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METAEVALUATION OF NATIONAL WEATHERIZATION ASSISTANCE PROGRAM BASED ON STATE STUDIES, 1996–1998

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EXECUTIVE SUMMARY

INTRODUCTION

The national Weatherization Assistance Program, sponsored by the U.S. Department of Energy (DOE) and implemented by state and local agencies throughout the United States, weatherizes homes for low-income residents in order to increase their energy efficiency and lower utility bills. Staff at Oak Ridge National Laboratory (ORNL) performed a metaevaluation of this program, which involved synthesizing the results from ten individual studies of state weatherization efforts completed between April 1996 and September 1998. The states whose studies were used in this metaevaluation, the dates of program operations covered by these studies, and the fuels that were examined are shown in Table ES-1. This effort represents a follow-up to an earlier ORNL metaevaluation of the Weatherization Assistance Program that looked at 19 state studies completed between 1990 and early 1996 (Berry 1997). That study, in turn, was done as an update to a national evaluation of the Weatherization Assistance Program that examined a representative sample of several thousand structures weatherized in 1989 (Brown, Berry, Balzer, and Faby 1993).

Table ES-1. Studies used in metaevaluation

		Fuel studied*		
State	Years covered	Natural gas	Electricity (space-heating)	Electricity (non-heating)
Colorado	1995–1996	X		X
Delaware	1995		X	
District of Columbia	1995	X	X	
Indiana	1993–1994	X		
Iowa	1996	X		X
Iowa	1997	X		X
Minnesota	1995–1996	X		
Minnesota	1996–1997	X		
Ohio	1994	X	X	
Vermont	1995–1996	X		X

*While additional fuels (e.g., propane, fuel oil) were covered in a few of the state studies, this evaluation focuses on natural gas and electricity because they were by far the most commonly used.

METHODS

State weatherization staff were contacted to determine which states had evaluated their programs since 1996, and key data required for this metaevaluation were obtained by reading state reports documenting study findings and through follow-up contacts with state-level evaluators. As a result of these efforts, we received usable information on ten recent weatherization program evaluations from seven states and the District of Columbia. Nine of these studies examined houses that used natural gas, three focused on houses with electric heat, and four looked only at the use of electricity for non-heating purposes. Separate analyses were performed for each fuel source and application: one using data from the nine state studies of gas-fueled houses; another using data from the three state studies of electrically-heated dwellings; and a third using the four evaluations of structures that used electricity for nonheating purposes.

The data analyses performed in this metaevaluation had three objectives: (1) to identify average savings experienced by weatherized households in the states that provided information for this evaluation; (2) to identify the key variables that explain the magnitude of weatherization-induced savings reported by the states included in this study; and (3) to estimate average household savings that could be expected nationwide, based on the findings from our set of state studies. The key variable(s) associated with energy savings were identified by running a regression analysis using energy savings as the dependent variable and a number of potentially-related factors as independent variables. The regression analysis was performed only for gas-fueled homes, because this was the only fuel for which there were enough state studies to allow a reasonably accurate analysis. Using the results of this regression analysis, we estimated average household energy savings that could be expected to be achieved nationwide. This was accomplished by taking the regression equation from the model with the best predictive ability and inserting the average national values for the independent variable(s).

KEY FINDINGS

Mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption were calculated from the average values reported in the nine state studies of gas-fueled residences. Mean annual pre-weatherization consumption for all end uses was 148.9 million BTUs per household; mean household energy savings amounted to 32.7 million BTUs annually; and mean energy savings equaled 21.0% of pre-weatherization consumption.

A simple regression analysis revealed a strong positive relationship between pre-weatherization energy consumption and weatherization-induced energy savings (R-Square = 0.657; p=.008). This means that, consistent with findings from previous studies, households with higher pre-weatherization energy use tend to save more energy. The R-Square of 0.657 means that 65.7% of the variance in energy savings is explained by pre-weatherization energy consumption.

According to the descriptive equation produced by the simple regression analysis mentioned above, natural gas savings equal -29.06 plus the product of pre-weatherization consumption times 0.415. By inserting the national average of pre-weatherization household natural gas consumption into the equation, we can estimate average national savings. According to the latest

national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), average pre-weatherization natural gas consumption for all end uses is 133 million BTUs per house, so our estimate of national household savings is 26.1 million BTUs annually. This amounts to 19.6% of average pre-weatherization consumption for all end uses.

Cost-effectiveness was calculated for the weatherization program nationwide. As in past evaluations, we used three different perspectives: the program perspective, which compares the discounted value of energy savings to *total* program costs; the installation perspective, which compares the discounted value of energy savings to labor and material costs; and the societal perspective, which compares the discounted value of both energy and non-energy benefits to total program costs. The benefit/cost ratios that we calculated were 1.51 from the program perspective, 2.02 from the installation perspective, and 2.12 from the societal perspective.

The average savings for gas-fueled households nationwide as calculated in this metaevaluation can be compared to the findings from the previous ORNL metaevaluation and the national evaluation of the 1989 weatherization program. As shown in Table ES-2, average national savings for gas-fueled households as a percent of pre-weatherization consumption for all end uses averaged 19.6% in the time period examined in the latest metaevaluation, 23.4% in the years covered by the previous metaevaluation, and 13.0% in 1989. Although most of the state studies did not measure the portion of total pre-weatherization consumption that went for space-heating, this can be estimated to allow comparison with previous studies. We found that, nationwide, household natural gas savings as a percent of pre-weatherization consumption for space-heating averaged 27.6% in the years covered by the current metaevaluation, 33.5% in the period examined in the previous ORNL metaevaluation, and 18.3% in 1989.

Table ES-2. Estimated nationwide savings from this metaevaluation and previous studies

	Average household natural gas savings, in MBTU (followed by 90% confidence interval)	Average household natural gas savings as a percent of pre-weatherization consumption for all end uses, in % (followed by 90% confidence interval)	Average household natural gas savings as a percent of pre-weatherization consumption for space-heating, in % (followed by 90% confidence interval)
Current ORNL metaevaluation: 1996–1998 studies	26.1 (19.4–32.8)	19.6 (14.6–24.6)	27.6 (20.5–34.7)
Previous ORNL metaevaluation: 1990–1996 studies	31.2 (22.9–38.6)	23.4 (17.2–29.0)	33.5 (24.6–41.4)
1989 national evaluation	17.3 (15.1–19.5)	13.0 (11.3–14.7)	18.3 (16.0–20.6)

A look at the 90% confidence intervals presented in Table ES-2 indicates that there is no significant difference between the average savings estimated by the two metaevaluations, because there is substantial overlap in their ranges of possible nationwide savings. In contrast, the 90% confidence interval for national savings from the 1989 national evaluation has no overlap with the confidence interval from the first metaevaluation and only an extremely small overlap with the confidence interval from the current metaevaluation. The implication of this finding is that weatherization-induced savings have, in fact, increased significantly since 1989. Accordingly, benefit/cost ratios have increased as well.

There are several possible reasons why weatherization-induced energy savings increased between 1989, the year studied in the national weatherization evaluation, and 1996, when the first metaevaluation was conducted. Advanced audits became widely used; the use of blower-doors as a diagnostic tool became commonplace; and cooling efficiency measures became allowable due to changes in DOE regulations. Since 1996, however, there have been no equally dramatic changes in the structure or practices of the Weatherization Assistance Program, and this accounts for the fact that there has been no significant change in the magnitude of energy savings between the previous metaevaluation and this one.

1. INTRODUCTION

1.1 BACKGROUND

Under the sponsorship of the U.S. Department of Energy (DOE), the national Weatherization Assistance Program has weatherized more than four million low-income residences since its inception in 1976. This federally funded program, which is implemented by state and local agencies in all 50 states and the District of Columbia, is designed to increase residential energy efficiency, thereby lowering energy costs for low income occupants and improving their health and comfort.

This report documents the findings of a recent metaevaluation of the Weatherization Assistance Program conducted by staff at Oak Ridge National Laboratory (ORNL). A metaevaluation is a study that uses as its data points the findings from a number of individual studies on the topic of interest. In this case, the performance of the national Weatherization Assistance Program is the focus, and the data points are the findings from ten evaluations of individual states' weatherization efforts completed between April 1996 and September 1998. The states whose studies were used in this metaevaluation are shown in Figure 1.

The study that is the focus of this report is a follow-up to a metaevaluation of the Weatherization Assistance Program performed by ORNL in 1996 (Berry 1997). That study, in turn, was performed in order to update the findings from a national evaluation of the Weatherization Assistance Program that ORNL conducted in the early 1990s (Brown, Berry, Balzer, and Faby 1993). The national evaluation examined a representative sample of several thousand structures weatherized in 1989, while the 1996 metaevaluation looked at 19 state studies that were completed between 1990 and early 1996.

The metaevaluation performed by ORNL in 1996 found substantially greater energy savings in the time period 1990–1996 than were realized by the Weatherization Assistance Program in 1989. There are several possible reasons for this, most notably: (1) advanced audits, which were not available in 1989, were widely used by the mid-1990s; (2) the use of blower-doors to guide efforts to reduce air infiltration became much more common after 1990 than had previously been the case; and (3) new DOE regulations permit the use of cooling efficiency measures that were previously not included in low-income weatherization efforts.

Between the completion of the 1996 metaevaluation and the current study, no dramatic changes were made in the structure or practices of the Weatherization Assistance Program. Accordingly, the authors began this project with the expectation that the magnitude of energy savings revealed by this study would be similar to what was found in the previous metaevaluation. This, in fact, proved to be the case.

1.2 SCOPE OF REPORT

The subsequent chapters of this report describe the research methods used in this metaevaluation and discuss the key findings. Chapter 2 provides information on the state studies that were examined and how the data provided by these individual studies were analyzed. Chapter 3 presents energy and dollar savings for buildings heated with natural gas, examines key

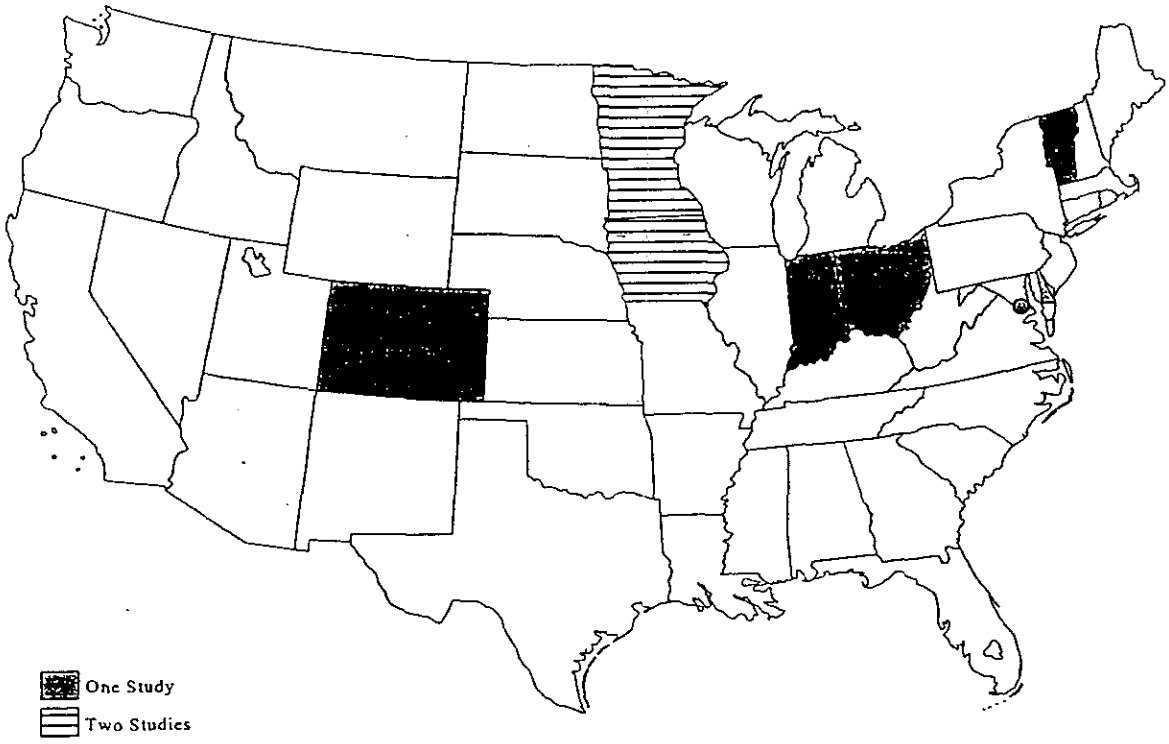

Figure 1. States with weatherization program studies used in metaevaluation.

factors that could possibly explain the findings, and gives an estimate of average household savings nationwide. Findings are not presented in the body of this report regarding electricity use because the number of states that studied this fuel is too small to allow reliable analytical results; however a brief discussion of electricity savings is presented in Appendix B. In Chapter 4, the findings from this study are compared to those from the previous metaevaluation and the earlier national evaluation of the Weatherization Assistance Program.

2. METHODS

2.1 SELECTING STATE EVALUATIONS

The first step in conducting the 1998 metaevaluation was to identify all states that had evaluated their weatherization programs since 1996, when the previous ORNL metaevaluation was performed. We already knew the status of evaluation efforts in four states[1] that had been working closely with ORNL to design and implement weatherization program evaluations. For the other 46 states and the District of Columbia, we elicited the needed information by sending a letter to their weatherization staff asking for a description of any evaluations that had been completed or documented in their jurisdiction since April 1996. These letters also asked for the name of an individual who could be contacted for more information and requested some information on each state's data system for keeping track of weatherization activities and on the weatherization measure selection techniques currently in use. The key information received from each state as a result of these contacts is presented in Appendix A.

After state weatherization staff responded to the information request letter described above, we made telephone calls to the appropriate contact person in each state where an evaluation had been completed since April 1996 and requested a copy of the report documenting their study. The reports that we received are cited in the References section. We also designed a data collection form indicating every variable that would be needed to perform a metaevaluation. After reading each report, we filled in a data collection form to the extent possible and made follow-up calls to the state weatherization contact to request any missing information. In those two cases where an evaluation had been performed but a report had not been written,[2] we sent a data collection form to the state contact and asked that individual to complete it.

As shown in Table 1, we received usable information[3] on ten recent weatherization program evaluations in seven states and the District of Columbia. Colorado, Delaware, Indiana, Ohio, Vermont, and Washington, D.C., each provided results from a single evaluation, while Iowa and Minnesota had conducted two separate evaluations apiece during the study period. Although we requested information only on those evaluations that had been completed or documented since April 1996, much of the data that we received covered program years prior to 1996 because of the substantial amount of time required to collect and analyze energy consumption data and prepare reports documenting study findings.

Most of the state studies used in this metaevaluation examined the use of natural gas, electricity, or both. Only a couple of evaluations included information on other fuels, such as propane or fuel oil, and they are too few to warrant discussion in this report. Nine of the ten state

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[1]The four states with which ORNL had already been working on weatherization program evaluations are California, Georgia, Texas, and Washington.

[2]Reports were not available for the evaluations of Indiana's 1993–1994 weatherization program and Minnesota's 1996–1997 program.

[3]To be usable, an evaluation had to identify the weatherization-induced energy savings that would occur in a year with typical weather, often referred to as "weather-normalized annual savings."

Table 1. Key features of state evaluations

State	Program year	Control group	Method of calculating energy savings	Fuel studied*	Number of weatherized buildings
Colorado	1995–1996	Yes	Regression analysis	Natural gas Electricity	2,442 1,937
Delaware	1995	Yes	PRISM	Electricity	25
District of Columbia	1995	No	Site-specific weather-sensitivity coefficients used to normalize energy consumption	Natural gas Electricity	159 10
Indiana	1993–1994	No	PRISM	Natural gas	49
Iowa	1996	No	Adjustment factors applied to tracking data base	Natural gas Electricity	1,074 829
Iowa	1997	No	Adjustment factors applied to tracking data base	Natural gas Electricity	1,877 2,229
Minnesota	1995–1996	No	Data loggers/ASAP (with DESLog software)	Natural gas	32
Minnesota	1996–1997	No	Data loggers/ASAP (with DESLog software)	Natural gas	44
Ohio	1994	Yes	PRISM	Natural gas Electricity	2,209 154
Vermont	1995–1996	No	PRISM	Natural gas Electricity	35 82

*A few state studies included information on additional fuels (e.g., propane, fuel oil), but this study focuses only on natural gas and electricity.

studies examined houses that used natural gas and seven looked at houses that used electricity (Table 1). Three of the studies of electricity use focused on houses with electric heat and four looked only at the use of electricity for nonheating purposes. The number of houses examined varied widely from study to study. For studies of natural gas consumption, four were based on

data for less than 100 houses while another four looked at over 1,000 houses. On the electricity side, three of the studies examined less than 100 houses and two evaluated savings for over 1,000 structures.

A variety of methods was used to calculate energy savings, as shown in Table 1. In the majority of cases, savings were identified by tracking monthly energy bills for a period of approximately 12 months both before and after weatherization. These billing records were most often analyzed with a software system called PRISM, which stands for PRInceton Scorekeeping Method (Fels, Kissock, Marean, and Reynolds 1995; Fels and Reynolds 1990). In two studies, data loggers were attached to heating systems to directly measure pre- and post-weatherization energy consumption with the Achieved Savings Assessment Program (ASAP) which uses DESLog software to do weather-normalization and calculate energy savings (Minnesota Office of Low-income Energy Programs 1998) and, in another two cases, savings were calculated by applying empirically-derived adjustment factors to engineering estimates of savings associated with the weatherization measures that were installed in the households under study. Of the ten state studies used for this metaevaluation, three used control groups and seven did not. Any changes in household energy use experienced during the study period by the control group—which is a set of unweatherized houses—represents change that is likely to have occurred in the treated houses in the absence of weatherization. Accordingly, the analyst can subtract these changes from those observed in the weatherized structures to get adjusted savings (often referred to as net savings), which are generally considered to be more accurate than unadjusted (gross) savings.

2.2 WORKING WITH THE DATA

The purpose of the data analysis performed in this metaevaluation was threefold: (1) to identify average savings experienced by weatherized households in the states that provided information for this evaluation; (2) to identify the key variables that explain the magnitude of weatherization-induced savings reported by the states included in this study; and (3) to estimate average household savings that could be expected nationwide, based on the findings from our set of state studies.

In a metaevaluation, the average value for any given variable from one study constitutes a single data point. So, for example, the portion of this metaevaluation that examines gas-fueled households has nine data points for pre-weatherization energy consumption, with each one consisting of the average consumption calculated from all houses examined in one of the state studies. No variable in this metaevaluation could have more than nine data points, because there are only nine state studies of gas-fueled dwellings in our data set. However, it is possible for there to be less than nine data points for a given variable because one or more studies might not have provided usable data for a particular item.

The major *outcome* of interest in this metaevaluation is the magnitude of energy savings experienced by weatherized households. Our data points for this variable are the average annual energy savings identified in each of the state studies described in Section 2.1. Most of the state studies did not employ a control group, so the energy savings they identified are gross (or unadjusted) savings. However, a few states reported net savings that had been adjusted based on the performance of a control group, and we used these adjusted savings whenever they were

available. Average savings for the entire set of state studies was calculated by taking the arithmetic mean of the average savings reported in the individual studies, and the 90% confidence interval also was computed.[4] Separate calculations were made for different fuel sources and applications: one using data from the nine state studies of gas-fueled houses; another using data from the three state studies of electrically-heated dwellings; and a third using the four evaluations of structures that used electricity for nonheating purposes. The findings for the gas-fueled homes are presented in Chapter 3, while electricity savings (which are based on a smaller number of observations) are discussed in Appendix B.

The key variable(s) that are associated with the magnitude of weatherization-induced energy savings were identified by running a regression analysis using energy savings as the dependent variable and a number of factors that could potentially explain energy savings as independent variables. These potential explanatory variables are: (1) pre-weatherization energy consumption; (2) square footage of the weatherized structures; (3) heating degree days in the project area; and (4) weatherization expenditures. They were selected because they had been shown to be significantly related to energy savings in the national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), the previous metaevaluation (Berry 1997), or both, and because data on these factors were provided by the state studies or could be easily estimated or obtained from another source. The regression analysis was performed only for gas-fueled homes, because this was the only fuel for which there were enough state studies (nine) to allow a reasonably accurate analysis. The samples for electrically-heated houses (three studies) and houses using electricity for non-heating purposes (four studies) were too small to produce meaningful results. More information about the independent variables used in the regression analysis of gas-fueled residences is provided in Appendix C.

Using the results of the regression analysis performed for the gas-fueled houses, we were able to estimate average household energy savings that could be expected to be achieved nationwide. This was done by taking the regression equation from the model with the best predictive ability and inserting the average national values for the independent variable(s). This process is explained more fully in Chapter 3.

[4]Confidence intervals, which were calculated for pre-weatherization consumption and energy savings, tell us the range within which the value of a given variable is likely to fall for an entire population, at a given level of certainty (e.g., 90%).

3. FINDINGS

3.1 NATURAL GAS SAVINGS FROM STATE STUDIES

Mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption were calculated from the average values reported in the nine state studies of gas-fueled residences. Mean annual pre-weatherization consumption for all end uses was 148.9 million BTUs per household; mean household energy savings amounted to 32.7 million BTUs annually; and mean energy savings equaled 21.0% of pre-weatherization consumption.[5] These values, plus the minimum and maximum and 90% confidence interval for each variable are shown in Table 2.

Table 2. Key findings from nine state weatherization program studies of gas-heated structures

	Minimum	Maximum	Mean	90% confidence interval
Pre-weatherization consumption for all end uses (MBTU)	102.3	190.2	148.9	131.2–166.6
Absolute savings* (MBTU)	11.0	60.5	32.7	23.7–41.8
Savings as a percent of pre-weatherization consumption (%)	8.5	29.8	21.0	17.1–24.9

*These numbers are calculated from net savings in those cases where a control group was used and gross savings in all other cases.

3.2 EXPLAINING NATURAL GAS SAVINGS

Several different regression analyses were run to examine possible relationships between natural gas savings and four potential explanatory variables: pre-weatherization consumption; square footage of structure; heating degree days; and weatherization expenditures. A simple regression analysis was performed using energy savings as the dependent variable and pre-weatherization consumption as the sole independent variable. Subsequent analyses used each of the other possible explanatory factors listed above as the sole independent variable in order to determine its relationship to energy savings. An additional simple regression analysis tested the possible relationship between one of the independent variables (heating degree days) and energy

[5]The mean value given here for energy savings as a percent of pre-weatherization consumption was calculated from the values for this variable reported by all the individual state studies. If this value were calculated from the nine-study average values for energy savings and pre-weatherization consumption, the result would be slightly different.

savings for a data set that excluded one of the state studies that had some atypical—and potentially confounding—values for the variables involved.[6] The results of these simple regression analyses are shown in Table 3.

Table 3. Results of simple regression analyses testing relationship between possible explanatory variables and natural gas savings

Explanatory variable	N	F-value	p-value	R-square
Pre-weatherization consumption for all end uses	9	13.40	.008	0.657
Square footage of structure	9	1.54	.25	0.181
Heating degree days	9	0.30	.60	0.041
Heating degree days for reduced data set	8	6.57	.04	0.523
Weatherization expenditures	6	0.17	.70	0.041

Like previous studies (e.g., Columbia Gas of Ohio 1995, Berry 1997), this metaevaluation found a strong positive relationship between pre-weatherization energy consumption and weatherization-induced energy savings (R-Square=0.657; p=.008). In other words, households with higher pre-weatherization energy use tend to save more energy (Figure 2). The R-Square of 0.657 means that 65.7% of the variance in energy savings is explained by pre-weatherization energy consumption, and the p-value of .008 means that there is a probability of only eight in a thousand that the observed relationship could have occurred by chance. The only other independent variable that was found to be significantly related to energy savings was heating degree days for the reduced data set that excluded one study focusing on households with abnormally high values for pre-weatherization consumption. For the reduced data set, energy savings and heating degree days were found to be positively related (p=.04; R-Square=0.523), although the relationship was not as strong as the one between pre-weatherization consumption and energy savings. Because heating degree days and pre-weatherization consumption tend to be positively related (i.e., houses in colder climates use more energy) and pre-weatherization consumption is strongly associated with energy savings, the finding that homes in colder climates tend to achieve greater savings is not surprising.

Following the series of simple regression analyses described above, we ran a multiple regression analysis to test the relationship between energy savings and all four independent variables in the presence of each other. We also ran multiple regression analyses using various

[6]One of the state studies focused on households that had especially high pre-weatherization energy consumption, despite their location in a relatively mild climate. The positive relationship between heating degree days and pre-weatherization consumption found in many other studies (i.e., as one goes up the other does too) did not apply here. Because pre-weatherization energy consumption typically is strongly related to energy savings, the inclusion of this study in the sample masked the relationship between heating degree days and energy savings.

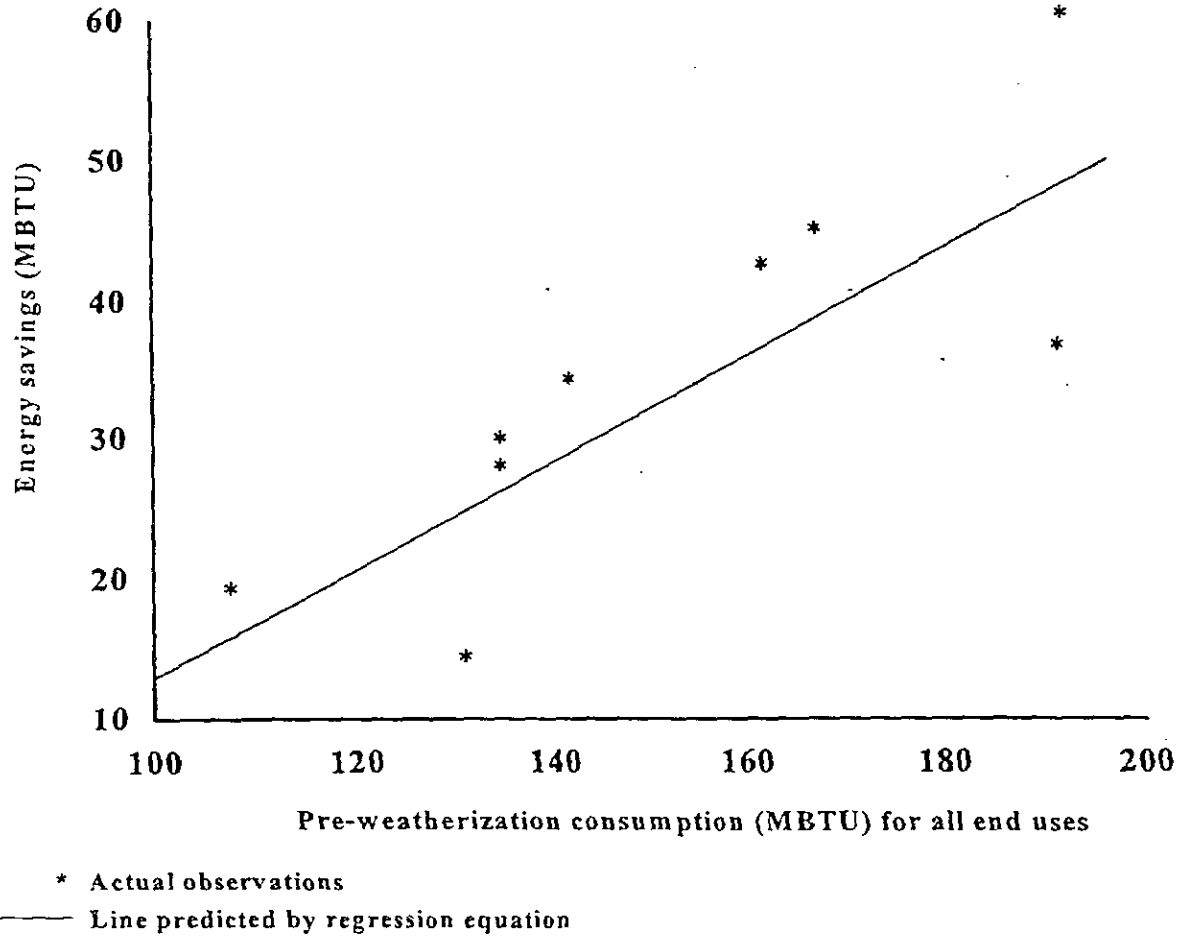

Figure 2. Plot of energy savings by pre-weatherization consumption for gas-heated structures.

subsets of the four independent variables. The result was that none of the multiple regression models yielded statistically significant results with greater explanatory power than the one-variable model using pre-weatherization energy consumption as the sole independent variable.

3.3 ESTIMATE OF AVERAGE NATIONAL SAVINGS FOR BUILDINGS HEATED WITH NATURAL GAS

As shown in Table 4, the one variable regression model that describes household natural gas savings in terms of its relationship with pre-weatherization energy consumption can be used to predict annual average savings nationwide. The descriptive equation produced by our simple regression analysis is that natural gas savings equal −29.06 plus the product of

Table 4. Estimate of average national savings using pre-weatherization consumption as predictive variable

One-variable regression equation [$R^2 = 0.657$; $p = .008$]:

Annual natural gas savings = −29.06 + (0.415 × pre-weatherization consumption)

National average of pre-weatherization household natural gas consumption for all end uses:

133 MBTU*

Predicted average household natural gas savings, nationwide:

−29.06 MBTU + (0.415 × 133 MBTU) = 26.1 MBTU
90% confidence interval: 19.4–32.8 MBTU (26.1 ± 6.7)

Predicted average household savings as a percent of pre-weatherization consumption for all end uses:

26.1 MBTU / 133MBTU = 19.6%
90% confidence interval: 14.6–24.6% (19.6% ± 5.0)

*National average taken from 1989 National Weatherization Evaluation (Brown, Berry, Balzer, and Faby 1993).

pre-weatherization consumption times 0.415.[7] By inserting the national average of pre-weatherization household natural gas consumption into the equation, we can estimate average national savings for dwellings using natural gas. According to the latest national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), average pre-weatherization natural gas consumption for all end uses is 133 million BTUs per house, so our estimate of national household savings is 26.1 million BTUs annually. This amounts to 19.6% of average pre-weatherization consumption for all end uses. The 90% confidence intervals for estimated average

[7]Although our study used MBTUs (million BTUs) as the unit of measure, this equation would apply to any energy unit (e.g., therms, ccf), used to measure natural gas consumption.

household energy savings and for average savings as a percent of pre-weatherization consumption are included in Table 4.

3.4 COST EFFECTIVENESS RESULTS FOR BUILDINGS HEATED WITH NATURAL GAS

Cost effectiveness was calculated for the weatherization program nationwide. Average annual energy savings per household (calculated in Sect. 3.3) was multiplied by average gas prices to get average annual dollar savings. Program costs were taken from the national weatherization program evaluation and adjusted for inflation.

As in past evaluations of the weatherization program, we used three perspectives for estimating cost effectiveness: the program perspective, the installation perspective, and the societal perspective. The program perspective compares the discounted value of energy savings to total program costs (including labor, materials, overhead, administrative and all other categories of fixed or variable costs). The installation perspective compares the discounted value of energy savings to installation-related costs (labor and materials). The societal perspective compares the discounted value of both energy and non-energy benefits[8] to total program costs.

To make the current benefit/cost ratios comparable to those from the previous metaevaluation and the national evaluation of the 1989 program, the same assumptions and procedures were used. In particular, the average measure lifetime was assumed to be 20 years and the discount rate used was 4.7%. Following the findings of the national evaluation, the net present value of non-energy benefits was assumed to be $976.

With the program perspective, the benefit/cost ratio for the current metaevaluation was 1.51, meaning that $1.51 of benefits were received for every $1 spent. Under the installation perspective, the benefit/cost ratio was substantially higher, at 2.02. With the societal perspective, which includes the value of non-energy benefits as well as all costs, the ratio was 2.12.

[8]The types of non-energy benefits considered in this analysis include affordable housing, comfort, health and safety, reduced utility arrearages and terminations, employment and economic benefits, and environmental externalities of the Weatherization Assistance Program.

4. CONCLUSIONS

Based on average savings reported in nine state-level studies of the weatherization of gas-fueled houses completed between 1996 and 1998, this metaevaluation found mean energy savings amounting to 21% of pre-weatherization consumption for all end uses. This is very close to the savings of 22% reported in the previous ORNL metaevaluation, which examined 17 studies of state weatherization programs conducted between 1990 and 1996 (Berry 1997).

Both metaevaluations went on to estimate average household savings *nationwide*, using the best regression model developed in the course of the evaluation and entering average national values for the independent variable(s). These estimates of nationwide savings can be compared to the findings from the national evaluation of the 1989 weatherization program to see how energy savings have changed over time. As shown in Table 5, national savings for gas-fueled households as a percent of pre-weatherization consumption for all end uses averaged 13.0% in 1989, 23.4% in the years covered by the previous metaevaluation, and 19.6% in the time period examined in the latest metaevaluation.

Table 5. Comparison of estimated average national savings from this metaevaluation with findings from past studies

	1989 national evaluation	Previous ORNL metaevaluation (1990–1996 studies)	Current ORNL metaevaluation (1996–1998 studies)
Average household natural gas savings (MBTU)	17.3	31.2	26.1
90% confidence interval:	*15.1–19.5*	*22.9–38.6*	*19.4–32.8*
Average household natural gas savings as a percent of pre-weatherization consumption for all end uses (%)	13.0	23.4	19.6
90% confidence interval:	*11.3–14.7*	*17.2–29.0*	*14.6–24.6*
Average household natural gas savings as a percent of pre-weatherization consumption for spaceheating (%)	18.3	33.5	27.6
90% confidence interval:	*16.0–20.6*	*24.6–41.4*	*20.5–34.7*

Most of the state studies reported pre-weatherization consumption for all end uses and did not measure the portion of this energy use that went for space-heating. However, in order to allow comparison with previous studies, we estimated pre-weatherization space-heating consumption and calculated average household savings as a percent of that.[9] Table 5 shows that, nationwide, household natural gas savings as a percent of pre-weatherization consumption for space-heating averaged 18.3% in 1989, 33.5% in the period examined in the previous ORNL metaevaluation, and 27.6% in the years covered by the latest metaevaluation.

The findings presented in Table 5 clearly show that energy savings have increased since 1989, but the national savings estimated by the latest metaevaluation are slightly less than those estimated in the earlier ORNL study. Does this mean that weatherization-induced savings have actually declined in the last two years?

A look at the 90% confidence intervals presented in Table 5 indicates that there is no significant difference between the average savings estimated by the two metaevaluations, because there is substantial overlap in their ranges of possible nationwide savings. This is illustrated graphically by Figure 3. The current metaevaluation indicates that there is a 90% probability that average household natural gas savings are between 14.6% and 24.6% of pre-weatherization consumption for all end uses, nationwide. The previous metaevaluation estimated that average savings fell somewhere between 17.2% and 29.0 % of pre-weatherization whole-house energy use. In contrast, the 90% confidence interval for national savings from the 1989 national evaluation has no overlap with the confidence interval from the first metaevaluation and only an extremely small overlap with the confidence interval from the current metaevaluation. The implication of this finding is that weatherization-induced savings have, in fact, increased significantly since 1989.

Because of the higher average national energy savings estimated by both ORNL metaevaluations, the benefit/cost ratios for these years also were higher than the ones reported by the national evaluation for the 1989 program year (Table 6).

As noted in Chapter 1, there are several possible reasons why weatherization-induced energy savings increased between 1989 and 1996, when the first metaevaluation was conducted. Advanced audits, which allow the identification and installation of more effective energy-saving measures, became widely used. Similarly, the use of blower-doors, which lead to greater reduction of air infiltration in weatherized houses, became commonplace.

Finally, cooling efficiency measures that were previously not included in the package of weatherization measures became allowable due to changes in DOE regulations. Since 1996, however, there have been no equally dramatic changes in the structure or practices of the Weatherization Assistance Program, and this accounts for the fact that the magnitude of energy savings has not changed significantly from the previous metaevaluation to this one.

Future evaluations can document the effects of any changes that are made in the way the Weatherization Assistance Program is structured and implemented. Within a given state, the effects of any new practice can be observed by comparing energy savings in the houses utilizing the new approach with savings in those houses served in the traditional manner. This applies to

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[9] A 1987 national survey found that, for gas-heated low-income households nationwide, 71% of total gas consumption went for space-heating (Brown, Berry, Balzer, and Faby 1993). The average pre-weatherization natural gas consumption of 133 million BTUs per house reported in the latest national weatherization program evaluation was multiplied by 0.71 to yield an average household pre-weatherization space-heating usage of 94.4 million BTUs.

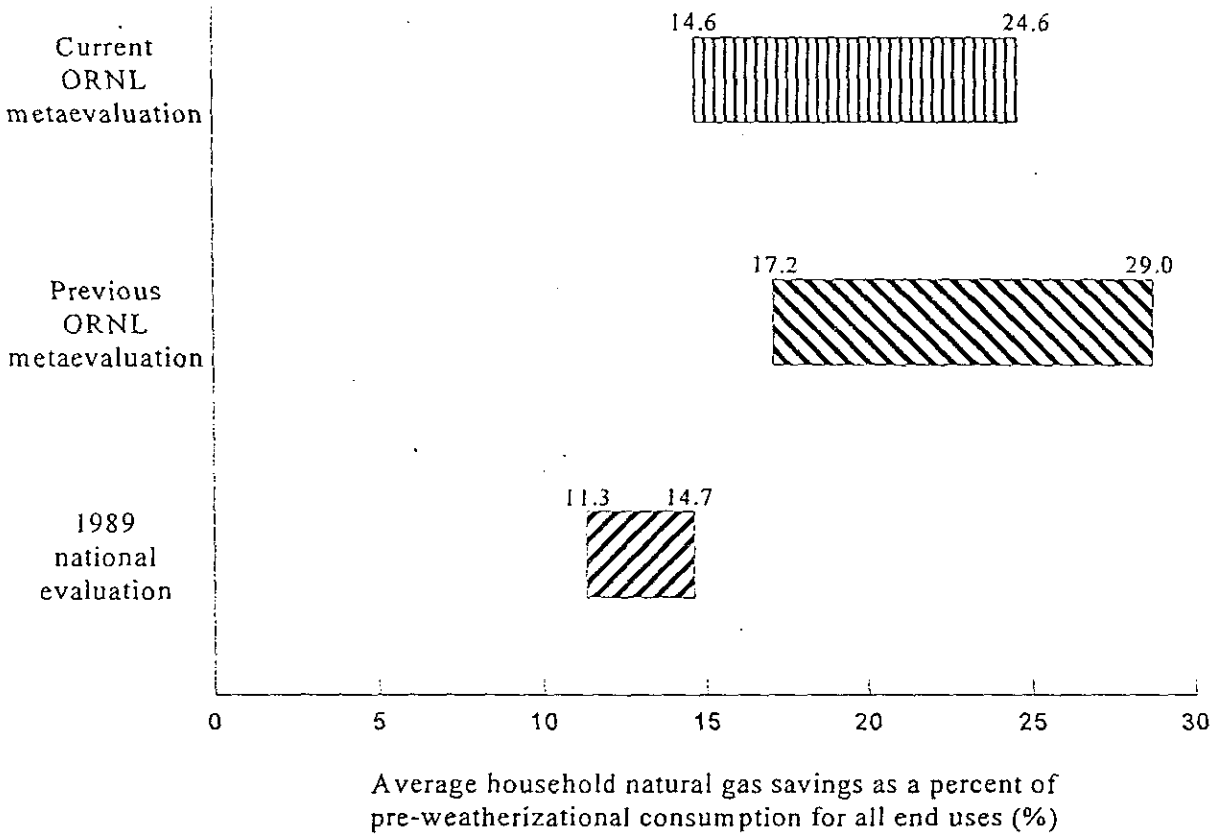

Figure 3. Average national whole-house savings: 90% confidence intervals from three evaluations.

Table 6. Benefit/cost ratios for national evaluation and both metaevaluations

	Program perspective	Installation perspective	Societal perspective
1989 national evaluation	1.06	1.58	1.61
Previous ORNL metaevaluation	1.79	2.39	2.40
Current ORNL metaevaluation	1.51	2.02	2.12

any changes in average expenditures per household that may occur over time as well as to the introduction of any other new procedures. At the meta level, average savings can be compared for states that differ from each other regarding key program characteristics.

This metaevaluation has shown that improvements to the Weatherization Assistance Program made in the first half of this decade continue to be effective and to reap benefits for program participants. Future metaevaluations can assist program administrators and other interested parties by showing the effects of any subsequent changes that are made to the Weatherization Assistance Program.

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APPENDIX A

STATE WEATHERIZATION OFFICE SURVEY RESULTS

Table A.1. State weatherization contacts, measure selection techniques, data systems, and evaluations

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Alabama	Ms. Brenda Jones Alabama Dept. of Economic and Community Affairs P.O. Box 5690 Montgomery, AL 36103-5690 Ph: (334) 242-5376 Fax: (334) 242-4203	None	National Energy Audit (NEAT) *and* a priority list	None	None	Measurement of pre- and post-weatherization energy consumption for homes served in 1997	No
Alaska	Mr. Scott Waterman Alaska Housing Finance Corp. P.O. Box 101020 Anchorage, AK 99510-1020 Ph: (907) 330-8195 Fax: (907) 338-1747	None	AKWarm (computerized audit)	None	None	Measurement of pre- and post-weatherization energy consumption and costs: analysis of billing data and oil use data logger	No
Arizona	Mr. Russell Clark Arizona Energy Office 3800 N. Central Phoenix, AZ 85012 Ph: (602) 280-1430 Fax: (602) 280-1445	None	REM Design (audit) *and* priority lists	None	None	Examination of post-weatherization energy consumption	No
Arkansas	Mr. Thomas E. Green Office of Community Services P.O. Box 1437, Slot 1330 Little Rock, AR 72203-1437 Ph: (501) 682-8715 Fax: (501) 682-6736	None	NEAT *and* Manufactured Home Energy Audit (MHEA)	None	None	None	No
California	Ms. Toni Curtis Department of Community Services and Development 700 North 10th St., Room 258 Sacramento, CA 95814 Ph: (916) 322-2940 Fax: (916) 327-3153	Ms. Maria Federer Ph: (916) 322-2458	Priority List from Heath Associates Study	None	None	Analysis of savings from homes weatherized between August 1, 1996, and March 31, 1997 with assistance from ORNL	No
Colorado	Mr. Robert DeSoto Office of Energy Conservation 1675 Broadway, Suite 1300 Denver, CO 80202-4613 Ph: (303) 620-4292 Fax: (303) 620-4288	Mr. Rick Hanger Office of Energy Conservation Ph: (719) 644-0136	The Audit Program (TAP)	No	Analysis of savings from weatherization program for 1995–1996	Analysis of savings from homes weatherized in 1996 and 1997 is expected	Yes

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Connecticut	Ms. Carlene Taylor State Dept. of Social Services 25 Sigourney Street Hartford, CT 06106 Ph: (860) 424-5889 Fax: (860) 424-4952	None	Portable Residential Conservation Service (RCS) Audit/ Conservation Services Group	None	None	None	No
Delaware	Mr. G. Kenneth Davis Office of Community Services Carvel State Office Building 820 N. French Street, 4th Floor Wilmington, DE 19801 Ph: (302) 577-4965, ext. 232 Fax: (302) 577-4973	Dr. John Byrne University of Delaware Ph: (302) 831-8405	NEAT *and* priority list	None	Evaluation of the impacts of the Delaware low-income weatherization program on energy and economic savings. Completed in December 1996	None	Yes
District of Columbia	Mr. Carl Williams DC Energy Office 2000 14th Street, NW, Suite 300E Washington, DC 20008 Ph: (202) 673-6741 Fax: (202) 673-6725	Mr. Darrell Riddick DC Energy Office Ph: (202) 673-6746	NEAT	None	Multiple regression analysis to determine factors responsible for energy savings	Study of the time involved in weatherizing homes and ways to decrease it	Yes
Florida	Mr. Earl Billings Dept. of Community Affairs 2740 Centerview Drive Tallahassee, FL 32399-2100 Ph: (850) 488-7541 Fax: (850) 488-2488	None	NEAT	None	None	None	No
Georgia	Ms. Cherry Ivy 2090 Equitable Bldg. 100 Peachtree St. NW Atlanta, GA 30303 Ph: (404) 656-3826	None	Priority List	None	None	Analysis of savings from homes weatherized between January 1996 and March 1997 with assistance from ORNL	No
Hawaii	Mr. Bob Hoffman Dept. of Labor and Industrial Relations 335 Merchant Street, Room 101 Honolulu, HI 96813 Ph: (808) 586-8675 Fax: (808) 586-8685	Mr. Dennis Doi Office of Community Services Ph: (808) 586-8675	Walk-through Audit	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Idaho	Ms. Neva Kaufman State Economic Opportunity Office 450 W. State Street State House Mail Boise, ID 83720-9990 Ph: (208) 334-5732 Fax: (208) 332-7343	Ms. Robyn Carlson Dept. of Health and Welfare Ph: (208) 334-5736	EA3 (spreadsheet)	None	Comparison of actual labor and support costs incurred during home weatherizations with numbers predicted by audit	Evaluation of potential cost savings from central bidding process and effects of changes in cost estimation procedures	No, because evaluation did not examine energy or cost savings
Illinois	Mr. Wayne E. Curtis IL Dept. of Commerce and Community Affairs 620 E. Adams St., 4th Floor Springfield, IL 62701 Ph: (217) 524-8024 Fax: (217) 782-1206	Mr. Edward Haber Dept. of Commerce and Community Affairs Ph: (217) 524-8032	Wisconsin Home Energy Audit (WHEA)	Reporting on measures completed	None	In process of developing an ongoing evaluation system	No
Indiana	Mr. Ed Gerardot Indiana CAP Directors' Association 902 N. Capitol Avenue Indianapolis, IN 46204 Ph: (317) 638-4232 Fax: (317) 634-7947	Dr. Bill Hill Ball State University Ph: (765) 285-8144	Priority list *and* NEAT, REM Design/ REM Rate	Sub-grantees collect pre- and post-weatherization data for some houses	Identified costs, benefits, and energy savings from weatherization pilot project with utility	May do analysis of pre- and post-weatherization energy use, based on billing data collected by subgrantees. May also do metered evaluation for bulk fuel client.	Yes
Iowa	Mr. Gregory K. Dalhoff Dalhoff and Associates 533 Marshall Circle Verona, WI 53593 Ph: (608) 845-6551 Fax: (608) 845-6544	None	NEAT	State's consultant is considering developing an integrated tool to allow routine assessment of performance	Report on impacts and costs of the state's 1996 and 1997 low-income weatherization programs	An assessment of the weatherization program's impacts on arrearages may be done in the future	Yes
Kansas	Ms. Norma Phillips Dept. of Commerce and Housing 700 S.W. Harrison Street, Suite 1300 Topeka, KS 66660-3755 Ph: (913) 296-2686 Fax: (913) 296-8985	Mr. Douglas Walter Kansas Bldg. Science Institute Ph: (785) 537-2425	NEAT *and* profiles of typical dwelling units based on a sample of 800 units	PRISM	None	Annual evaluations of energy savings	No
Kentucky	Mr. Pat Bishop Dept. for Social Insurance 275 Main Street, 3rd Fl. Frankfort, KY 40621 Ph: (502) 564-4847 Fax: (502) 564-6907	Mr. Rich Eversman Dept. for Social Insurance Ph: (502) 564-4847	NEAT/MHEA *and* priority list	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Louisiana	Ms. Brenda Grogan Louisiana Dept. of Social Services P.O. Box 3318 Baton Rouge, La 70821 Ph: (504) 342-5278 Fax: (504) 342-4038	None	NEAT, MHEA	None	None	Will consider doing future evaluation	No
Maine	Mr. Warren Cunningham Maine State Housing Authority 353 Water Street Augusta, ME 04330-4633 Ph: (207) 626-4600 Fax: (207) 626-4878	Mr. Tony Gill Maine State Housing Authority Ph: (207) 626-4651	Computer-aided audit system using MEADOW 96 software (developed in Maine)	MEADOW 96 calculates savings to investment ratio for each weatherization task and the whole job	None	Will use pre- and post-weatherization billing data to correlate measures installed with savings	No
Maryland	Ms. Eileen Hagan Maryland Dept. of Housing and Community Development 100 Community Place Crownsville, MD 21032-2023 Ph: (410) 514-7542 Fax: (410) 514-7499	None	Priority list	Currently working on development of a data system to measure program performance	None	None	No
Massachusetts	Mr. Ken Rauseo Dept. of Housing and Community Development 100 Cambridge St., Room 1803 Boston, MA 02202 Ph: (617) 727-7004 Fax: (617) 727-4259	None	NEAT and priority lists based on NEAT results	Data base containing all Building Weatherization Reports submitted by subgrantees, showing installed measures, costs, heating system type and fuel, and client information	None	None	No
Michigan	Ms. Lynda Crandall MI Dept. of Social Services P.O. Box 30037 Lansing, MI 48909 Ph: (517) 335-3094 Fax: (517) 335-7771	None	NEAT and priority lists based on NEAT results	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Minnesota	Mr. Mark Kaszynski Dept. of Children, Families, and Learning 550 Cedar Street St. Paul, MN 55101 Ph: (651) 582-8566 Fax: (651) 582-8490	Ms. Carol Raabe Dept. of Children, Families, and Learning Ph: (651) 582-8431	SIR Audit, using NEAT engineering calculations and local costs to identify cost-effective measures	Achieved Savings Assessment Program, using run-time data loggers and custom-designed software	Achieved Savings Assessment Program measured energy savings for 1995–1996 and 1996–1997 program years	Ongoing annual assessments of weatherization program energy savings	Yes
Mississippi	Mr. Bobby Pamplin Dept. of Human Services 750 N. State Street, 6th Floor Jackson, MS 39202 Ph: (601) 359-4775 Fax: (601) 359-4370	Ms. Sollie B. Norwood Dept. of Human Services Ph: (601) 359-4768	NEAT *and* priority list	Data on projected costs and energy savings produced by NEAT audits	None	None	No
Missouri	Ms. Cher Stuewe-Portnoff Division of Energy P.O. Box 176 Jefferson City, MO 65102 Ph: (573) 751-4000 Fax: (573) 751-6860	Ms. Lesa Jenkins Dept. of Natural Resources Ph: (573) 751-8593	NEAT *and* priority list for mobile homes (but will implement MHEA in FY 1999)	None	None	None	No
Montana	Mr. Jim Nolan Dept. of Social and Rehabilitation Services P.O. Box 4210 Helena, MT 59604 Ph: (406) 447-4260 Fax: (406) 447-4287	Mr. Kane Quenemoen State of Montana Ph: (406) 447-4267	Montana Energy Audit	Oracle (client-tracking data base)	Evaluation of energy savings from 1995–1996 weatherization program	None	No, because results are not comparable to other studies
Nebraska	Mr. Peter Davis Nebraska Energy Office P.O. Box 95085 Lincoln, NE 68509 Ph: (402) 471-2867 Fax: (402) 471-3064	None	NEAT *and* priority list for mobile homes	None	Report documenting evaluation of energy and cost savings was completed in August 1996	None	No, because findings were used in 1996 meta evaluation
Nevada	Mr. Craig Davis Nevada State Welfare Division 2527 N. Carson Street Carson City, NV 89710 Ph: (702) 687-4258, ext. 226 Fax: (702) 687-4040	None	REM Design Audit *and* priority list and recommendations based on blower door and combustion appliance safety tests	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
New Hampshire	Mr. Mitch Koenig Governor's Office of Energy and Community Services 57 Regional Drive Concord, NH 03301-8506 Ph: (603) 271-2611 Fax: (603) 271-2615	None	NEAT and priority list for mobile homes	New data base	None	None	No
New Jersey	Ms. Clarice Sabree NJ Dept. of Community Affairs 101 S. Broad CN-814 Trenton, NJ 08625 Ph: (609) 984-3301 Fax: (609) 292-9798	None	EA-QUIP (Energy Audit)	None	None	None	No
New Mexico	Mr. Lionel Holguin NM Mortgage Finance Authority 344 Fourth Street, SW Albuquerque, NM 87102 Ph: (505) 843-6880 Fax: (505) 243-3289	None	NEAT *plus* Retro-tech for mobile homes *plus* priority lists	Will install WIN SAGA in late 1998 to track weatherization results.	None	State plans to initiate an analysis program	No
New York	Mr. Patrick Sweeney NYS Division of Housing and Community Renewal 38–40 State Street Albany, NY 12207 Ph: (518) 474-5700 Fax: (518) 486-4663	Mr. J. Patrick Connolly Energy Services Bureau Ph: (518) 474-5700	Targeted Investment Protocol System (TIPS) Audit	Subgrantees collect pre- and post-weatherization billing data	Average energy savings were calculated for a representative sample of buildings weatherized over the past four program years, *using pre- and post-*weatherization billing data	Subgrantees continue to collect pre- and post-weatherization data and state continues to analyze energy savings on an ongoing basis	No, because results are not comparable to other studies
North Carolina	Mr. Percy Carter Dept. of Commerce 430 N. Salisbury Street Raleigh, NC 27611 Ph: (919) 733-1904 Fax: (919) 733-2953	Mr. Eugene Mesley N.C. Energy Division Ph: (919) 733-0518	NEAT 2.1 and MHEA	Statewide client information data base showing characteristics of weatherized units, measures installed, *costs, and projected* savings	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
North Dakota	Mr. Howard Sage Office of Intergovernmental Assistance 600 East Blvd., 14th Floor Bismarck, ND 58505 Ph: (701) 328-2094 Fax: (701) 328-2308	None	WXEOR	None	None	None	No
Ohio	Ms. Sara Ward Ohio Dept. of Development P.O. Box 1001 Columbus, OH 43266-0101 Ph: (614) 466-6954 Fax: (614) 466-4708	Mr. Stjepan Vlahovich Ohio Office of Energy Efficiency Ph: (614) 466-0545	NEAT *and* priority list based on NEAT	Integrated application for tracking information on grants, budgets, and other activities. Also has access to energy use data for subset of customers.	Analysis of 1994 program, including energy and cost savings	None	Yes
Oklahoma	Ms. Kathy McLaughlin OK Dept. of Commerce P.O. Box 26980 Oklahoma City, OK 73126-0980 Ph: (405) 815-5339 Fax: (405) 815-5344	Mr. Mark Thompson Forefront Economics Ph: (503) 626-1657	NEAT	None	None	State may do analysis of effect of new audit technique on energy usage	No
Oregon	Mr. Jack Hruska OR Housing and Community Services Dept. 123 N.E. 3rd , Suite 3470 Convention Center Plaza Portland, OR 97232 Ph: (503) 230-8011, ext. 231 Fax: (503) 230-8863	Mr. Kevin Nehila OR Housing and Community Services Dept.	Computerized audit using WEXOR	None (but one is under construction)	Preliminary findings from initial study of REACH program (which has a weatherization component)	Continuation of REACH evaluation and possibly an evaluation of a proposed utility pilot program that targets high energy users	No, because preliminary findings are not weather-normalized
Pennsylvania	Mr. Tony Kimmel Dept. of Community and Economic Development Community Empowerment Office Room 352, Forum Building Harrisburg, PA 17120 Ph: (717) 787-1984 Fax: (717) 234-4560	None	NEAT	None	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Rhode Island	Mr. Michael Snitzer Governor's Office of Energy Assistance 275 Westminster Mall Providence, RI 02903 Ph: (401) 277-6920 Fax: (401) 222-1260	None	NEAT	None	None	None	No
South Carolina	Mr. Holcombe Smith Office of the Governor 1205 Pendelton Street Columbia, SC 29201 Ph: (803) 734-0684 Fax: (803) 734-0356	None	Computerized audit *and* priority list	Statewide client information data base showing characteristics of weatherized units and projected savings	None	Would like to start tracking actual energy savings	No
South Dakota	Ms. Abbie Rathbun Dept. of Social Services 206 W. Missouri Avenue Pierre, SD 57501-4517 Ph: (605) 773-3668 Fax: (605) 773-6657	None	NEAT	None	None	None	No
Tennessee	Mr. Steve Neece Dept. of Human Services 400 Deaderick Street Nashville, TN 37248-9500 Ph: (615) 313-4765 Fax: (615) 532-9956	Ms. Zelma Waller Dept. of Human Services Ph: (615) 313-4766	NEAT *and* priority list	None	None	None	No
Texas	Ms. Peggy Colvin Texas Department of Housing and Community Affairs Energy Assistance Section 507 Sabine St., Suite 400 Austin, TX 78711-3941 Ph: (512) 475-3864	Ms. Wendy Pollard Ph: (512) 475-2559 Fax: (512) 475-3935	EASY Audit	EASY Audit files are stored electronically	None	Analysis of energy savings from homes weatherized between January 1, 1997, and September 31, 1997 with assistance from ORNL	No
Utah	Mr. Michael Johnson Office of Energy Services 324 S. State Street, Suite 230 Salt Lake City, UT 84111 Ph: (801) 538-8657 Fax: (801) 538-8660	None	NEAT	Collects data for each home weatherized, including demographics, consumption and improvements	None	None	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Vermont	Mr. Jules Junker Office of Economic Opportunity 103 S. Main Street Waterbury, VT 05676-1801 Ph: (802) 241-2452 Fax: (802) 241-1225	None	"Market Manager" Audit System	Weatherization Data Management System (WDMS) collects information on buildings, measures installed, costs of measures, and fuel consumption	Impact evaluation of Vermont's Weatherization Assistance Program completed in December 1997	Subsequent evaluations planned at two year intervals	Yes
Virginia	Mr. William Beachy Division of Housing 501 2nd Street Richmond, VA 23219-1747 Ph: (804) 371-7112 Fax: (804) 371-7091	None	Priority list supported by NEAT	None	None	None	No
Washington	Mr. Steve Payne Department of Community, Trade and Economic Development 906 Columbia Street SW P.O. Box 48300 Olympia, WA 98504 Ph: (360) 586-8980 Fax: (360) 586-5880	Ms. Carolyn Wyman Ph: (360) 586-0495	NEAT *and* a priority matrix created from NEAT	None	None	Analysis of savings from homes weatherized between June 1996 and June 1998 with assistance from ORNL	No
West Virginia	Mr. Bob Scott WV Office of Economic Opportunity 950 Kanawha Blvd. East Charleston, WV 25301 Ph: (304) 558-8860 Fax: (304) 558-4210	None	Priority list based on NEAT	Data base that includes information on installed measures, blower door readings, and insulation levels, to provide data for future energy savings evaluations	None	State plans to evaluate utility project sometime in the future, using a yet-to-be developed model evaluation tool that will be provided by DOE's Philadelphia Support Office	No
Wisconsin	Mr. Gary Gorlen Division of Housing, 4th Floor P.O. Box 8944 Madison, WI 53708-8944 Ph: (608) 266-6789 Fax: (608) 264-6688	None	Wisconsin Energy Conservation Corporation (WECC) v. 4.0	None	None	Comparison of pre- and post-weatherization furnace run-time for 30–40 homes	No

Table A.1. Continued

State	Initial contact	Other contact recommended for additional information	Technique(s) used to select weatherization measures	Data system(s) that could be used to measure program performance	Evaluation(s) completed or documented between April 1996 and September 1998	Planned evaluation(s) to be completed after September 1998	State evaluation results used in meta evaluation?
Wyoming	Ms. Jan Stiles Dept. of Family Services Hathaway Bldg., 3rd Floor Cheyenne, WY 82002 Ph: (307) 777-6137 Fax: (307) 777-7747	Ms. Rana Belshe Conservation Connection Consulting Ph: (715) 334-2707	NEAT, in conjunction with fuel indexing	None	None	Final documentation of 1994–1995 and 1995–1996 weatherization program savings	No

APPENDIX B

ELECTRICITY SAVINGS

B.1 SAVINGS BY ELECTRICALLY-HEATED HOUSES

Mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption were calculated from the average values reported in the three state studies of electrically-heated houses.[10] These studies reported electricity use and savings in terms of kilowatt hours (kWh) metered at the household level, and we converted this to BTUs by multiplying the number of kWh by 3,413. Mean annual pre-weatherization consumption for all end uses was 68.4 million BTUs per household; mean household energy savings amounted to 6.0 million BTUs annually; and mean energy savings equaled 9.1% of pre-weatherization consumption. These values, plus the minimum and maximum and 90% confidence interval for each variable, are shown in Table B.1. Because the sample size was very small (only three studies), the confidence intervals are substantially greater than those reported in Chapter 3 for the gas-fueled structures. For example, there is a 90% probability that *average* savings for the entire population of electrically-heated houses will fall somewhere between 3.2% and 15.1% of pre-weatherization consumption, which represents an extremely broad range.

Table B.1. Key findings from three state weatherization program studies of electric-heated structures

	Minimum	Maximum	Mean	90% confidence interval
Pre-weatherization consumption for all end uses (MBTU)	60.3	73.2	68.4	56.5–80.3
Absolute savings* (MBTU)	4.5	7.5	6.0	3.5–8.5
Savings as a percent of pre-weatherization consumption (%)	6.3	13.1	9.1	3.2–15.1

*These numbers are calculated from net savings in those cases where a control group was used and gross savings in all other cases.

[10]The three studies of electrically-heated houses were performed by Delaware, the District of Columbia, and Ohio.

B.2 SAVINGS BY HOUSES USING ELECTRICITY FOR NON-HEATING PURPOSES

This metaevaluation examined four state studies of houses that use electricity for non-heating purposes.[11] From the average values reported in these studies, we calculated mean values for pre-weatherization energy consumption, weatherization-induced energy savings, and savings as a percent of pre-weatherization consumption.[12] As shown in Table B.2, mean annual pre-weatherization consumption was 27.9 million BTUs per household; mean household energy savings were 1.0 million BTUs annually; and mean energy savings amounted to 2.3% of pre-weatherization consumption. These values are much smaller than those reported for electrically-heated houses but this is not surprising because heating—a major consumer of energy and target for energy savings in most houses—is not addressed. Once again, the sample size (four studies) is small and the confidence intervals are relatively large. Accordingly, there is a 90% chance that *average* savings for the entire population of houses using electricity for non-heating purposes falls somewhere between -2.3%[13] and 6.7% of pre-weatherization consumption.

Table B.2. Key findings from four state weatherization program studies of non-heating electricity use

	Minimum	Maximum	Mean	90% confidence interval
Pre-weatherization consumption (MBTU)*	23.5	32.2	27.9	0.4–55.3
Absolute savings** (MBTU)	0.4	1.3	1.0	0.5–1.4
Savings as a percent of pre-weatherization consumption (%)*.	1.6	3	2.3	-2.1–6.7

*Absolute savings were reported by four states, but only two states had good data on pre-weatherization consumption and savings as a percent of that.

**These numbers are calculated from net savings in those cases where a control group was used and gross savings in all other cases.

[11]The four studies of houses using electricity for non-heating purposes were performed by Colorado, Iowa (two studies), and Vermont.

[12]Like the studies of electrically-heated houses, these studies reported electricity use and savings in terms of kWh at the point of consumption and we converted those numbers to BTUs by multiplying by 3,413.

[13]A negative savings means that energy use actually increases following weatherization, which is clearly counterintuitive.

APPENDIX C

INDEPENDENT VARIABLES USED IN REGRESSION ANALYSIS

Four independent variables were used in the regression analysis of natural gas savings: (1) pre-weatherization energy consumption; (2) square footage of weatherized structures; (3) heating degree days in the project area; and (4) weatherization expenditures. The minimum, maximum, and mean values for each of these variables, along with the number of observations, are presented in Table C.1. Where possible, these data were extracted from reports documenting the state studies or from follow-up contacts with state weatherization staff. If a state did not directly provide heating degree days, this information was taken from a National Oceanic and Atmospheric Administration compilation (Heim, Garvin, and Nicodemus 1993) of long-term population-weighted heating degree days for the states. In five cases, the state contact could not provide the average square footage for the weatherized structures so we used the national average of 1149 square feet per weatherized single family detached unit (Brown, Berry, Balzer, and Faby 1993). Six of the nine studies of gas-fueled residences reported agency expenditures. Three reported these expenditures for 1996 and the others reported expenditures for previous years. Expenditures made in years prior to 1996 were converted to 1996 dollars using an adjustment factor to account for inflation. In those instances where information on agency expenditures was not available, we did not attempt to provide an estimate for this variable because of the potential for introducing substantial error.

Table C.1. Values of independent variables used in regression analysis of natural gas savings

	Number of observations	Minimum	Maximum	Mean
Pre-weatherization consumption (MBTU)	9	102.3	190.2	148.9
Square footage of structures	9	1006.0	1270.0	1141.8
Heating degree days	9	4455	7903	6436.7
Weatherization expenditures (1996 dollars)	6	720.00	3081.00	2169.76

Table C.2 shows the findings of a correlation analysis run on the set of four independent variables used in this evaluation. As this table illustrates, the strongest correlations were between (1) square footage of structures and weatherization expenditures ($r=0.675$, $p=.14$); and (2) square footage of structures and pre-weatherization energy consumption ($r=0.591$, $p=.09$). When we excluded one study focusing on households with abnormally high values for pre-weatherization consumption from the data set, we found that the relationship between pre-weatherization energy

consumption and heating degree days was strengthened (r=0.516, p=.19). However, none of these relationships was significant at the .05 level.

Table C.2. Correlations among independent variables used in regression analysis of natural gas savings

	Square footage of structures	Heating degree days	Weatherization expenditures
Pre-weatherization consumption	r = 0.591 p = .09	r = 0.225 p = .56	r = 0.374 p = .47
Square footage of structures		r = −0.479 p = .16	r = 0.675 p = .14
Heating degree days			r = −0.104 p = .84

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