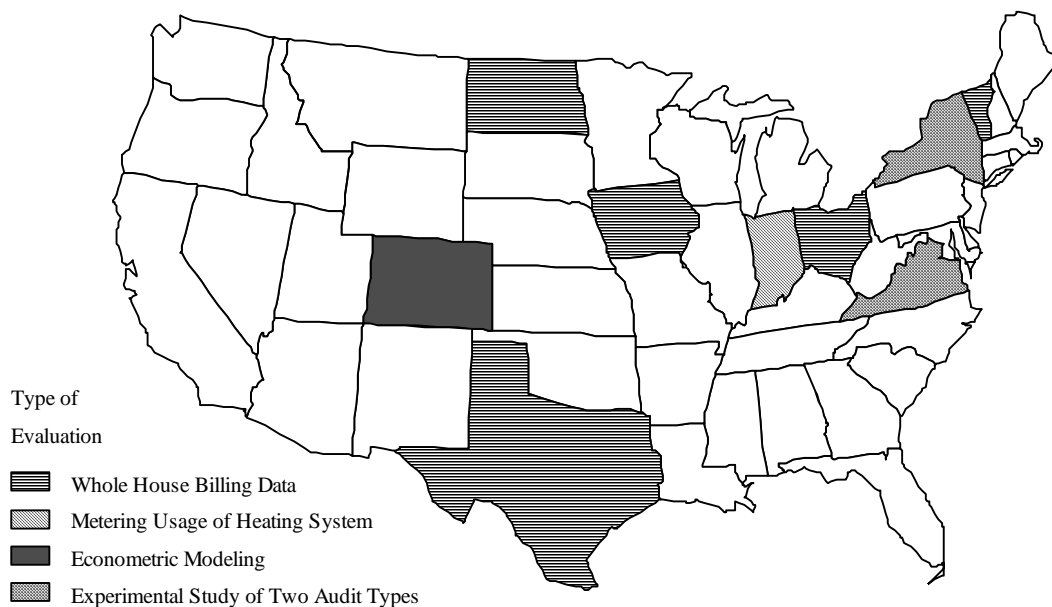

Type of
Evaluation

▭ Whole House Billing Data
▭ Metering Usage of Heating System
▭ Econometric Modeling
▭ Experimental Study of Two Audit Types

Figure 1. States with Published Evaluations of the Program in 1990-1995.

Three of the published evaluations were conducted by utility companies (Public Service Company of Colorado, 1995; Columbia Gas of Ohio, 1993 and Columbia Gas of Ohio, 1995). All three of these evaluations, although conducted by utility staff or their contractors, were of programs that followed DOE procedures. In each case, the state Weatherization Program contacts and the utility contacts believed that the evaluations were good indicators of the DOE Program's performance in their states. In addition, the two Columbia Gas evaluations, conducted for homes weatherized in 1990-91 and in 1993-94, provide an indication of the rate of increase in Program savings over time. The Colorado evaluation was based on econometric modeling. Both of the Ohio evaluations were based on analysis of whole house natural gas billing data.

Two of the eleven published evaluations (Sharp, 1994; New York Energy Research and Development Authority and New York Department of State, 1993) were experimental studies which provided measurements of the energy savings obtained with two types of audit procedures. In both New York and North Carolina, the evaluations compared energy savings results for a group of homes treated with standard state procedures at the time of the study to results for a group of homes treated with an advanced audit (Targeted Investment Protocol (TIPS) in New York, and an initial version of the National Energy Audit (NEAT) in North Carolina). These two studies provide particularly useful information because they measure the degree of improvement that occurs with the introduction of an advanced audit.

Of the remaining six published evaluations (Indiana CAP Director's Association, 1992; The Statewide Low-Income Collaborative Evaluation (SLICE) of Iowa, 1994; North Dakota Weatherization Assistance Program, 1993; Texas Department of Housing, 1995; Vermont State Office of Economic Opportunity, 1993; Vermont State Office of Economic Opportunity, 1995) five developed savings estimates from billing data analyzed with PRISM (Princeton Scorekeeping Method. See Fels, 1986) or a similar weather normalization procedure. These five evaluations produced whole house estimates of savings for dwellings using natural gas as the primary heating fuel. The two Vermont evaluations, conducted for homes weatherized in 1992-93 with a weather normalization procedure developed by the Wisconsin Energy Conservation Corporation, and in 1993-94 with PRISM, also provide an indication of the rate of increase in Program savings over time. The Indiana evaluation used a different methodology. It relied on short-term metering of furnace run times to estimate heating savings only (Indiana CAP Director's Association, 1992).

Six states provided unpublished evaluation results that were used as input to this metaevaluation (Fig. 2). Kansas provided results based on a PRISM analysis of 165 Kansas homes weatherized in 1993 and 1994. Nebraska provided results based on a PRISM analysis of 37 Nebraska homes weatherized in 1994. North Carolina provided summary data from a state-wide data collection system based on NEAT input and output files for 1994. Ohio provided preliminary results from a PRISM analysis of 1510 homes weatherized in 1995. Wisconsin provided results based on a PRISM analysis of 675 Wisconsin homes weatherized in 1992. Wyoming provided preliminary estimates of savings based on monitoring of the usage of space-heating equipment in 38 homes weatherized in 1996. These results will be supplemented with a PRISM analysis of over 200 Wyoming homes which will be completed later this year. Because the results from these states are based on extensive data, and on methodologies which seemed to be sound, they are included as input to a regression model designed to estimate national savings.
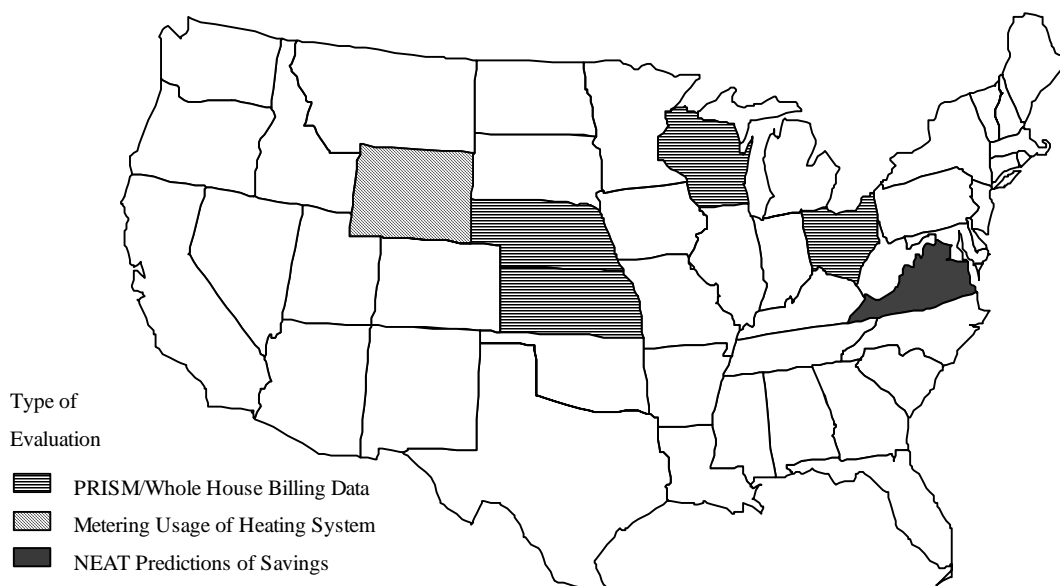

Type of Evaluation

PRISM/Whole House Billing Data

Metering Usage of Heating System

NEAT Predictions of Savings

Figure 2. States with Unpublished Evaluation Results for the Program in 1992-1996.

After locating and reviewing the state-level evaluations described above, the next task was to develop a way of comparing and integrating their findings. The approach chosen to estimate national savings was to use regression modeling to develop the best linear equation for predicting savings. The data from the recent state-level evaluations (1990-1995) were used to develop this predictive tool. Then the parameters of the best predictive model were applied to the appropriate average national input values for each predictor in the equation. For example, the average heating degree days for the available evaluations was 5,942. Nationally, the population weighted 30-year average of heating degree days is 4,499. Therefore, the national average of 4,499 heating degree days is used as the input to the regression model used to predict national savings. For the most part, national input values are taken from the National Evaluation, which was based upon a representative national sample. Details of the rationale for selecting specific national input values, and for changing some state input values to account for definitional issues are discussed in Berry (1997), which also describes the model development process.

Findings

This review of state-level evaluations clearly showed a trend toward increased Program savings. Three types of evidence support the finding that savings are increasing:

- a literature review,
- within-state comparisons of savings over time, and
- regression modeling results.

Literature Review

The 1991 literature review, conducted in preparation for the National Evaluation, concluded that the evaluations available at that time (covering the years of 1981-1989) showed typical energy savings (expressed as the percentage reduction in the total consumption of the primary heating fuel) of between 12% and 16%, with a range of 6% to 23% savings in various locations. This 1996 review, of 18 state-level evaluations covering 1990 to 1996, showed typical savings of 18% to 24%, with a range of savings of from 13% to 34% (Table 1).

Trends Within States

Two states for which savings can be compared over time, Vermont and Ohio, both showed significant increases in savings. The trend toward increased savings over time in these states is unmistakable (Table 2).

Regression Modeling Results

As Table 3 shows, the regression-based national estimate of savings for 1996 is considerably higher than the savings for 1989 estimated by the National Evaluation.

National savings, in homes using natural gas as the primary heating fuel, for the 1989 Program Year were 17.3 MBtu, which is 18.3% of space heating consumption, or 13.0% of the total consumption of natural gas for all end uses. The regression-based national estimate for 1996 is 31.2 MBtu, which was 33.5% of natural gas space heating consumption, or 23.4% of the total consumption of natural gas for all end uses.

As Table 4 shows, the pre-weatherization level of consumption is the strongest predictor in the regression model used to estimate 1996 savings. This means that dwellings that consume more energy prior to weatherization, save more energy after weatherization. Pre-weatherization energy consumption reflects occupant characteristics (e.g., the appliances owned by a household, household management of the thermostat), dwelling characteristics (e.g., the size of the dwelling, the leakiness of the building shell, and the efficiency of its heating system), climate characteristics (e.g., heating and cooling degree days, solar insolation, humidity, wind speeds), and a host of other influences.

The correlation between high pre-weatherization energy use and high savings potential has been recognized in the procedures of many state and utility programs. A common feature of the higher saving state-level programs is the targeting of high-consuming households. The New York Program, for example, uses the TIPS audit to guide investment levels. TIPS calibrates the appropriate investment level to the level of pre-weatherization energy efficiency in the dwelling, which is measured as Btu/HDD/square foot consumed annually.

As Table 4 shows, although pre-weatherization consumption is a highly significant predictor of energy savings, the variables of audit type, and year of weatherization have limited predictive ability. Pre-weatherization consumption is significant at a level of less than 0.001. The other two variables are statistically significant at levels of less than 0.188 for year of weatherization, and 0.090 for audit type. One indicator of the relative importance of the three independent variables is shown by the standardized coefficients in Table 4. The standardized coefficient for pre-weatherization consumption is over three times as large as the standardized coefficient for year, and over seven times as large as the standardized coefficient for audit type.

The overall model fit for the three variable model described in Table 4 is good with an adjusted R^2 of 0.75. As Figure 3 shows, this model can predict state-level savings with considerable accuracy.

Table 4 to average national values for pre-weatherization consumption (133 MBtu), audit type (50% advanced audits), and year (1996).

A confidence interval for the national estimate of savings was calculated with SAS. For the national estimate of 31.2 MBtu was obtained by applying the coefficients shown in the lower bound for the 90% confidence in-

Table 1. Literature Review Findings on Central Tendencies Characterizing the Percentage of Energy Savings in 1981-1989 and in 1990-1995

	n	Median	Mean	Interquartile Range	Range
1980-89	25	12%	13%	12-16%	6-23%
1990-96	17	20%	22%	18-24%	13-34%

Table 2. Trends in Energy Savings in Ohio and Vermont

Ohio			Vermont		
	Mbtu	**Percent**		**MBtu**	**Percent**
1990-91	20.5	12.6%	**1992-93**	18.0	17.8%
1993-94	29.3	20.4%	**1993-94**	24.5	20.1%
1994-95	34.8	27.0%	**n/a**	n/a	n/a

Table 3. Estimated National Program Energy Savings in 1989 and 1996 in Homes that Heat Primarily with Natural Gas

	MBtu of Natural Gas	Percentage Reduction in Natural Gas Consumption for Space-Heating	Percentage Reduction in Natural Gas Consumption for All End Uses
National Evaluation Results for 1989	17.3	18.3%	13.0%
Metaevaluation Results for 1996 based on Regression Model	31.2	33.5%	23.4%

Table 4. Regression Analysis of Average State-Level Energy Savings (in MBtu)

Dependent Variable=Average State-Level Energy Savings (in MBtu) **Predictor**	**Unstandardized Regression Coefficient**	**Standard Error**	**T-value**	**Standardized Regression Coefficient**
Intercept	-375.949	294.008	-1.279	0.000
Pre-weatherization consumption	0.985	0.156	6.313*	0.784
Year of weatherization	113.741	89.121	1.276	0.188
Advanced audit	0.041	0.069	0.597	0.090

Coefficient of Determination (R^2) = 0.793
Adjusted Coefficient of Determination (R^2) = 0.751
F-Value = 19.109
Sample Size = 19
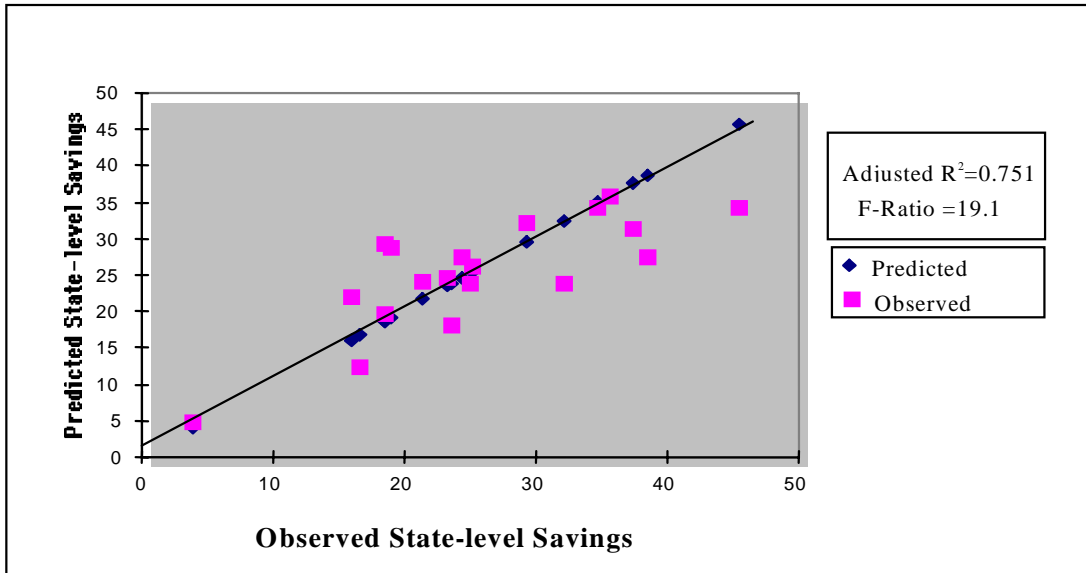
* significant at p<0.001

Figure 3. Goodness of Fit for the Three-Variable (Pre-Weatherization Consumption Year, Audit Type) Regression Model Shown in Table 4.
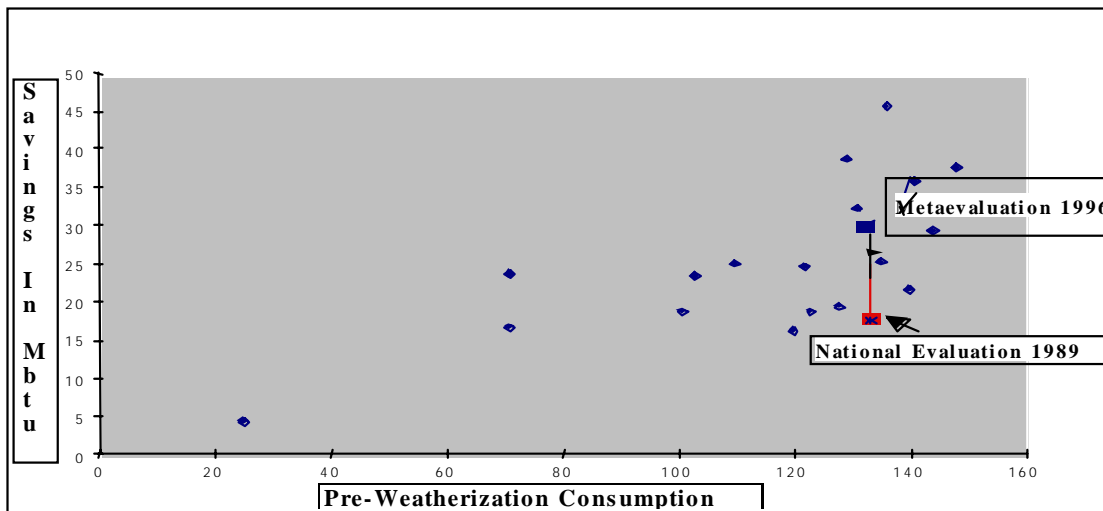

Figure 4. State-level Energy Savings per Dwelling in 1990-95 and Average National Savings per Dwelling in 1989 and 1996 by Pre-Weatherization Consumption.

terval is 22.9 MBtu, and the upper bound is 38.6 MBtu.Thus, the lower bound for the 1996 estimate is well above the 1989 estimate of 17.6 MBtu. The 90% confidence -interval reported in Brown, et al. (1993) for savings in gas heated homes was 15.1 to 19.5 MBtu. As Figure 4 shows, the 1996 estimate of national savings, and most of the savings estimates reported in state-level evaluations conducted since 1990, are higher than the average national savings measured in 1989.

Conclusions and Recommendations

State-level evaluations of the Weatherization Assistance Program offer an important resource for Program management. These evaluations are conducted with some frequency and are usually technically sound. Both previous literature reviews of state-level evaluations conducted between 1980 and 1989, and this 1996 metaevaluation of state-level evaluations conducted since 1990, found that the synthesis of state-level evaluations offered a reasonable

characterization of national Program performance. In addition, reviews of state-level evaluations can provide important insights into the effectiveness of various weatherization practices, and into the remaining potential for improving savings and cost effectiveness.

Because of the value of state-level evaluations, the monitoring of their availability and the synthesizing their findings should be ongoing Program management activities. Although national level evaluation efforts are sometimes needed to definitively demonstrate Program performance, reviews of state-level evaluations provide useful, and inexpensive, benchmarks of progress during the years between such large-scale national assessments.

This review of the state-level evaluations conducted since 1990 concluded that Program performance has improved significantly in the last seven years. In the National Evaluation, which measured performance in 1989, the average national savings for homes heating with natural gas was 17.3 MBtu, which was 18.3% of space heating consumption, or 13.0% of the total consumption of natural gas for all end uses. Findings from this state-level evaluation review indicated average savings in 1996 had increased to 31.2 MBtu, which was 33.5% of space heating consumption, or 23.4% of the total consumption of natural gas for all end uses.

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