Report

Ohio Home Weatherization Assistance Program Impact Evaluation

Prepared for:
Ohio Office of Energy Efficiency

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1. Executive Summary

This impact evaluation focuses on the 2003 Program Year (PY03) of Ohio's Home Weatherization Assistance Program (HWAP, the Program).

Program Overview

HWAP is designed to accomplish three primary objectives:

- Increase the energy efficiency of dwellings owned or occupied by low-income persons
- Reduce participants' total residential energy expenditures
- Improve participants' health and safety

Since 1977, HWAP and its predecessor programs have been implemented by the Ohio Department of Development (ODOD). In 1991, the Office of Energy Efficiency (OEE) was created within ODOD to oversee the implementation of HWAP. Ohio's HWAP is delivered through a network of 58 community and local government organizations (Agencies). Households with incomes of 150% or less of the Federal Poverty Level are eligible to receive the following services:

- An inspection or audit to determine what energy-efficiency measures are appropriate
- Client energy education to empower HWAP recipients to take specific actions
- Installation of weatherization and any necessary health and safety measures
- Final inspection of the measure installation

Since 1981, Ohio has supplemented Department of Energy (DOE) Weatherization Assistance Program (WAP) funds with 15% of the Low Income Home Energy Assistance Program (LIHEAP) funds. Those funds are distributed to Ohio by the U.S. Department of Health and Human Services (HHS) for its Home Energy Assistance Program (HEAP). Ohio was the first state to legislatively mandate the 15% set-aside for weatherization.

Evaluation Overview

This impact evaluation was conducted in conjunction with a Program process evaluation and training evaluation, which have been completed and are reported on separately. All three studies were performed by Quantec, LLC. The last evaluation of Ohio's HWAP addressed the PY94 Program.

This evaluation was designed to answer specific questions in the following categories:

- Impacts of HWAP only
- Impacts of HWAP implemented in conjunction with other programs
- HWAP cost and cost effectiveness

- Non-energy benefits of HWAP

To address these questions, the impact evaluation plan was developed with the following components:

- Billing analysis to evaluate Program impacts on consumption of natural gas (and other fossils fuels) and electricity
- Payment analysis to examine whether the Program made bill payment easier for participants
- Disconnection and collection action analysis to determine whether participants were less likely to have utility service disconnected
- Non-energy benefit analysis to evaluate environmental, economic, and health benefits of the Program
- Benefit-cost analysis to assess Program cost effectiveness
- Site visits to explore what factors might have contributed to the poor energy performance of a sample of homes participating in the Program

Major Findings

Cost-Effectiveness

Our evaluation determined that the Program is cost-effective overall, from both a Program perspective and societal perspective. This was determined by evaluating benefit-cost ratios from both these perspectives for selected home and fuel types as well as the Program overall, with administration costs distributed equally across all homes weatherized. The Program perspective benefit-cost ratio was 1.10 and the societal perspective ratio was 1.87. Although the benefit-cost ratio was less than one for certain groups of participants, the overall ratios for all participants were greater than one. The net benefits from the Program perspective were $3,039,742 and they were $26,872,722 from the societal perspective. The majority of individual measures installed through the Program were also found to be cost-effective.

Natural Gas Savings

Gas savings were determined by analyzing gas usage data from four utilities – Columbia Gas, Dominion, Cincinnati Gas and Electric (Cinergy), and Vectren – representing 98% of gas heated participants.

We determined that HWAP participants reduced their gas consumption an average of 326 therms per year for single-family homes (including mobile homes), or 25% of their pre consumption. The non-participant group reduced their usage 58 therms, or approximately 5% of their pre consumption. The non-participant savings were likely due in part to the large increase in gas rates between the pre and post Program period, i.e., between 2002 and 2004/2005. The participant gross savings compare favorably with the 315 therm (23% of pre) savings estimated in the 1994 evaluation. Net savings for participants' were calculated by subtracting the non-participant savings from the gross participant savings resulting in net savings of 268 therms per year.

For the one utility where we were able estimate energy savings for customers receiving joint utility-HWAP weatherization to those receiving HWAP only the net natural gas savings increased by 90 therms per year for the jointly treated homes, or about a 30% increase in the energy savings.

Electricity Savings

The electricity savings analysis approach was similar to that used for gas-heated homes. This analysis included both homes heated with electricity and those heated with fuels other than electricity. For electrically-heated homes, we obtained data from American Electric Power (AEP), which accounted for 74% of the electrically-heated homes. For homes not heated with electricity, we obtained billing data from AEP and Cinergy.

The net savings for electrically heated single-family homes were 1,473 kWh per year and multifamily homes saved 572 kWh. Single-family gas-heated homes had net savings of 303 kWh and multifamily homes saved 201 kWh.

Payment Behavior

Payment data were provided by all utilities. We examined the effect of the Program on participation in the Ohio Percentage of Income Payment Plan (PIPP). The customer net shortfall (payment shortfall before accounting for fuel assistance funds) for PIPP participants declined 53% and for non-PIPP participants it declined 16%. The results of our analysis are consistent with the PY94 findings, where there was a 47% reduction in the net customer shortfall for regular PIPP, a 42% for intermittent PIPP, and a 28% reduction for no PIPP. The PY03 results are higher for the PIPP group, and lower for the non-PIPP group. Overall, HWAP participation resulted in a 19% net reduction in the households with bills over 10% of their income. Hence, it appears that, due to HWAP Program participation, the number of participants that needed to stay on PIPP declined.

Non-Energy Benefits

HWAP provides numerous non-energy benefits in the areas of economic impact, environmental benefits, forced mobility, and health and safety benefits. Our economic impact analysis concluded that for PY03, the Program created about 403 net job-years of employment and added $17.7 million to the Ohio economy. Though these numbers are small compared to Ohio’s economy and work force as a whole, this analysis shows that HWAP has a positive effect on Ohio’s economy. In measuring environmental benefits, we assigned dollar values to the three most substantial air emission reductions based on relevant market values as of December 2005. As markets for emission reductions continue to emerge, values should continue to rise, so assuming a constant value for emissions provides a conservative estimate for societal benefits. Over the life of weatherization, the societal benefit in 2003 was $2,533,447.

Causes of Poor Performance

One objective of this study was to examine what factors might be contributing to the poor performance of some homes in the Program. We identified and conduct site visits to homes that saved less than predicted, with the hypothesis that factors such as poor quality of work, some unanticipated failure of a measure, measures that were not identified for installation that could have been effective, or unusual occupant behavior could be identified to explain the poor performance.

For the homes we visited, we found that inadequate measure installation was a primary factor causing poor performance. Where measures were not fully or adequately installed, actual savings would have fallen below estimates of expected savings. In terms of missed opportunities and the number of technician's comments, air sealing ranked at the top of the list of possible reasons for low energy savings. Many cases of inadequate or missing air sealing were reported.

Comparison to Other Programs

The results from this evaluation compare favorably to similar studies of other WAP evaluations from around the United States for gas-heated, single-family homes. Half of the programs with higher savings also had higher pre-use, which tends to drive up savings. We concluded that Ohio has one of the most successful programs in the nation in terms of energy savings when compared with recent studies from Iowa, Wisconsin, and Illinois. The results of this evaluation are also close to the national meta evaluation estimates of 23% savings and 305 therms saved for gas-heated single-family homes.

Recommendations

As a result of the findings presented in this report, recommendations were generated with regard to the questions posed for the study. These recommendations are intended to provide a guide to OEE on potential Program improvements to maximize the impact of HWAP dollars.

Obtaining Applicant Energy Histories

Many studies have shown (including this one) that pre-consumption is the biggest factor in energy savings potential through weatherization. In light of this, it would be worthwhile for OEE to acquire applicant energy usage histories and group them based on pre-consumption with the highest consumers being the top priority.

Measure Installation Based on Pre-Consumption

All HWAP measures, except furnace tune-up, are worth installing in high-usage houses when deemed necessary; however, fewer measures are cost effective for medium- and low-consumption homes. Furnace replacement, tune-up, and other measures (water heater and duct insulation) were not found to be cost effective for medium consumption homes and only air leakage reduction and wall and attic insulation were found to be cost effective for low consumers. By following this guide to measure installation, OEE should be able to maximize energy saved per dollar spent.

Combo Job Tracking

It is currently extremely difficult to determine if a weatherization job received money jointly from HWAP and a utility program. Data must be received from both OEE and the given utility and then merged together based on household data (account number, social security number, etc.). Altering the Building Weatherization Report (BWR) to include either a "combo job" checkbox or a field to capture the utility name would allow for much easier tracking of these jobs. This information could be stored in the Program database (OATS) and would be readily available to compare joint weatherization to HWAP-only weatherization.

Labor Cost Tracking

In order for an accurate calculation of measure cost effectiveness, the full cost of a measure's installation must be tracked. Currently, the BWR records material costs by measure, but all labor costs are combined. In this evaluation, a regression was required to estimate labor costs by installed measure, but the need for such an approach could be avoided with measure-level labor cost tracking.

2. Introduction

This report presents an impact evaluation of Ohio's implementation of the national Weatherization Assistance Program for Low-Income Persons (or WAP), commonly referred to in Ohio as the Home Weatherization Assistance Program (HWAP, the Program). The report focuses on Program Year 2003.

Program Overview

HWAP is implemented in accordance with regulations promulgated by the U.S. Department of Energy (DOE) in 10CFR Part 440. According to the purpose and scope of the Program, it is designed to accomplish three objectives:

- Increase the energy efficiency of dwellings owned or occupied by low-income persons
- Reduce participants' total residential energy expenditures
- Improve participants' health and safety

DOE regulations (10 CFR Part 440, Section 440.16(b)) further provide that efforts to accomplish these objectives shall ensure that priority is given to five specific particularly vulnerable populations of low-income energy users:

- The elderly
- Persons with disabilities
- Families with children
- High residential energy users
- Households with high energy burdens

HWAP has provided weatherization services to low-income households in Ohio since 1977. Since 1992, HWAP has been implemented at the state level by the Office of Energy Efficiency (OEE) in the Ohio Department of Development (ODOD).

Eligibility for HWAP services in Ohio is based on household income. The state uses 150% of the Federal poverty guidelines as the upper income limit for eligibility; this is higher than the minimum of 125% established by DOE, allowing more households to qualify. DOE's regulations permit states to set a higher level based on the Home Energy Assistance Program (HEAP) eligibility requirements.[1]

Since the inception of Ohio's HWAP, the primary source of funding has been DOE. Since 1981, Ohio has supplemented DOE funds with 15% of the funds that the U.S. Department of Health

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1 This program is usually referred to as the Low Income Home Energy Assistance Program (LIHEAP) at the Federal level.

and Human Services (HHS) distributes to Ohio for HEAP.[2] Ohio was the first state to legislatively mandate the 15% set-aside for weatherization.

HWAP services are provided at no cost to qualified households and include:

- An inspection or audit to determine what energy efficiency measures are appropriate and if other repairs are necessary before weatherization can be conducted
- Client energy education to help empower HWAP recipients to take specific actions that will result in increased control of their energy consumption, energy costs, and comfort
- Installation of weatherization and any necessary health and safety measures
- Final inspection of the measure installation

Utilities also offer programs that expand the overall weatherization activities in the state.

OEE is the central HWAP organization in Ohio. It provides overall guidance, requirements (for example, through the Weatherization Program Standards), policy, and oversight; secures and distributes federal funds; and provides the interface with the federal funding agencies.

Ohio's HWAP is delivered through a network of community and local government organizations. These include Community Action Organizations (CAOs), local government entities and community-based non-profit organizations (CBOs). OEE disburses the funds to these groups (hereafter, Agencies), which then have the responsibility of delivering the weatherization services. Some Agencies ("grantees") contract with OEE and, in turn, subcontract to other Agencies (delegates) that implement weatherization. The actual services are delivered by implementing Agency staff and, in some cases, private contractors hired by the Agency.

The Agencies are responsible for meeting specific targets in delivering the HWAP services. These targets include production (number of housing units weatherized) and average cost per weatherized unit.

HWAP requires skilled staff to implement weatherization effectively, so training is an important component of the Program. The Ohio Weatherization Training Center (OWTC) provides training to Agency weatherization staff. The Corporation for Ohio Appalachian Development (COAD) runs the center. OEE staff also provides training through their Training and Technical Assistance (T&TA) activities.

For several years, HWAP funds have been allocated to Agencies based on a stability factor that takes into account the allocation the Agency received in 1994. In addition, the allocation takes into account two elements: the percent of households that are income-qualified for HWAP and the percent of qualified households that spend more than 25% of their income on energy (their energy burden). These percentages are based on census data for the Agency's service area.

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2 HEAP is administered by the Office of Community Services, a separate office within ODOD.

Evaluation Overview

In August 2004 the OEE released a request for proposals (RFP) for an impact evaluation and process evaluation of HWAP's 2003 Program Year (PY03). The last evaluation was conducted on the 1994 Program Year (PY94) and this RFP was issued to evaluate whether the Program had improved, remained static, or regressed since the previous evaluation.

The key questions to be answered in this impact evaluation are:

HWAP Only

- What is the impact of HWAP on the gas and electric usage of participants?
- What is the impact of HWAP on participants in the Ohio Percentage of Income Payment Plan (PIPP) ability to avoid service disconnection?
- How do the impacts of HWAP compare to previous evaluations and to other weatherization efforts in Ohio and nationally?
- What potential does HWAP have for collecting consumption histories for its customers? How effectively is this potential being used? Would it be an effective system for identifying households (based on usage information, customer shortfall, etc.) who have the most to gain from participation in the program?

HWAP and Utility Programs

- How do energy savings differ for houses jointly treated with utility funding vs. HWAP-only houses?
- What percentage of HWAP completions during PY03 received multiple services?

Cost and Cost Effectiveness

- Is HWAP cost effective and how do the costs of the PY03 HWAP compare to costs identified in previous evaluations and to other weatherization efforts in Ohio and nationally?
- What effect does HWAP have on the need for PIPP subsidies?

Non-Energy Benefits

- What impact does HWAP have on the economy of Ohio in terms of job creation and avoided energy imports?
- What are the environmental impacts associated with the energy savings produced by HWAP?
- What other non-energy benefits does HWAP provide?

To address these questions, this impact evaluation plan was developed with the following components:

- Billing analysis to evaluate Program impacts on electricity and gas consumption

- Payment analysis to examine whether the Program made bill payment easier for participants
- Disconnection and collection action analysis to determine whether participants were less likely to have utility service disconnected
- Non-energy benefit analysis to evaluate environmental, economic, and health benefits of the Program
- Benefit-cost analysis
- Site visits to explore persistence of measures, quality of weatherization and missed opportunities in poorly performing weatherized homes

Report Contents

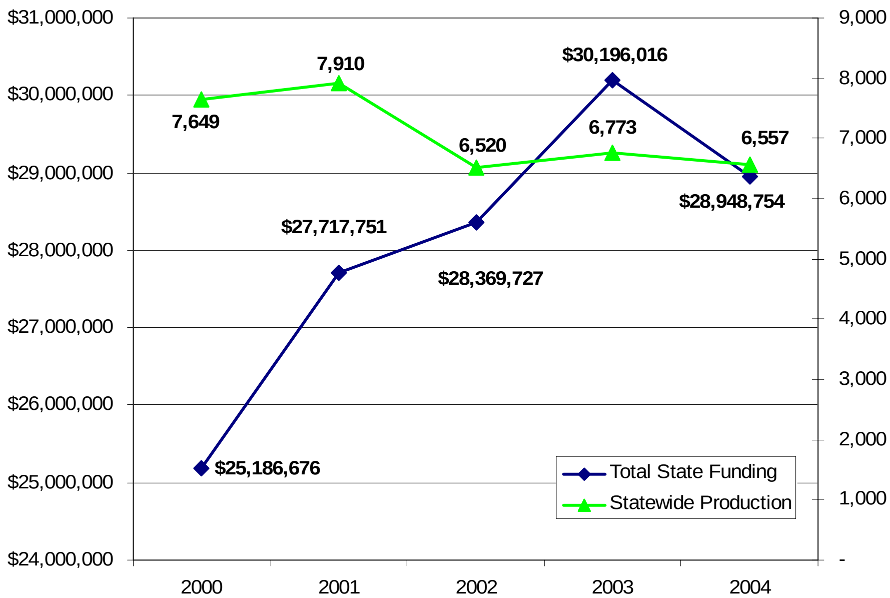
Chapter 3 describes HWAP PY03 in terms of budget, homes weatherized, and participant characteristics. Chapter 4 presents the results of the gas billing analysis. Chapter 5 presents the results of the electric billing analysis. Chapter 6 analyzes HWAP's effect on payment behavior: customer shortfall, disconnections, collections, and PIPP participation. Chapter 7 explains the non-energy benefits of HWAP and calculates the societal benefits. Chapter 8 analyzes the success of the Program from the perspective of cost effectiveness. Chapter 9 presents the findings from home site visits that were performed to examine reasons for low savings among certain participants. Chapter 10 compares the results from this study to those from other studies. Chapter 11 presents the recommendations resulting from this evaluation. Appendix A: presents the results of a geographic information system (GIS) study we conducted to examine the relationships among geographic and demographic characteristics and the Program. Appendixes B through E present more details on our analysis methodologies.

3. Program Description

Program Funding History and Participant Characteristics

Program funding and the number of completed units for 2000-2004 are shown in Figure 1.[3] Although Program funding rose for most of this period, an increase in the maximum allowed cost per home caused the number of homes weatherized to fall and then stay nearly constant.

Figure 1. Program Spending and Production



All participant information is tracked in the OEE Activity Tracking System (OATS) database. In PY03, the Program provided weatherization services to 6,411 housing units in 5,609 buildings representing 15,093 people.[4] Table 1 shows participant characteristics across housing types.

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[3] For detailed funding information see Process Evaluation.

[4] The number of homes differs from the number shown in Figure 1 because of the way multifamily homes are tracked. If a multiplex has one eligible participant, but has shell work done, then all units are counted towards the PY03 6,773 total shown in Table 1. However, only 6,411 eligible participants were served, so this is the number that will be used for total participants throughout this report.

Table 1. Participant Characteristics by Housing Type

Characteristic	Site-Built Single-Family	Mobile Home[5]	Multifamily	All Units
Total Units	3,803	1,401	1,207	6,411
Home Characteristics				
Living Area (sq. ft.)	1,440	938	856	1,220
Built pre-1939	78%	0%	77%	42%
Forced Air Heat Distribution	89%	97%	77%	89%
Demographics				
Renter	16%	9%	100%*	30%
Mean Annual Income	$12,268	$10,825	$8,455	$11,235
Household Size	2.52	2.21	1.50	2.3
Senior	35%	29%	34%	33%
Person w/ Disability	32%	38%	35%	34%

* Ownership is not tracked for multifamily homes, though it can be assumed that close to 100% are renters.

Heating fuels by home type are shown in Figure 2. For site-built and multifamily homes, gas and electric comprise almost all space heating (89% and 100%, respectively), while only 67% of mobile homes are heated by one of these fuels.

Figure 2. Space Heating Fuel Distribution by Home Type

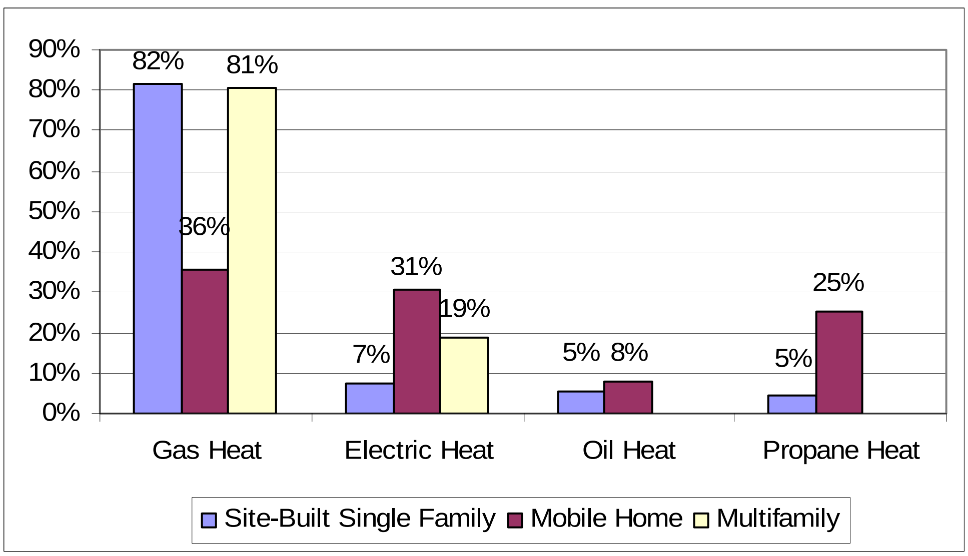
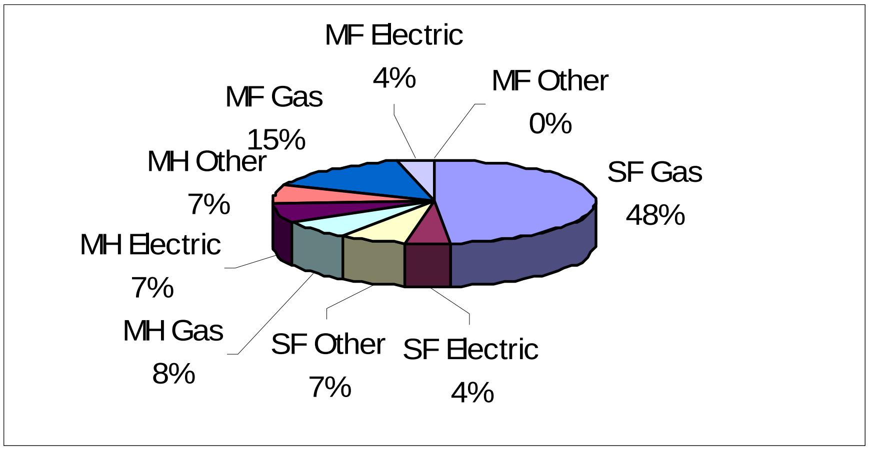


Figure 3 shows the distribution of participants by home type and space heating fuel, where all fuels besides gas and electricity have been combined into "other." As in the 1994 evaluation, single-family gas heat accounted for almost half of the participants, and thus provided most of

[5] Although such homes built after 1974 should be called "manufactured homes" based on the National Manufactured Home Construction and Safety Standards Act of 1974, the term "mobile home" is used to be consistent with the previous evaluation.

the data for the gas analysis. Conversely, mobile home and multifamily electric accounts represented 70% of all electrically heated homes, and played a large role in that analysis.

Figure 3. Space Heating Fuel Distribution by Home Type and Fuel



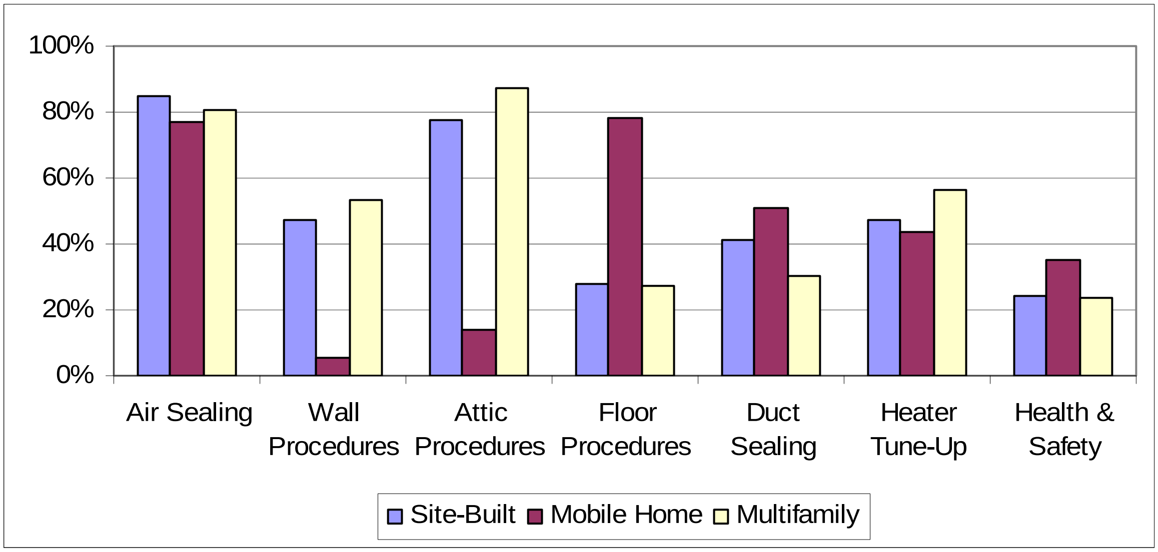
Program Treatments

All job costs for a home are recorded on a Building Weatherization Report (BWR) and entered into the OATS database, allowing for measure tracking across Program homes. Figure 4 shows the percent of homes that received given measures across building types.[6] The data in Figure 4 are based on cases where any funds on individual jobs were listed in the measure category shown. Measure installation rates for site-built and multifamily homes are similar, but rates for mobile homes differ greatly for wall, window, and floor procedures, and they receive more health and safety work.

It was not possible to compare these results with those from the PY94 evaluation because the way the measures were counted in the study was not defined in the report. Measure costs are presented in Chapter 8 of this report.

[6] Multifamily measures are reported at the building level, not the unit level.

Figure 4. Percentage of Homes Receiving Given Measure by House Type



Utility Weatherization Programs

Many Ohio utilities offer weatherization programs in addition to HWAP. For an eligible home, an Agency can use both HWAP and utility funds to cover the cost of weatherization. Weatherization data were obtained from Columbia Gas for those homes that were jointly treated through HWAP and the WarmChoice program and this information was used to closely examine savings and measures for jointly treated homes.[7]

WarmChoice provides more specific data on health and safety problems than OATS, and Table 2 compares the frequency of these problems to PY94. Since 1994, occurrences of all of these health and safety problems have remained constant or decreased.

Table 2. Utility Weatherization Programs WarmChoice Health and Safety Problems Comparison between 1994 and 2003

	1994 Evaluation	Current Evaluation
Gas Leak	17%	12%
Combustion Venting Problems	39%	33%
Cracked Heat Exchanger	21%	18%
One or More of the Above	60%	50%
Carbon Monoxide >150ppm in Flue	6%	<1%
Unsafe Wiring	10%	10%
Any of the Above Safety Problems	64%	55%

7 We requested utility program participation data from all utilities, but only received data from Columbia Gas on their WarmChoice program regarding participation .

4. Gas Savings

The weather-adjusted (normalized) annual energy consumption for the 2003 HWAP participants and a matching group of non-participants was estimated using a modeling approach similar to the PRInceton Scorekeeping Method (PRISM™). A fixed reference temperature base of 65ºF was used in this analysis.[8] House level savings (difference in normalized annual consumption, DNAC) are then calculated as the difference between normalized pre-annual consumption (PRENAC) and normalized post-annual consumption (POSTNAC).

We obtained gas usage data from four utilities – Columbia Gas, Dominion, Cincinnati Gas and Electric (Cinergy), and Vectren – representing 98% of gas heated participants (see Appendix B Figure A.1 for more detail). Approximately 79% of these accounts were matched with utility records.

Almost two thirds of these matched accounts had sufficient data in the pre and post period for billing analysis and provided reasonably reliable results (see Appendix B for more details on data screening and attrition).

After the weather normalized usage was obtained, non-participants were matched at the utility level to quartiles of participants' pre consumption. The non-participant selection process is described in detail in section E of Appendix B.

Findings

Table 3 below summarizes the results of the gas billing analysis. HWAP participants saved an average of 326 therms per year for single-family homes (including mobile homes), or 25% of their pre consumption. The non-participant group saved 58 therms, or approximately 5% of their pre consumption. The non-participant savings are likely due in part to the large increase in gas rates from 2002 to 2004-2005 (see Table 4). The participant gross savings compare favorably with the 315 therm (23% of pre) savings in the 1994 evaluation. However, the net savings of 268 therms are about 20% lower, because of the reduction in consumption observed for non-participants.

The multifamily savings are considerably lower than estimated in the PY94 analysis, which showed average gross annual savings of 213 therms (20% of pre). The gross savings are now 101 therms (13% of pre), and the net savings are 83 therms (11% of pre). The main factor in the lower savings is that the pre consumption for multifamily homes is considerably lower for the PY03 participants (756 therms vs. 1,049 therms in the PY94 evaluation). The multifamily houses in the PY03 analysis are also smaller (856 sq. ft. vs. 952 sq. ft. in the PY94 evaluation). Moreover, the homes in the current evaluation were more efficient to begin with, using

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8 In the 1994 analysis, the PRISM reference temperature (τ) was allowed to take on any value. If the reference temperature (τ) is not fixed, then PRISM can produce unrealistic values as low as 40ºF and as high as 80ºF. To alleviate this problem, we opted for this simpler specification, because it generally provided similar savings estimates to PRISM. The regression model used in our analysis is equivalent to a PRISM model with fixed τ.

0.88 therms per square foot, while the 1994 evaluation homes were using 1.10 therms per square foot.

Table 3. Gas Usage and Savings Summary Results

	# Units	Pre Therms	Post Therms	Savings (Therms) (90% confidence level relative precision)	% Savings	% of Temperature Dependent Savings
Single-Family Houses						
Participants	1,625	1,290	964	326 (±4%)	25.3%	30.0%
Non-Participants	3,520	1,288	1,230	58 (±10%)	4.5%	5.4%
Net Savings[9]				268 (±5%)	20.8%	24.7%
Multifamily (per unit)						
Participants	514	756	655	101 (±21%)	13.4%	17.8%
Non-Participants	*	*	*	18*	2.4%	
Net Savings				*83 (±23%)*	*11.0%*	*14.6%*

The precisions of these estimates are also listed in parentheses. For the single-family estimate the relative precision is 5% at the 90% confidence level. For multifamily homes the precision is 23% at the 90% confidence level.

A separate multifamily non-participant group was not available because the HEAP database did not contain building type information for non-participants. We applied the savings percentage for single-family non-participants to estimate the comparison group multifamily savings of 18 therms.[10] As shown in the table, this approach gives an estimate of multifamily non-participant savings of 2.4%. This appeared to be reasonable given the relationships we found between home pre usage, home size, and energy savings that are discussed later.

The temperature-dependent savings summarize the savings as a percentage of the weather sensitive load. These savings are estimated to be the percent of space heating end use, although some water heating usage is also likely included. Thus, the single-family gross savings represent about 30% of temperature dependent usage, while the net savings represent nearly 25%.

The single-family gross savings percentage is higher than the 1994 evaluation (25.3% vs. 22.6%), but the net savings percentage is lower due to the adjustment for non-participant savings. In the 1994 evaluation, non-participants increased consumption from pre to post. However, as Table 3 shows, in this evaluation, non-participants actually decreased gas usage from pre to post. The most likely explanation for this difference is the rise in utility gas rates from the pre to the post period. Table 4 shows a comparison of average gas rates between the pre

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9 Single family includes both site-built homes and mobile homes. Site-built homes saved 282 therms, or 21.2% of pre consumption, and mobile homes saved 90 therms or 11.4% of pre consumption.

10 The non-participant savings are obtained from the single family savings ratios of non-participants to participants, i.e., (58/326) * 101 = 18 therms.

and post period for major Ohio utilities.[11] It is clear that rates rose substantially between the pre and post periods. Averaged over the utilities shown, rates increased by 71%.

Table 4. Utility Rates in Pre and Post Periods[12]

Utility	$/therm Average during Period		
	Pre	Post	% change
Columbia Gas	$0.60	$0.91	53%
Dominion	$0.46	$0.89	94%
Vectren	$0.50	$0.78	57%
Cinergy	$0.42	$0.75	79%
Average	$0.49	$0.83	71%

Visual representations comparing the pre and post usage and savings for single-family participants are presented in Figure 5 through Figure 7. The y-axis represents the frequency of customers in each consumption/savings group. As can be seen in Figure 5, the distributions in the non-participant and participant groups matched very closely. This was a direct result of the strategy used to select non-participants.

Figure 5. Comparison of Single-Family Pre-Period Usage (PRENAC)

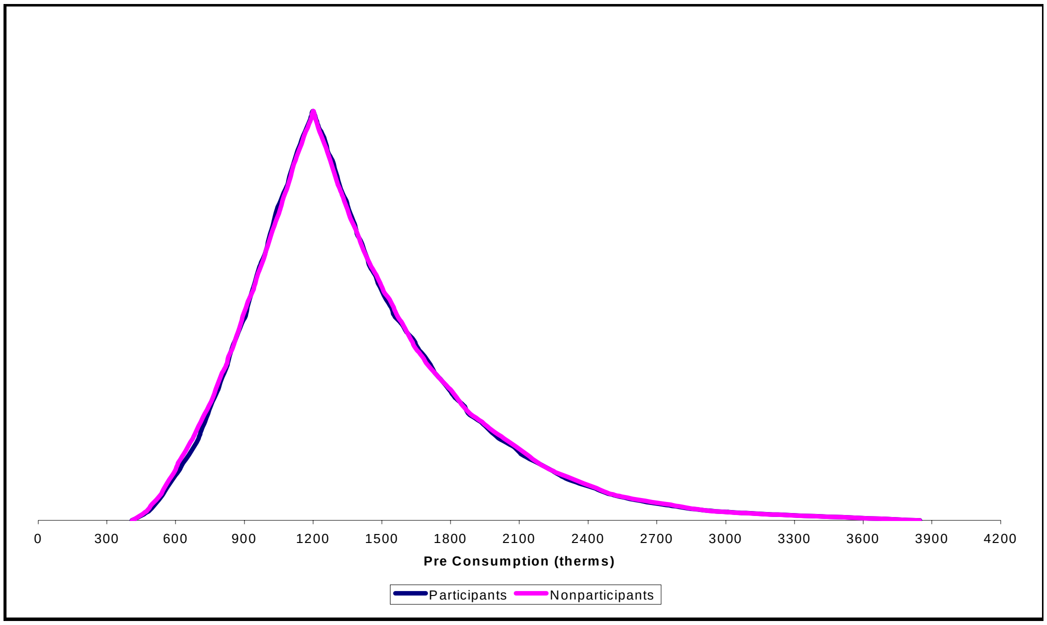

Figure 6 shows post-period usage. The participant group has shifted consumption much more than the non-participants. The savings distribution is found in Figure 7, and shows the increased savings from participation.

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[11] Based on data from Ohio Consumers' Counsel.

[12] The pre period was from February 2002 to February 2003; the post period was from April 2004 to April 2005.

Figure 6. Comparison of Single-Family Post-Period Usage (POSTNAC)

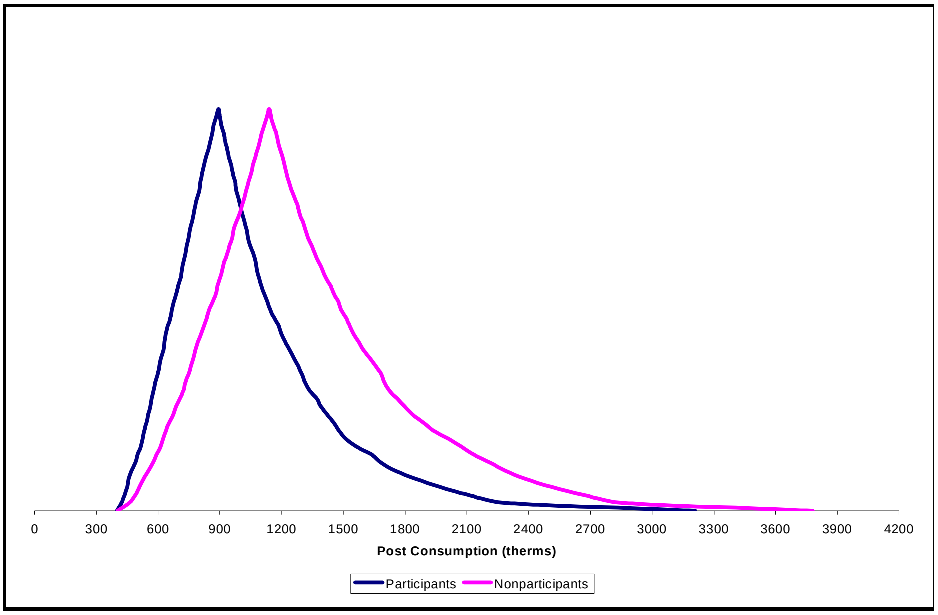


Figure 7. Comparison of Single-Family Savings (DNAC)

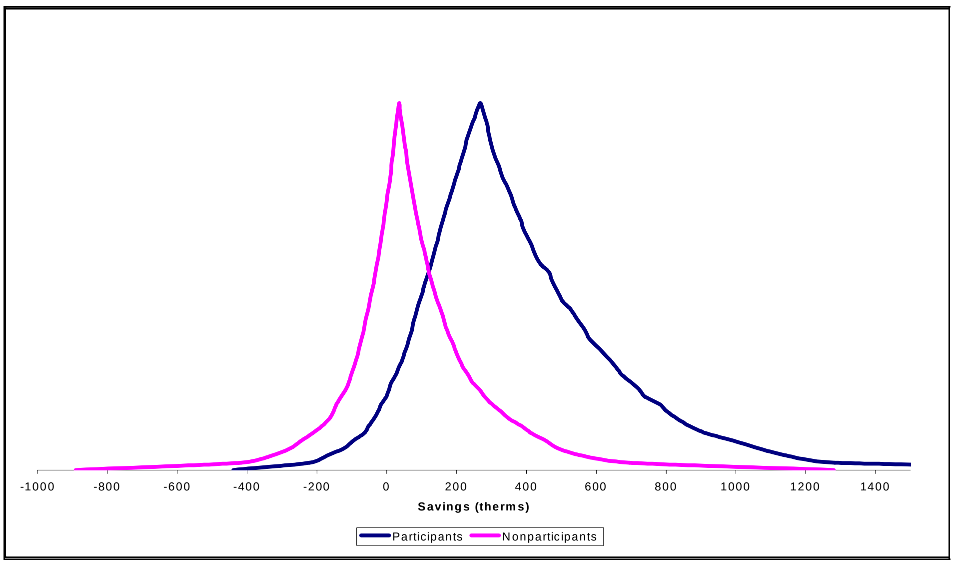


Figure 8 presents the distribution of single-family percent savings. The largest percent of homes saved 20% to 30% of pre-period consumption, followed by an almost equal group that saved 10% to 20%. About 5% of participants saved more than 50% of pre-period consumption; less than 10% of participants increased consumption.

Figure 8. Distribution of Single-Family Gross Gas Savings

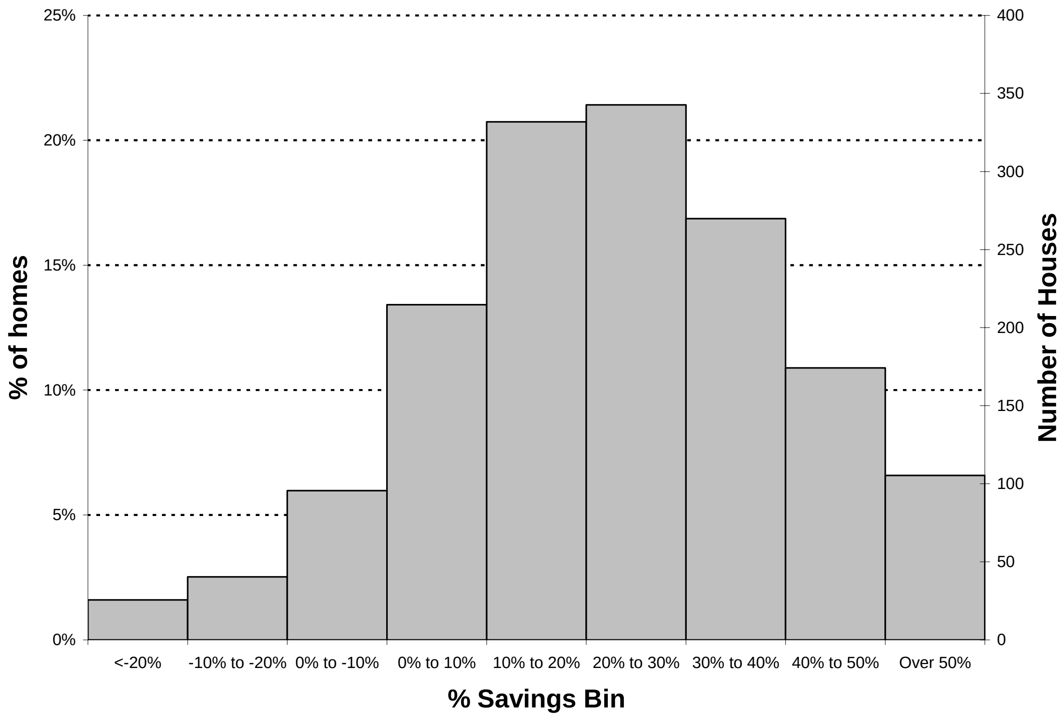
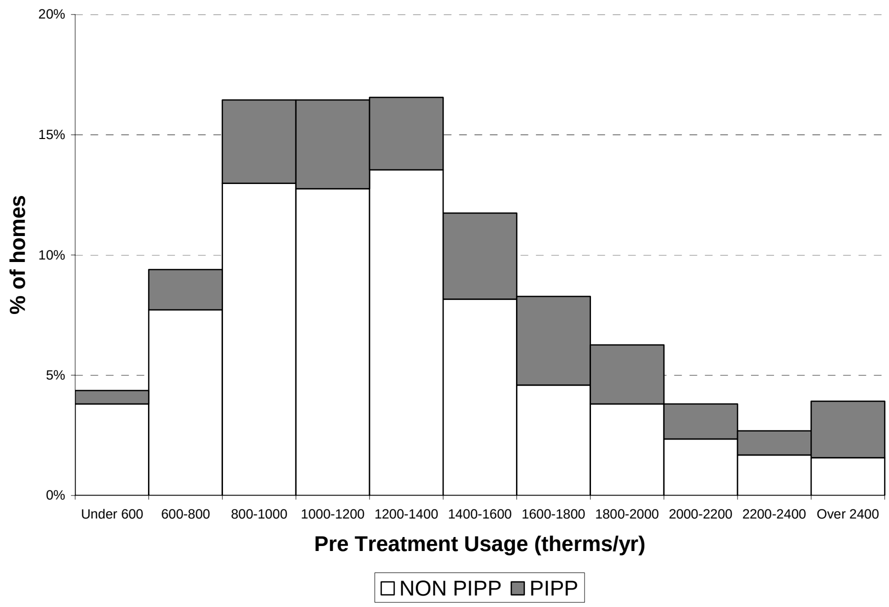


Figure 9 summarizes the pre-period consumption distribution and the PIPP mix in single-family homes. The average pre-period consumption was 1,290 therms, and the median was 1,200 therms. About 29% had usage under 1,000 therms. About 17% of participants have usages over 1,800 therms. As can also be seen from this chart, as consumption increases the PIPP share of the homes increases noticeably.

Figure 9. Distribution of Pre Usage by PIPP Status (Single-Family Participants)



Utility-Specific Results

Figure 10 shows the utility-level net participant savings estimates. The single-family savings range from 231 therms for Cinergy customers to 282 therms for Columbia Gas customers (including Warm-Choice) and include the effects of HWAP and utility weatherization. Sample sizes of single-family participants by utility ranged from 88 to 748 (see Table 5). The multifamily savings could not be separated by utility because of large error bands in estimation due to small sample sizes.

Figure 10. Net Savings by Utility

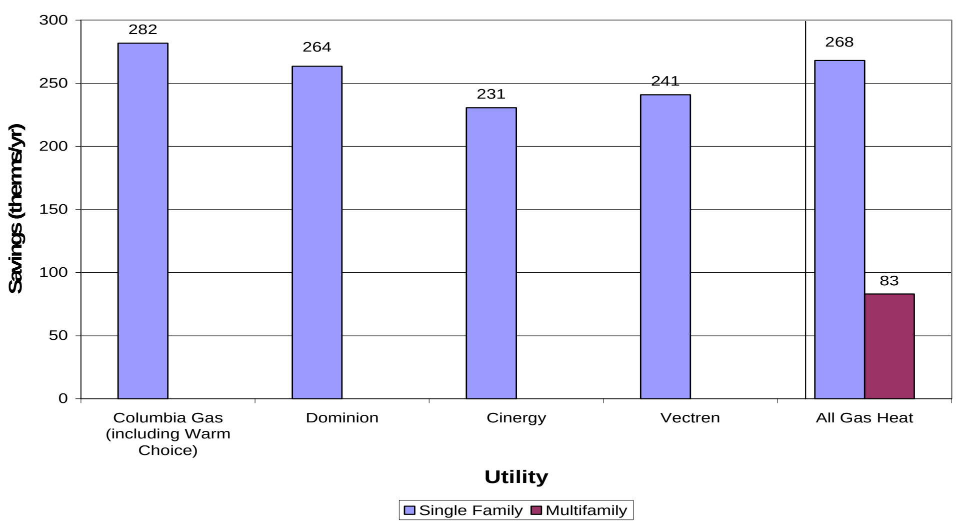


Figure 11 presents the net percent savings estimates for participants by utility. The net savings range from 20% to 22%, with an average of 21%. The Columbia Gas percent savings are highest, primarily because they include savings from joint weatherization through WarmChoice.

Figure 11. Net Percent Savings by Utility

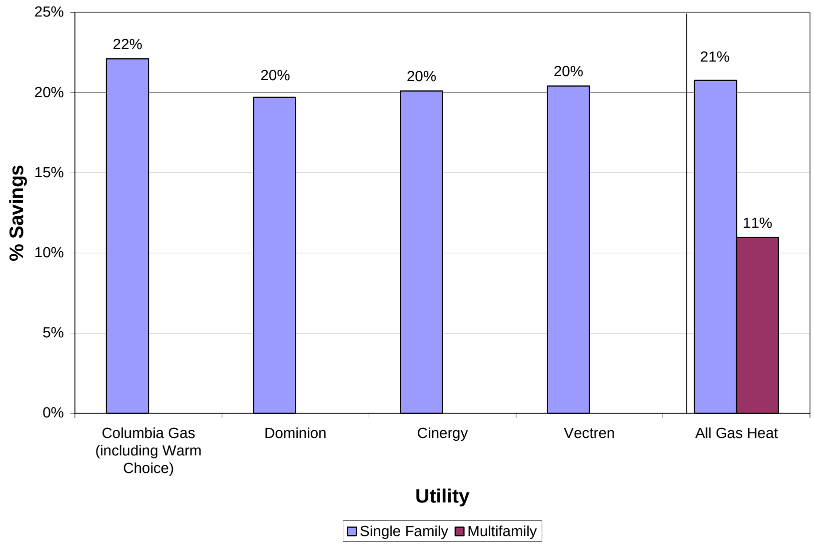


Table 5 gives more details on the utility specific estimates. As can be seen from this table, the pre-consumption values for participants and non-participants are almost identical at the utility level because they were matched by usage quartiles. Cinergy and Vectren HWAP participants had the smallest pre-period usages and the lowest net savings estimates (231 therms and 241 therms, respectively). These two utilities also had the smallest sample sizes and largest error bands.

Table 5. Gas Usage and Net Savings Summary by Utility

	# Units	Pre Therms	Post Therms	Savings (Therms) (90% Confidence Level Relative Precision)	% Savings	% of Temperature Dependent Savings
Single-Family Houses (Columbia Gas)						
Participants	681	1,274	918	356 (±6%)	27.9%	32.9%
Non-participants	1,108	1,269	1,195	74 (±14%)	5.8%	6.9%
Net Savings				*282 (±9%)*	*22.1%*	*26.1%*
Single-Family Houses (Dominion)						
Participants	748	1,337	1,024	313 (±5%)	23.4%	28.1%
Non-participants	1,218	1,338	1,289	49 (±18%)	3.7%	4.5%
Net Savings				*264 (±7%)*	*19.7%*	*23.6%*
Single-Family Houses (Cinergy)						
Participants	108	1,147	893	254 (±17%)	22.1%	25.8%
Non-participants	176	1,146	1,123	23 (±109%)	2.0%	2.3%
Net Savings				*231 (±20%)*	*20.1%*	*23.4%*
Single-Family Houses (Vectren)						
Participants	88	1,180	890	290 (±19%)	24.6%	28.9%
Non-participants	142	1,181	1,132	49 (±45%)	4.2%	4.9%
Net Savings				*241 (±26%)*	*20.4%*	*24.1%*
Single-Family Houses (Overall)						
Participants	1,625	1,290	964	326 (±4%)	25.3%	30.0%
Non-participants	3,520	1,288	1,230	58 (±10%)	4.5%	5.4%
Net Savings				*268 (±5%)*	*20.8%*	*24.7%*

Factors Associated with Savings

One of the study objectives was to assess patterns in usage and savings to help provide insight into what causes high or low savings. Table 6 summarizes the characteristics of high and low savings of single-family gas heated participants. High savers are defined as the top quartile of savings (savings greater than 482 therms/year) and low savers are defined as the bottom quartile (savings less than 107 therms/year).

The high savers had much higher pre usage (1,811 therms) than the low savers (951 therms). The high savers had gross savings of 767 therms, or 42% of their pre. The low savers had no savings on average. The high savers had a higher proportion of measures installed, particularly for wall insulation and furnace replacement – two of the measures associated with highest savings. The blower door percent reduction was 39%[13] for high savers and 27%[14] for low savers. Moreover, the high savers had leakier houses to begin with (as shown by the air leakage per square foot values). They also received more utility weatherization, and none of the high savers are in the mobile home category. The measure installed cost is double that of the low savers.

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[13] (5089-3111)/5089 = 39% reduction

[14] (3286-2383)/3286 = 27% reduction

Table 6. Characteristics of High and Low Savers

Characteristic	High Savers	Low Savers
Pre-Use (therms/yr)	1,811	951
Savings (therms/yr)	767	-2
Savings (% of total pre-use)	42%	0%
Square Footage	1,485	1,290
Pre-Use per Sqft	1.34	0.79
Attic insulated	89%	65%
Walls Insulated	71%	33%
Furnace Replaced	34%	17%
Air Leakage Pre-CFM50	5,089	3,286
Air Leakage Post-CFM50	3,111	2,383
Air Leakage Pre-CFM50 per sqft	3.82	2.77
Air Leakage Post-CFM50 per sqft	2.31	2.01
Utility Weatherization	57%	37%
Mobile Homes	0%	16%
Total Job Costs[15]	*$3,833*	*$1,934*

In order to examine the differences between high savers and low savers in more detail the two groups were further separated into high- and low-usage categories.

As Table 7 shows, in homes in the high usage group (over 1,800 therms), the highest savers tended to have more measures installed. A large proportion (46%) of high savers in the high usage group also received a new heating system, while only 8% of the lowest quartile savers received a heating system. Also, high savers received more wall insulation. Results showed leakage decreased 40% between pre and post blower door tests in those homes categorized as high usage-high savers, but decreased to only 28% for the high usage-low savers. Thus, houses with larger leakage reductions were associated with higher savings.

In the low usage group (under 1,000 therms) those that saved most tended to have a higher proportion of wall insulation, and the heating system was replaced more often. Also 20% of the lowest savers were mobile homes.

15 From BWR data and WarmChoice excluding administration costs.

Table 7. Characteristics of High and Low Savers by Usage Group

Characteristics	High Usage (>1800 therms)		Low Usage (<1000 therms)	
	High Savers	Low Savers	High Savers	Low Savers
Pre-Use (ccf/yr)	2,471	2,188	875	715
Savings (ccf/yr)	1,284	189	310	-60
Savings (% of total pre-use)	52%	9%	35%	-8%
Square Footage	1,555	1,706	1,197	1,156
Pre-Use per Sqft	4.53	3.69	2.94	2.82
Attic Insulated	87%	79%	83%	60%
Walls Insulated	70%	54%	52%	27%
Furnace Replaced	46%	8%	29%	17%
Air Leakage Pre-CFM50	6,205	5,825	3,185	2,940
Air Leakage Post-CFM50	3,616	4,167	2,155	2,247
Air Leakage Pre-CFM50 per sqft	2.57	2.68	1.98	2.07
Air Leakage Post-CFM50 per sqft	1.81	1.38	0.82	0.67
Utility Weatherization	68%	50%	51%	37%
Mobile Homes	0%	0%	8%	19%
Total Job Costs	*$4,433*	*$3,007*	*$2,699*	*$1,581*

Figure 12 shows how net gas savings varied with several key variables. The results are presented in more detail in Table 8. The participants that received utility weatherization saved an additional 90 therms on average.[16] The participants that were also on PIPP saved 318 therms vs. 233 therms for non-PIPP. The main driver for the higher savings is the higher pre consumption for PIPP.

Mobile homes saved considerably less (90 therms) compared to site-built homes (282 therms). Based on usage groups, customers with the highest usage (above 1,800 therms) saved the most (580 therms), customers with medium usage (1,000-1,800 therms) saved 284 therms, and customer in the low usage group (under 1,000 therms) saved only 98 therms.

With regard to weatherization measures, those houses receiving wall insulation saved on average approximately 333 therms versus 192 therms for those that did not. This cannot be interpreted necessarily to mean that wall insulation alone produces these additional savings since other measures could be associated with the addition of wall insulation or the characteristics of houses receiving wall insulation could be different. Similarly, homes that received furnace replacements saved more than those without heating system replacements (350 therms vs. 241 therms).

[16] This is based only on WarmChoice participation.

Figure 12. Net Savings by Key Variables (Average Savings=268 therms)

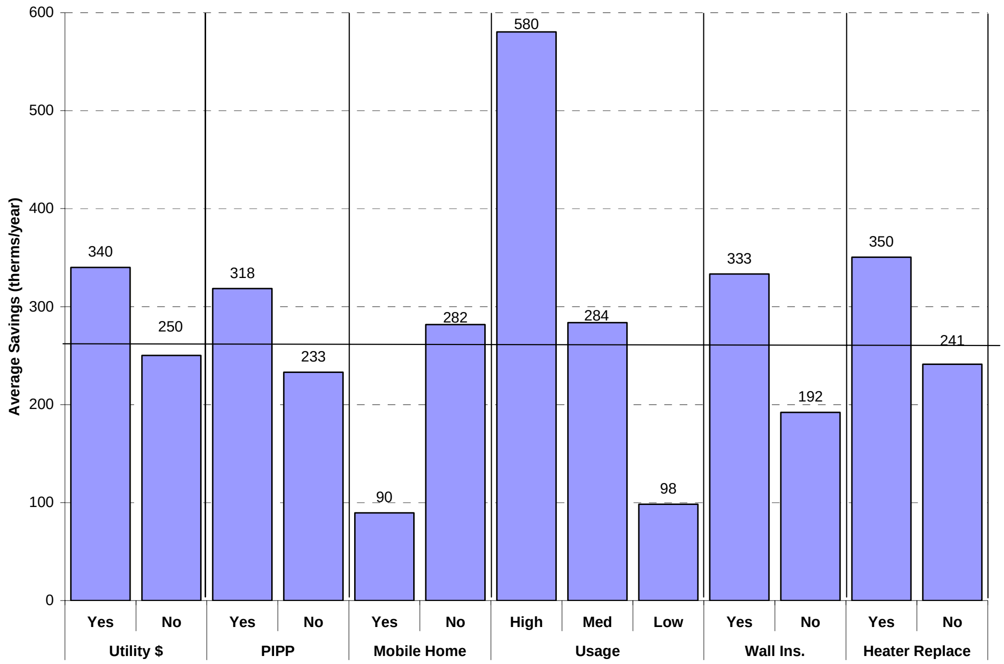

Table 8. Net Savings Details by Key Variables

Group	% of Units	Pre-Use	Net Savings (therms) (90% Confidence Level Relative Precision)	% Savings
Utility Weatherization[17,18]				
Joint Treatment w/Utility	47%	1,309	340 (±9%)	26.0%
HWAP only	53%	1,243	250 (±10%)	20.1%
PIPP Participation				
PIPP Participation	26%	1,480	318 (±9%)	21.5%
Never PIPP	74%	1,211	233 (±5%)	19.2%
Mobile Homes vs. Site-Built				
Site-Built Houses	93%	1,330	282 (±4%)	21.2%
Mobile Homes	7%	783	90 (±19%)	11.4%
Pre-Treatment Usage				
High Use (>1800)	16%	2,245	580 (±6%)	25.9%
Mid Use (1000-1800)	51%	1,336	284 (±4%)	21.2%
Low Use(<1000)	34%	774	98 (±9%)	12.7%
Wall Insulation				
Walls Insulated	54%	1,406	333 (±5%)	23.7%
No Wall Insulation	46%	1,155	192 (±7%)	16.6%
Furnace Replacement				
Furnace Replaced	32%	1,342	350 (±8%)	26.1%
Furnace not Replaced	68%	1,273	241 (±5%)	19.0%

The net savings by pre-usage groups are summarized in Figure 13. In this chart the net savings are calculated as the difference between the participants and non-participants within each usage subgroup.

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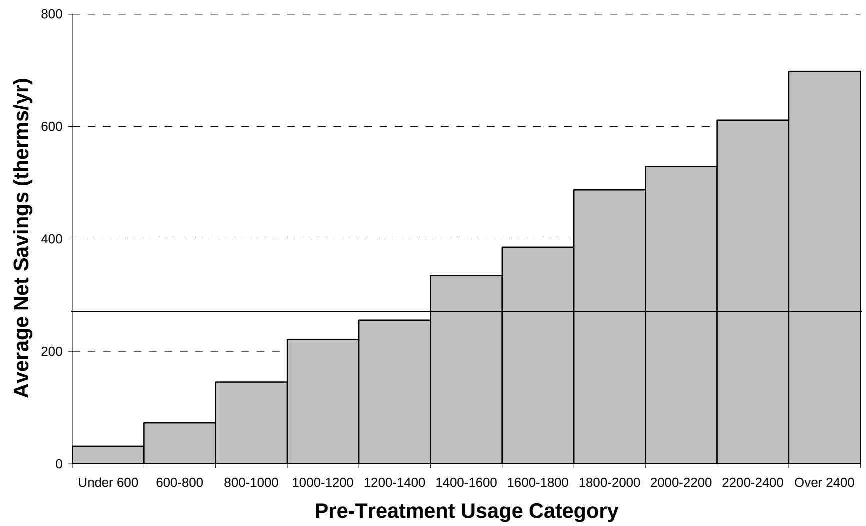
17 An evaluation of Columbia Gas's 1997 WarmChoice Program (*Impact Evaluation of the 1997-1998 WarmChoice Program*, Tom Zimmer and Richard Sims, Columbia Gas of Ohio, July 2000) estimated savings for jointly treated homes of 33.7% as opposed to 14.5% for jobs only receiving HWAP work. However, the pre consumption for the HWAP-only sample in that study was about 400 therms (nearly 30%) less than either the WarmChoice-only or jointly treated sample pre consumption, thus suggesting there were some fundamental differences between the homes in the samples. Furthermore, there were only 30 homes in the HWAP-only sample in that study, whereas our sample was comprised of nearly 900 homes. Consequently, we do not believe those results can be compared directly with our estimates.

18 Note that the distribution by joint treatment and HWAP-only is based only on Columbia Gas customers so these results cannot be used to estimate the savings across all utilities.

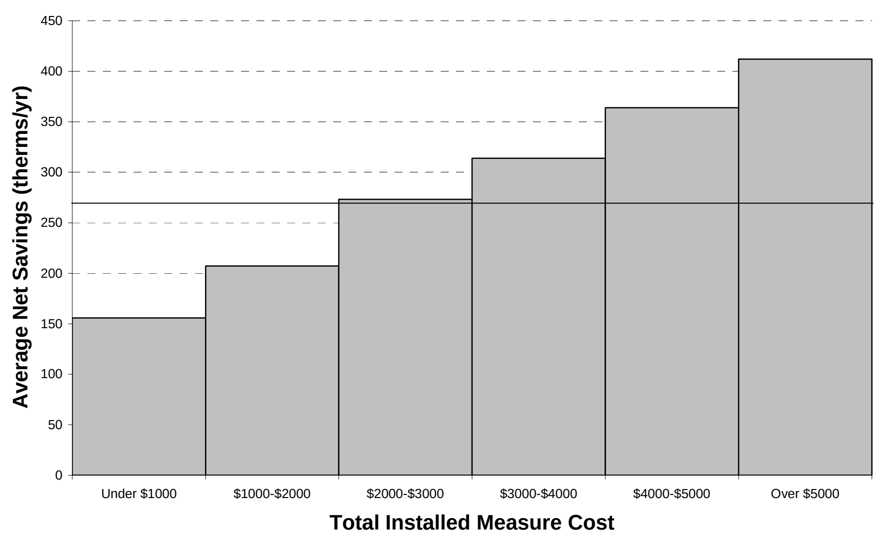
Figure 13. Single-Family Net Savings by Pre-Usage (Average Savings=268 therms)



Measure Savings Estimates

Figure 14 shows the relationship between energy savings and the installed measure cost. Average savings are associated with measure installation costs of $2,000 to $3,000. Since measure cost is likely to be higher for larger homes and larger homes are likely to have higher pre usage levels, higher measure costs would be expected to be correlated with higher savings.

Figure 14. Net Savings by Total Measure Cost (Average Savings=268 therms)



We conducted analyses to attempt to further disaggregate the savings by measure, by pre consumption level using two methods: a standard regression based approach, and a Monte Carlo regression simulation. The reader should note that in the remainder of this report we use the terms "floor insulation," "sidewall insulation," and "attic insulation" to refer to the categories used in the BWRs for floor, sidewall, and attic measures, respectively. Though the weatherization measures in these categories usually included insulation, some of the measures implemented in the floor, wall, and attic components were more limited. The data did not specify, however, whether the measures included insulation or not so we adopted the convention of using the term "insulation" to refer to any measure implemented in the individual building shell components.

The standard regression model approach was reliable for measures with low installation rates (duct insulation, floor insulation, and furnace replacement). This approach, however, was not reliable for measures with high installation rates (air leakage reduction, attic insulation, furnace tune-up and repair, wall insulation) because the models were unable to disaggregate measure impacts due to collinearity (i.e., several measures were installed together in over 80% of the homes).[19]

For the measures where collinearity was a problem in the standard regression models, we used a Monte Carlo regression simulation approach to better disaggregate the measure savings estimates. This consisted of drawing 500 random samples from the groups installing a measure. Separate samples were drawn by measure and by pre consumption level group. For each of the 500 sub-samples, the same dummy variable regression model was run on the sample subset with all measures accounted for in the regression. The average of the 500 coefficients for the measure of interest was used to obtain the measure-specific savings estimate. This led to more reasonable savings estimates for those measures with high installation rates.

Table 9 summarizes the results of the savings results of the regression / Monte Carlo regression simulation analysis for site-built homes. See Appendix E: for information about the Monte Carlo methodology.

Table 9. Measure Level Savings by Pre Group

	Low Usage		Medium Usage		High Usage	
	Savings	% of Pre	Savings	% of Pre	Savings	% of Pre
Air Leakage Reduction*	70	8.5%	113	9.1%	144	7.5%
Attic Insulation*	52	6.3%	45	3.6%	153	8.0%
Duct Insulation	6	0.7%	-21	-1.7%	51	2.7%
Floor Insulation	11	1.3%	46	3.7%	78	4.2%
Furnace Replacement	74	8.8%	118	9.4%	217	11.1%
Furnace Tune-Up & Repair *	-6	-0.7%	35	2.8%	64	3.3%
Wall Insulation*	78	9.4%	169	13.6%	252	7.2%
Water Heater Insulation**	-16	-2.0%	26	2.1%	0	0%

* Monte Carlo sub-sample regression approach was used.

** Monte Carlo sub-sample regression approach yielded unreasonable values so standard regression approach was used instead.

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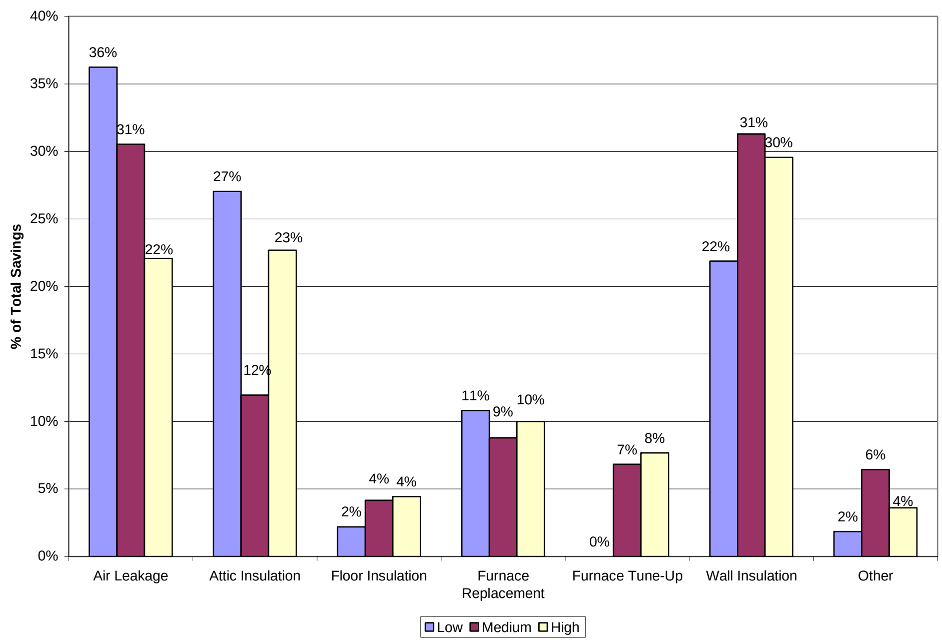
[19] Regression model results can be found in Appendix E.

The relative installation rates were combined with the estimates in Table 9 to provide average savings per participant (i.e., accounting for penetration rates of each measure). Results are summarized in Figure 15. In the low usage group most of the savings are achieved in homes that install air leakage measures (36%), attic insulation (27%), and wall insulation (22%). These account for 85% of the total savings in this group. Furnace replacement measures account for most of the remaining savings. Similarly, in the middle and high usage groups, most of the savings are from air leakage reduction, attic insulation, and wall insulation.

Figure 15. Percent Savings Contribution by Measure and Pre Usage Group



PIPP Usage and Savings

We analyzed PIPP results using an approach similar to that used for the 1994 analysis. PIPP participants saved 35% more and used 20% more energy than non-PIPP participants.

The PIPP group has changed in composition since the PY94 report. It appears that because of large gas utility rate increases even lower usage customers are turning to PIPP for assistance.

Comparing the PIPP and non-PIPP participants, the PIPP participants:

- Have 30% leakier houses based on blower door tests
- Have more occupants (2.6 vs. 2.1)
- Are less likely to have senior occupants (13% vs. 43%)
- Are 13% less likely to live in mobile homes
- Have lower incomes (10% less)

- Are slightly more likely to install wall insulation (56% vs. 51%)

These differences are not as large as they were in the 1994 analysis.

Sample Representativeness

Table 10 compares the final single-family analysis sample with the attrition group (i.e., the participants dropped from the analysis from screens such as unreasonable PRISM parameters insufficient data, and unavailability of data). Generally, the sample participants installed more measures. For example, 54% installed wall insulation vs. 45% in the attrition group. The air leakage reduction was similar for the two groups. Utility weatherization was more common in the analysis sample. The average measure costs are fairly similar between the two groups.

It is likely that most of the differences are associated with the smaller proportion of mobile homes in the analysis sample. There are fewer mobile homes in the final analysis sample (7%) than in the sample of homes that were dropped (18%). Our analysis showed that mobile homes tended to be smaller, consumed less energy, had fewer measures installed, and saved less energy than site-built houses. However, the data and analysis screens we used dropped a larger share of them from our analysis sample so they were underrepresented in the analysis sample and overrepresented in the attrition group. When we estimated Program savings, however, these differences introduced no bias because our estimated savings were developed by housing type and the overall savings estimates reflected the population shares of each housing type.

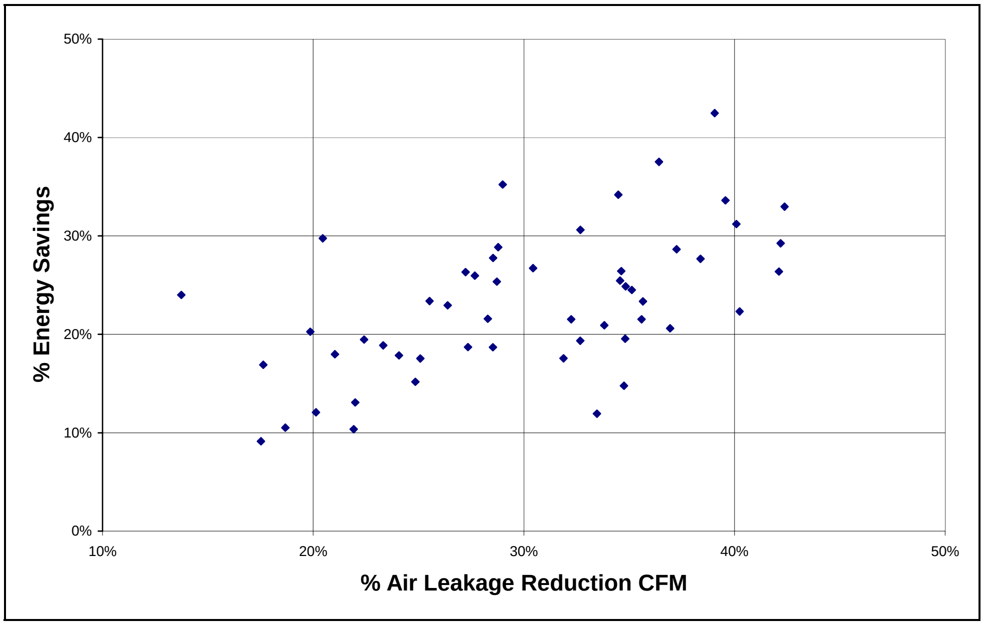
Table 10. Characteristics of the Sample and Attrition Groups (Single-Family Gas Heat)

Characteristics	Analysis Sample	Attrition Group
# Units	1,625	1,965
Attic Insulated	79%	69%
Walls Insulated	54%	45%
Furnace Replaced	24%	21%
Air Leakage Pre CFM50	4,033	3,983
Air Leakage Post CFM50	2,698	2,636
Utility Weatherization	47%	35%
Mobile Homes	7%	18%
Job Costs (HWAP measures only)	$1,897	$1,774
Job Costs (HWAP Health/Safety)	$1,528	$1,373
Total Job Costs (HWAP)	$2,369	$2,218

Air Leakage and Energy Savings by Agency

To be consistent with the 1994 analysis, we examined the relationship between average percent air leakage reduction and average percent energy savings at the Agency level. Figure 16 presents the results of our analysis. These results are presented for illustrative purposes and, as would be expected, show a correlation between air leakage reduction and energy savings. A similar trend was observed in the PY94 Program evaluation. The data show that the average leakage reduction varies widely – from about 15% to over 40%. Average energy savings range from about 10% to a little more than 40%.

Figure 16. Agency Level Air Leakage Reduction and Percent Gas Savings



5. Electricity Savings

This chapter presents our analysis and findings on Program impacts on electricity usage. The approach was similar to that used for gas-heated homes. Our analysis included both homes heated with electricity and those heated with fuels other than electricity.

For electrically heated homes, we obtained data from American Electric Power (AEP). For homes not heated with electricity, we obtained billing data from AEP and Cinergy.

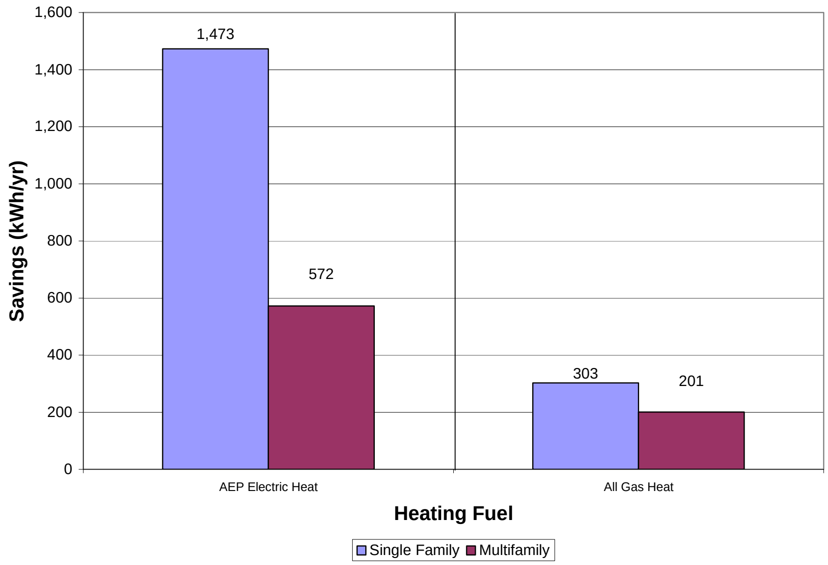
Findings

Electric billing data for electrically heated homes were obtained from AEP only. This utility accounted for 74% of the electrically heated homes. For the gas heating model, electric billing data were received from AEP and Cinergy. Billing data were not available directly for First Energy and Dayton Power & Light. We were, however, able to obtain billing data for PIPP participants from the HEAP database. With the inclusion of these accounts, about 50% of the gas-heated home accounts were matched up for the electricity analysis.[20]

Figure 17 below summarizes the net electricity savings results by utility and space heating fuel. Electrically heated single-family homes saved 1,473 kWh per year and multifamily homes saved 572 kWh. Single-family gas-heated homes saved 303 kWh and multifamily homes saved 201 kWh. Results were unreliable at the utility level for gas-heated homes, and the standard errors for these estimates are quite large so no conclusions should be drawn about how savings varied by utility. The overall average is the best estimate of gas-heated electric savings.

[20] Some participants and non-participants also received services under the Electric Partnership Program (EPP). All HWAP electric savings estimates exclude any savings that are due to EPP.

Figure 17. Electricity Savings Summary by Utility



Electricity Savings in Electrically Heated Homes

Electricity savings in electrically heated homes were obtained by using PRISM heating and cooling models.

The electric heat savings are summarized in Table 11. The gross savings estimates for the single-family participants are nearly 2,500 kWh. This is a considerably higher estimate than the 1994 analysis. The non-participants, however, are saving 1,016 kWh in the post period.[21] The net savings are 1,473 kWh, which is lower than the 2,002 kWh estimate from the 1994 report.

The estimate of net savings for multifamily homes is 572 kWh, lower than the 895 kWh estimate from the 1994 report. Again, the gross savings are actually higher than in 1994; however, after the non-participant savings are accounted for, the net savings are lower.

The sample sizes in the electric heat analysis are rather low, hence there is a larger error band in the estimates.

Figure 18 shows the distribution of participant and non-participant total savings.

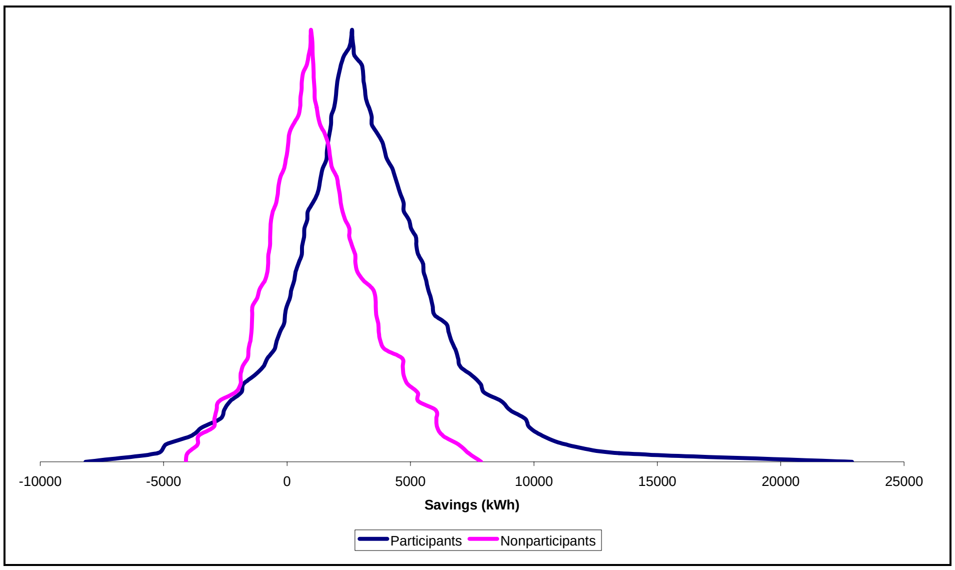
[21] Electricity prices did not rise between the pre and post Program periods as they did for natural gas because an electricity rate freeze was in effect. Consequently, changes in electricity prices would not account for the observed savings in non-participant homes. The savings presented are also net of EPP participation. Regardless of the cause, it is important to control for changes in the energy use of the non-participants.

Table 11. Electricity – Electric Heat Usage and Savings Summary Results

	# Units	Pre kWh	Post kWh	Savings (kWh) (90% Confidence Level Relative Precision)	% Savings	% of Temperature Dependent Savings
Single-family Houses						
Participants	213	22,282	19,793	2,489 (±15%)	11.2%	22.7%
Non-Participants	105	22,136	21,120	1,016 (±38%)	4.6%	9.7%
Net Savings[22]				1,473 (±48%)	6.6%	13.0%
Multi Family (per unit)						
Participants	77	11,728	10,761	967 (±33%)	8.2%	16.8%
Non-Participants	*	*	*	395*		
Net Savings				572 (±33%)	4.9%	9.7%

* Home type is not available for non-participants. Single-family participant to non-participant savings percent used.

Figure 18. Electric Heat Savings Participant and Non-Participant Comparison



Electricity Savings in Gas-Heated Homes

A pooled fixed-effects model was used to estimate the electric savings for gas-heated homes. PRISM could not be used since temperature-dependent usage was not expected. This model is described in more detail in section D of Appendix B.

In Table 12, participants in single-family homes saved approximately 139 kWh; however, the non-participants with gas heat actually increased consumption. It is possible that the non-

[22] Single-family includes both site-built homes and mobile homes. Site-built homes saved 1,251 kWh or 5.8% of pre consumption, and mobile homes saved 1,584 kWh or 7.0% of pre consumption.

participant increase of 164 kWh was caused by a stronger reliance on electric backup heat to counteract higher gas prices in the post period. As a result, participants saved a net of 303 kWh from HWAP participation.

For multifamily units, there was a gross reduction of 92 kWh, although the error band on the estimate is large. Again, applying the single-family participant savings percentage to multifamily non-participants, we estimated that the multifamily non-participants with gas heat increased consumption by 109 kWh. Adding these two values provides the net savings estimate of 201 kWh for multifamily homes.

Table 12. Gas-Heated Homes Electricity Usage and Savings Summary Results

	# Units	Pre kWh	Post kWh	Savings (kWh) (90% Confidence Level Relative Precision)	% Savings
Single-Family Houses					
Participants	839	9,635	9,496	139 (±64%)	1.4%
Non-Participants	1,425	9,597	9,761	-164 (±39%)	-1.7%
Net Savings[23]				303 (±36%)	3.2%
Multifamily (per unit)					
Participants	237	6,362	6,268	92	1.4%
Non-Participants	*	*	*	-109*	
Net Savings				201	3.2%

* Home type is not available for non-participants. Single-family participant to non-participant savings percent used.

[23] Single-family includes both site-built homes and mobile homes. Site-built homes saved 326 kWh or 3.4% of pre consumption, and mobile homes saved 105 kWh or 1.2% of pre consumption.

6. Payment Behavior

Bills, Payments, Customer Shortfall and PIPP Shortfalls

Payment data were provided by all utilities. The Cinergy payment data were received, but they could not be included in the payment analysis because they did not include billed amounts, and some of the additional assistance payment amounts were missing. This analysis could not be separated out for electrically heated customers because of small sample sizes.

The payment data were merged with the final sites from the billing analysis. This allowed for a better non-participant match to the participants.

Under PIPP, if a customer heats with gas, he pays only 10% of his monthly household income to the gas company and 5% to the electric company.

There is a drop-off of fuel assistance funds used by non-participants from the pre to post periods for the PIPP group.[24] This tends to exaggerate the net savings. A more reliable indicator is the customer shortfall estimate based on payment amounts and billed amounts only, without taking into account fuel assistance.

In Table 13, we can see that for PIPP:

- Pre-period bills were similar: $1,255 for HWAP participants and $1,280 for non-participants
- In the post period, there is actually a reduction in bills to $1,184 for participants, even with the higher rates. The effects of the rate increase are more than offset by participation in the Program.
- For the non-participants, however, the bills have gone up significantly to $1,512, mainly due to the increase in rates.
- The customer payment amounts are similar between participants and non-participants in the pre period, and both groups are paying more in the post period.
- In terms of percentage paid, participants paid 56% of their pre period bill, and this improved to 62%, excluding other fuel assistance. The non-participants, on the other hand, paid 53% of their bill in the pre period and this decreased to 47% in the post period.

[24] We were not able to separate the PIPP group into regular PIPP and intermittent PIPP, as in the 1994 evaluation, because this type of detail was not available for all utilities. Customers with PIPP status unknown are not included in the payment analysis.

- The gross customer shortfall for the participants with PIPP was $102, or a 19% improvement, but, taking into account the change in the shortfall for non-participants, the net reduction was $290, or a 53% improvement.[25]

For non-PIPP customers:

- The pre period retail bills for participants and non-participants were similar at about $1,000.
- The participant post period bills decreased to $940, but the non-participants' bills went up.
- In terms of percent of bill paid, the participants paid 77% in the pre period, and 85% in the post period.
- Non-participants were also able to keep up with their bills, paying 74% of their bills in the pre period and 82% of their bills in the post period. As a result, the net customer shortfall reduction is only $36 (a 16% reduction).

These results are consistent with the PY94 findings, where there was a 47% reduction in the customer shortfall for regular PIPP, a 42% reduction for intermittent PIPP, and a 28% reduction for non-PIPP customers. The PY03 results are higher for the PIPP group, and lower for the non-PIPP group.

Table 13. Annual Bill and Payment Impacts of HWAP by PIPP Status

	Participants			Non-Participants			Net $ Savings
	Pre $	Post $	$ Saved	Pre $	Post $	$ Saved	
PIPP (541 Participants, 798 Non-participants)							
Full Retail Bill	$1,255	$1,184	$71	$1,280	$1,512	-$232	$303
Customer Payments	$706	$737	-$31	$674	$718	-$44	$13
Customer Shortfall	$549	$447	$102	$606	$794	-$188	$290
Fuel Assistance	$132	$141	-$9	$171	$148	$23	-$31
Net Shortfall	$417	$306	$110	$435	$646	-$211	$321
NON-PIPP (964 Participants, 1426 Non-participants)							
Full Retail Bill	$1,017	$940	$77	$946	$1,046	-$100	$177
Customer Payments	$788	$801	-$13	$704	$858	-$154	$141
Customer Shortfall	$229	$139	$90	$242	$188	$54	$36
Fuel Assistance	$94	$89	$5	$123	$122	$1	$4
Net Shortfall	$135	$50	$85	$119	$66	$53	$32

The societal benefit of payment impacts is a one-time decrease in the participant shortfall. After weighting based on PIPP participation, the total customer shortfall benefits are $649,819.

[25] The percent improvement is even more pronounced if fuel assistance is included; however, as mentioned above, this is not such a reliable indicator because non-participants received less assistance in the post.

Disconnections and Collections

The effects of the program on disconnection and collection actions for participants and non-participants are summarized in Table 14. In the pre period, about 6% of all participants had disconnections. The disconnection rate was reduced to 5% in the post period, or a 16% reduction. The non-participants, on the other hand, had disconnections increasing from 5% to nearly 7%, or a 34% increase. Adjusting for the disconnection rate changes of non-participants, the net impact was an average decrease of about 50% in the disconnections experienced by participants.

While disconnection data were available for all utilities except Dominion, collections data were available for only one utility (Vectren), and the data seemed questionable. Both participants and non-participants received more collections notices in the post period. In addition, collection actions were much more frequent among the participants than the non-participants during the pre period. Overall, there was a net decrease of 55% in collection actions associated with Program participation. However, for the reasons mentioned here, we did not consider this to be a very reliable estimate.

Table 14. Disconnections and Collections Actions

	# Cases	Pre	Post	Reduction	% Reduction
Disconnections (% cases with disconnections)					
Participants	1,111	6.0%	5.0%	1.0%	16.4%
Non-Participants	1,660	5.2%	6.9%	-1.7%	-33.7%
Net Reduction	2,771				50.1%
Collection Actions (% cases with action)					
Participants	209	49.6%	65.9%	-16.3%	-32.8%
Non-Participants	306	17.4%	32.7%	-15.3%	-88.2%
Net Reduction	515				55.4%

For the purpose of valuing disconnection and collection benefits, we assumed a societal benefit value of $100 per avoided disconnection with a benefit lifetime of ten years and attributed no benefits to the change in collection actions. This method is consistent with the 1994 evaluation. Using this approach, the total lifetime societal benefit is $162,724.

HWAP and PIPP Participation Rates

Table 15 summarizes the percent of customers with gas heat whose gas bills exceed 10% of their income. As expected, the proportion among PIPP customers is much larger, so they are less able to pay their higher bills.[26] The table shows that for PIPP customers the proportion of HWAP participants with bills exceeding 10% of their income dropped between the pre and post periods,

[26] Note that the gas bill amount used in this table is based on the amount that would be due if customers were not in PIPP. Since those customers identified as PIPP participants were flagged in the database as participants at some unspecified point in time and could have been unqualified at other times or dropped out of PIPP, the percent of PIPP participants with bills greater than 10% of income can be less than 100%.

even with the large increase in natural gas rates. The percent of non-participants that had bills exceeding 10% of their income, on the other hand, increased substantially.

For the non-PIPP group, similar patterns were observed. The percent of HWAP participants with high bills relative to their income declined, and the percent of non-participants rose.

Overall, HWAP participation resulted in a 19% net reduction in the households with bills over 10% of their income. Hence, it appears that, due to HWAP Program participation, the number of participants that needed to stay on PIPP declined.

Table 15. Households with Gas Bills More Than 10% of Income, HWAP Participants vs. Non-Participants

	% with Gas Bills >10% of Income		
	Pre	Post	%Reduction
PIPP (n=541) Participants	66.5%	63.3%	5%
PIPP (n=798) Non-participants	73.9%	80.2%	-9%
PIPP (n=1339) Net % Reduction			14%
Never PIPP (n=964) Participants	39.5%	35.7%	10%
Never PIPP (n=1426) Non-Participants	44.5%	51.4%	-15%
Never PIPP (n=2390) Net % Reduction			25%
All Cases (n=1505) Participants	49.6%	46.0%	7%
All Cases (n=2224) Non-Participants	55.0%	61.7%	-12%
All Cases (n=3729) Net % Reduction			19%

7. Non-Energy Benefits

In addition to the benefits already discussed in Chapters 4 through 6 of this report, HWAP also provides numerous non-energy benefits. This chapter identifies these benefits and explains the analysis performed to quantify these benefits. For the purpose of valuing benefits, the life of weatherization is assumed to be 20 years, with a discount rate of 3.2%.[27]

Economic Impacts

HWAP affects the economy in several ways:

- It uses tax money to pay salaries and buy products used in the weatherization process.
- Participants have lower energy bills and are able to use the extra money to purchase goods and services in other economic sectors.
- Utilities receive less revenue due to lower energy bills for participants.

Input-output modeling was used to quantify the effect of each of these monetary shifts individually, as well as the impact on the Ohio economy as a whole.[28] This method of modeling allows for an in-depth look at individual economic segments, as well as the effect that the entire economy sees. The economy is represented as a matrix that relates industries to each other so that effects of events can be tracked. In this case, these events are Program spending, changes in household spending, reduced utility revenue, etc. When an event is specified, the matrix tracks all direct, indirect, and induced effects on the economy. For example, the direct effect of participants having lower energy bills is effectively an increase in household income. The indirect effects are the redistribution of this income across the economy, thus creating more jobs in the industries where households are spending money. These new jobs create another increase in household income for the new employees and the induced effects are the redistribution of this new income across the economy. For the purpose of this evaluation, direct, indirect, and induced benefits have all been used to determine the benefits to the Ohio economy.

Table 16 summarizes the events that are caused by HWAP. Because the funding to pay for Program activities ultimately comes from tax dollars, this has been modeled as a decrease to household income. This money is then distributed to certain industries that provide the materials and labor for weatherization. Modeling participant utility bill savings and utility lost revenue is somewhat more complex, because they do not completely offset one another. Although the participants' savings are equal to their full avoided utility payments, this amount is not all lost revenues to the utility because reduced sales to customers are offset by the amount that the utility reduces its purchases of required fuel or energy. Because the total energy savings are small in comparison to total energy sales in Ohio, it is assumed that this will have no effect on ratepayers' payments towards the utilities' fixed costs and that the portion of rates that are fixed is lost revenue to the utilities. To be consistent with the 1994 evaluation, we assume that 30% of natural

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27 These assumptions are consistent with the Oak Ridge meta evaluation.

28 IMPLAN Professional 2.0 was used for this analysis, utilizing state-level data for Ohio from 2002.

gas, propane, and fuel oil rates and prices are due to fixed costs, while 70% of electricity rates are assumed due to fixed costs.

Table 16. Economic Input Summary

Event	Value (2003 dollars $Million)
Installation Labor	18.0
Admin and Support Labor	7.3
Insulation Materials	2.0
General Weatherization Materials	1.9
Space Heating System Materials	1.6
Window and Door Materials	0.1
Total Program Spending	30.8
Change in Household Income to Fund Program	-30.8
Lifetime Avoided Gas Payments	24.1
Lifetime Avoided Electric Payments	4.2
Lifetime Avoided Propane Payments	3.4
Lifetime Avoided Fuel Oil Payments	2.2
Total Lifetime Avoided Payments	33.8
Lifetime Gas Provider Lost Revenue	-7.2
Lifetime Propane Provider Lost Revenue	-0.7
Lifetime Fuel Oil Provider Lost Revenue	-0.4
Change in Fuel Provider Revenue	-11.3

* Differences between sums and totals are due to rounding

When all of these inputs are run through the model, the output is expressed in value added to the Ohio economy and job-years created. Table 17 provides a detailed summary of the economic benefits of HWAP.

Table 17. Economic Output

	Value Added (2003 $ Million)				Employment
	Personal Income	Property Income	Indirect Business Taxes	Total	
Program Spending	16.8	6.7	1.3	24.7	449
Reduced Household Expenditures	-10.6	-6.9	-1.9	-19.4	-360
Fuel Provider Lost Revenue	-3.8	-3.9	-1.2	-9.0	-79
Increased Household Expenditures	12.0	7.3	2.0	21.4	393
Total	*14.4*	*3.1*	*0.2*	*17.7*	*403*

These results show that in 2003, the Program created about 403 net job-years of employment and added $17.7 million to the Ohio economy. Though these numbers are small compared to Ohio's economy and work force as a whole, this analysis shows that HWAP has a positive effect on Ohio's economy.

Environmental Benefits

Reducing participants' energy consumption also reduces the amount of pollution created by electricity generation and fuel use. In order to determine the total amount of avoided pollution and assign a dollar value to this environmental benefit, four steps were necessary:

1. Calculate the total Program energy savings by fuel
2. Apply Ohio electricity generation statistics to determine the amount of fuel that was saved because of avoided electricity demand
3. Use Clean Air and Climate Protection Software to calculate the avoided emissions attributable to the Program
4. Obtain dollar values by pollutant to determine societal benefit

To accomplish the first task, gas and electric savings by building type were summed across all HWAP participants. For participants heating with oil or propane, savings were assumed to be the same as gas and a conversion was performed to determine the quantity of these fuels saved. Similarly, it was assumed that electric savings for oil and propane participants was the same as for gas participants.

Next, the Environmental Protection Agency's Emission and Generation Resource Integrated Database (eGrid v2.01) was used to obtain Ohio-specific electric generation data. Table 18 shows both the amount of each fuel saved by participants and the amount saved due to avoided electric generation.

Table 18. Total Energy Savings by Fuel Type

Fuel Type	Annual Participant Savings	Annual Avoided Fuel Use to Generate Electricity	Annual Total Savings	Lifetime Savings
Total Electricity (MWh)	2,605	- - -	2,605	52,095,290
Natural Gas (therms)	994,815	1,422	996,238	19,924,758
Propane (gallons)	90,206	- - -	90,206	1,804,126
Fuel Oil (gallons)	50,174	448	50,621	1,012,426
Coal (tons)	- - -	818	818	16,364

Dollar values were assigned to the three most substantial air emission reductions based on relevant market values as of December 2005, and are summarized in Table 19. As markets for emission reductions continue to emerge, values should continue to rise, so assuming a constant value for emissions provides a conservative estimate for societal benefits. Over the life of weatherization, the societal benefit in 2003 was $2,533,447.

Table 19. Avoided Emissions and Societal Benefits

Pollutant	Lifetime Avoided Emission (tons)	Value Per Ton ($)	Societal Benefit (2003 $)
Carbon Dioxide	188,060	$1.81[a]	$257,164
NOx	420	$1,950[b]	$617,258
SOx	1,140	$1,630 [c]	$1,400,475
Carbon Monoxide	140		
Volatile Organic Compounds	20		
Particulate Matter	100		
Total			*$2,533,447*

a Value from the Chicago Climate Exchange: December 2, 2005
b Value from Seattle NOx price curve: December 9, 2005
c Value from Seattle SOx price curve: December 9, 2005

Forced Mobility

Because of the energy burden on low income households, when bills get unmanageable, families are often left with no choice but to move to a new home. Weatherization programs can have an effect on this "forced mobility" because of the reduction in monthly energy bills. A 2002 study by Oak Ridge National Laboratory estimated that the benefit to a family of not having to move could be as high as $1,460.[29]

To determine whether participants moved less frequently than they would have had their homes not been weatherized, an analysis was done based on 2003 HEAP participants. This analysis investigated whether a participant moved between the pre and post period. The database was, therefore, pared down to those households that participated in HEAP every year from 2002 to 2004. For participants meeting this requirement, addresses were compared between 2002 and 2004. Using this method, it is not possible to know how many times a participant moved in this span, only whether or not a move occurred. Once it had been determined if a move occurred, HWAP participants were compared to non-participants to see if there was a difference in mobility. About 20% (19.9%) of non-participants moved in this period, compared to 12.6% of participants. This indicates a net difference of 7.3%, or 466 HWAP participants who avoided moving as a result of the Program.

Renters are far more likely to move than owners and any differences in the home ownership rates between the HWAP and HEAP samples could affect these results. Because the HEAP database did not contain data indicating whether a participant owned or rented, it cannot be determined whether the home ownership percentage differed between HWAP participants and the HEAP participants. Because of this, the decrease in mobility cannot confidently be attributed to HWAP and to be conservative, the value of this benefit will be left out of the cost effectiveness analysis.

29 Non-energy benefits from the weatherization assistance program: a summary of findings from the recent literature, Oak Ridge National Laboratory, April 2002

Health and Safety Benefits

It is extremely difficult to quantify and assign dollar values to health and safety benefits. As in the 1994 evaluation, the assumption was made that if the benefits of the health and safety work did not at least equal the costs, the work would not have been performed. Therefore, the benefits and the costs are assumed to be equal, providing a conservative estimate of health and safety benefits.

8. Cost Effectiveness

Cost effectiveness is a crucial component in determining whether a program was successful. The question in this case is: Do the benefits of HWAP outweigh its costs? By summing up all Program benefits and dividing this number by the corresponding costs, a Benefit-Cost (BC) ratio is obtained. If this ratio is greater than one, then the Program's benefits outweigh its costs and the Program is said to be cost effective.

Program Benefit-Cost Analysis

To determine Program costs, it is not sufficient to merely look at the amount that the state of Ohio spends on HWAP. Because many HWAP jobs receive a combination of funding from Ohio and a utility, it is important to include the money that utilities spend on HWAP jobs in a calculation of the total cost of the Program.

Program benefits are analyzed in Chapters 4 through 7 of this report. They include the direct and indirect effects of the reduction of participant energy consumption and the economic effects of HWAP spending. Table 20 summarizes all costs and benefits of the PY03 HWAP that we were able to estimate.

Table 20. PY03 Program Costs and Benefits

Costs	
HWAP Actual Expenditure	$28,709,172[a]
Columbia Gas WarmChoice	$1,448,669
Dominion Housewarming	$624,266
Total	*$30,782,107*
Benefits	
Lifetime Participant Avoided Energy Payments	$33,827,839[b]
Economic	$17,747,363
Health and Safety	$2,739,626
Environmental	$2,533,447
Impacts on Arrears	$649,819[c]
Disconnections	$162,724[d]
Total	*$57,660,818*

a The budget is broken into its components in Table D.1.

b A detailed summary of participant savings is provided in Table D.2.

c The societal benefit of payment impacts is a one-time decrease in participant shortfall.

d A societal benefit value of $100 per avoided disconnection with a benefit lifetime of 10 years was assumed. This method is consistent with the 1994 evaluation. See Chapter 7 for in-depth disconnection analysis.

Benefit-cost ratios were calculated from two different perspectives:

- ***The Program Perspective*** considers only the discounted value of energy savings and total Program costs

- ***The Societal Perspective*** considers all benefits, including non-energy, and total Program costs

Table 21 presents the benefit-cost ratios from both these perspectives for selected home and fuel types as well as the Program overall, with administration costs distributed equally across all homes weatherized. This table shows that HWAP is cost effective overall from both perspectives, with both BC ratios greater than one. Weatherization of single-family homes is cost effective in all cases, except from the Program perspective for those heated with electricity. From the Program perspective, weatherization of mobile homes is not cost effective for any heating fuel type; from the societal perspective, however, weatherization of mobile homes is cost effective for all space heating types. Weatherization of multifamily homes is cost effective in all cases from the societal perspective, but not from the Program perspective.

Table 21. Benefit-Cost Ratios and Net Benefits by Home and Fuel Type

Space Heating Fuel Type	Home Type	Program Perspective		Societal Perspective	
		BC Ratio	Net Benefits	BC Ratio	Net Benefits
Gas	Single-family	1.22	$4,087,715	1.85	$15,767,954
	Mobile Home	0.58	-$836,680	1.52	$1,053,326
	Multifamily	0.62	-$1,375,450	1.61	$2,196,662
Electric	Single-family	0.70	-$240,887	2.01	$802,396
	Mobile Home	0.83	-$218,272	2.08	$1,407,133
	Multifamily	0.62	-$155,124	2.69	$684,039
Propane	Single-family	2.54	$1,301,623	3.31	$1,955,565
	Mobile Home	0.92	-$120,965	1.80	$1,205,820
Fuel Oil	Single-family	1.63	$769,570	2.27	$1,552,032
	Mobile Home	0.66	-$171,787	1.48	$247,794
Overall		*1.10*	*$3,039,742*	*1.87*	*$26,872,722*

Measure Level Benefit-Cost Analysis

In Chapter 4, an analysis of gas savings by measure was presented, and these numbers can be combined with measure costs to calculate BC ratios at the measure level. Because the OATS database doesn’t track labor costs at the measure level, a regression model was employed to disaggregate labor to the measure level. This model used total labor cost as the dependent variable, and measure installation variables (1=installed, 0= not installed) as the independent variables. Table 22 summarizes average cost components by usage group for site-built single-family gas heated homes.

Table 22. Measure, Labor, and Total Installed Costs by Usage Category, Site-Built Gas Heated Homes

	Low Usage			Medium Usage			High Usage		
	Materials	Labor	Total	Materials	Labor	Total	Materials	Labor	Total
Air Leakage Reduction	$96	$113	$209	$107	$91	$198	$141	$224	$365
Attic Insulation	$355	$254	$610	$403	$354	$757	$454	$526	$980
Duct Insulation	$35	$124	$159	$34	$104	$137	$37	$114	$151
Floor Insulation	$193	$207	$400	$141	$151	$292	$130	$140	$270
Furnace Replacement	$1,045	$551	$1,596	$1,125	$813	$1,938	$1,278	$1,144	$2,422
Furnace Tune-Up & Repair	$187	$283	$470	$197	$347	$544	$222	$489	$711
Wall Insulation	$248	$426	$674	$324	$469	$793	$394	$632	$1,026
Water Heater Insulation	$21	$62	$83	$19	$168	$187	$19	$163	$182

Because savings and costs are so dependent on home size and usage group, the cost-benefit analysis was performed by usage group, and the BC ratios are show in Figure 19.[30] Here are the key findings from this analysis:

- Air leakage measures are cost effective in all cases, although they are even more so for homes with higher usage.
- Attic insulation measures are typically cost effective.[31]
- Wall insulation measures are cost effective for all usage groups.
- Floor insulation is not cost effective for site-built homes with small usage (less than 1,000 therms per year), but highly cost effective otherwise.
- Furnace replacement is cost effective only for high use homes.
- Furnace tune-up is not cost effective for any group.
- Other measures (duct insulation and water heating wrap) are not cost effective, however they are most cost-effective for the highest usage group.

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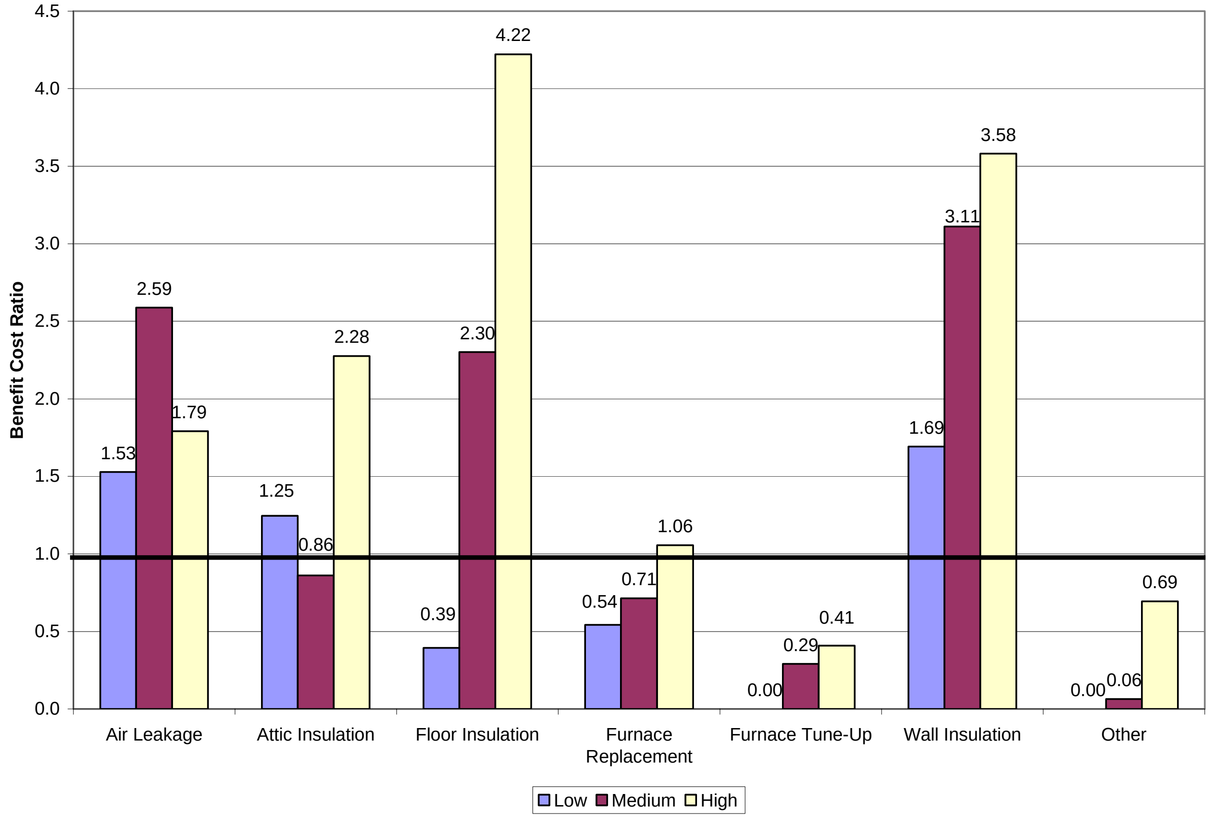
30 A $1.00 per therm rate was assumed in the benefit-cost calculations.

31 We note that the attic insulation measures installed in medium-usage homes did not meet the cost-effectiveness test, primarily because the estimated measure-level energy savings for these homes were less than the savings in either low- or high-usage homes. We conducted additional analyses with this group, but could not fully explain this result. It is likely that the collinearity effects could not be completely eliminated, even with the Monte Carlo approach employed. Without further analysis, we note that this finding is more likely to be attributable to the problem of separating out the effects of multiple measures than poor performance of attic insulation measures in medium-usage homes.

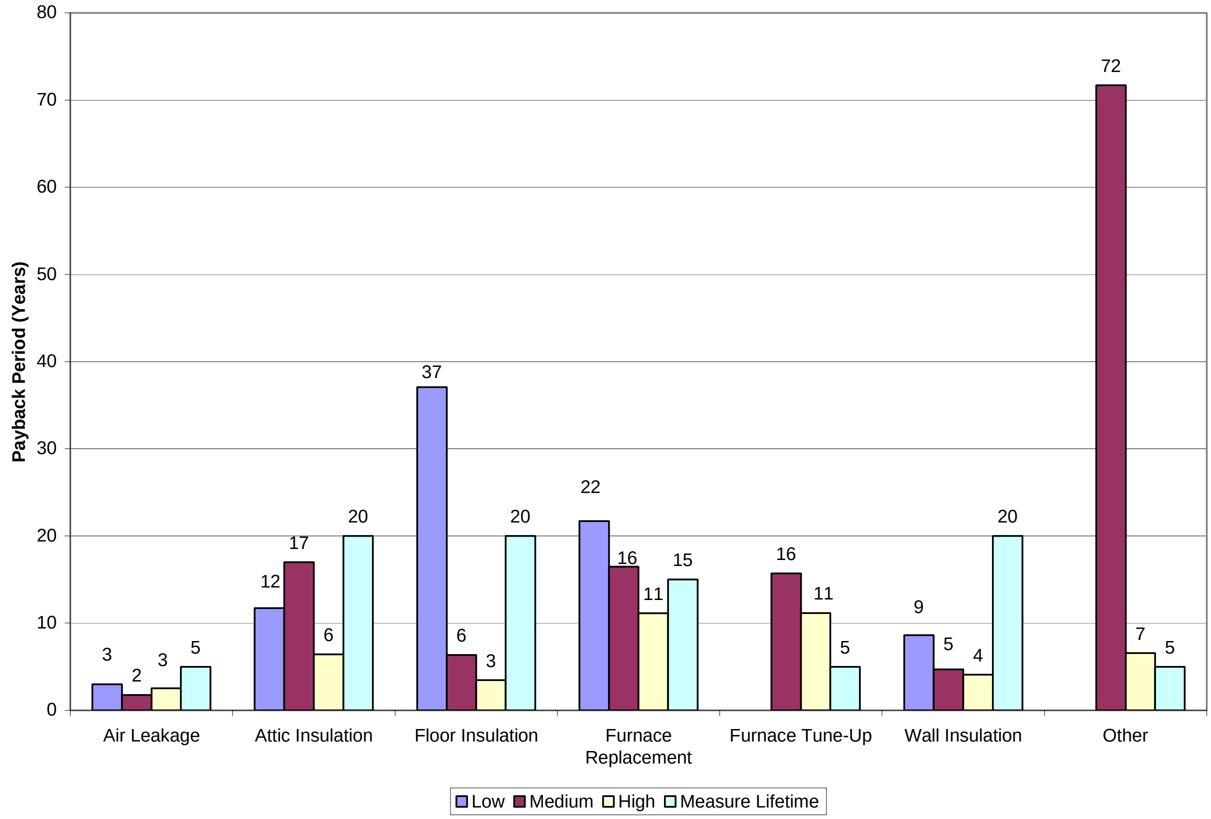
Figure 19. Site Built Single-Family Measure-Level Cost Effectiveness by Natural Gas Usage Category[32]



A different way to look at how well the measures are performing relative to their cost is to examine the payback period of the measures. Figure 20 summarizes the payback period and assumed measure life for each measure by usage category. All measures except furnace tune-up pay for themselves before they expire for high users. In addition, most measures pay for themselves in low- and medium-usage households, with some notable exceptions being floor insulation in low usage and furnace replacement for both low and medium usage levels.

32 This figure includes site-built homes only.

Figure 20. Site Built Single-Family Measure Payback Time by Natural Gas Usage Category[33]



Examining the results of this analysis may be an effective way of maximizing energy savings if the pre-consumption category is known at the time of weatherization.

[33] This figure includes site-built homes only. The bars for low usage furnace tune-up and other measures are not shown in this figure because the savings are negative.

9. Causes of Poor Performance

One objective of this study was to examine what factors might be contributing to the poor performance of some homes in the Program. We used the analysis described in Chapter 4 to identify and then conduct site visits to homes that saved less than predicted. Three screens were used to identify homes for the sample. Our hypothesis was that factors such as poor quality of work, some unanticipated failure of a measure, measures that were not identified for installation that could have been effective, or unusual occupant behavior could be identified to explain the poor performance.

Once we had selected poorly performing homes, a telephone screening process was used to identify and exclude homes that had been remodeled to increase the size or where additional people had moved in since the time of weatherization. These factors could cause increased energy use but were exogenous changes that were unrelated to the Program. Very few homes were screened out using these criteria. We offered households $30 as an incentive to participate and in the end, 52 homes received site visits. Visits were made in three phases and included homes in Columbus, Dayton, Toledo, Cleveland, Akron, Springfield, Marion, and Findlay.

Inspection tasks included measure installation verification, an assessment of the quality of workmanship, identification of missed energy saving opportunities, and an assessment of the relative energy saving potential of the missed opportunities.[34] A blower door test was conducted and results were compared with the original test results.

For the homes we visited, we found that inadequate measure installation was a primary factor causing poor performance. The expected energy savings were computed based on all measures being fully installed that were reported installed. Therefore, where measures were not fully or adequately installed, actual savings would have fallen below estimates of expected savings.

In terms of missed opportunities and the number of technician's comments, air sealing ranked at the top of the list of possible reasons for low energy savings. Many cases of inadequate or missing air sealing were reported. Likewise, if a measure was listed as installed, it was assumed to be fully installed. Our technicians' comments about the quality of work identified areas where insulation, for example, was not fully installed. Where measures were not completely installed (a missed section of floor, wall, or attic, for example), lower energy savings would result.

The estimates of expected savings also assumed that other measures in the home were in good operating condition, including windows and heating systems. While window replacements were rarely qualified measures under the Program, windows that were broken, leaky, or otherwise in poor condition at the time of the site visit impacted the amount of savings the home was able to

[34] For the purposes of this review, we defined missed opportunities as measures that were not listed as installed in each home, but that our field technicians believed would have been applicable. Note that some missed opportunity window and door measures were not eligible under the terms of the Program, but they were identified during the site visits because of their potential impacts and effect on factors such as air leakage.

achieve. Heating systems that required repair, replacement, or a tune-up also lowered the home's ability to save energy.

Overall, the quality and completeness of the measures installed were factors leading to fewer energy savings than originally estimated, based on the measures installed.

Overall Findings

The quality of each measure and its installation were rated on a scale from 1 to 5, with 1 being low and 5 being high quality. Missed opportunities were recorded and the relative value of the missed energy savings ranked on a scale from 1 to 5, with 1 being low savings potential and 5 being high savings potential. That is, if the factor was given a rating of 5, its potential to save energy was high if it had been specified and installed properly. The ranking was subjective and determined by our experienced field technicians. The objective was to rate the potential benefits of installing the measures that were not originally listed as installed so that the relative savings potential could be compared across measures.

The field technicians rated the performance of installed measures at the time of the field verification. In most cases, the ratings reflected the quality of the original weatherization work. However, in a few cases (for example, instances of broken windows), the condition could have deteriorated since weatherization occurred. Under these circumstances, it was not possible to determine whether the savings opportunity had been missed originally or the condition had deteriorated since weatherization took place. Regardless of the situation, our primary purpose was to identify what factors were contributing to poor energy performance so these cases were all documented and reported.

The site verification identified and documented factors that we believe could have contributed to the poor performance of these homes. In some cases, occupant actions could have contributed to poor performance and we made notes of obvious cases, but the focus was on physical characteristics of the building when the site visit was conducted. All of these homes were under-performing and we strived to identify causes related to weatherization that could explain their poor performance.

Table 23 shows that 202 measures were listed as installed in the 52 homes. We were able to verify the installation of 182, or 90%, of the measures. This table orders measures from most to least number installed as reported in the Program tracking database.

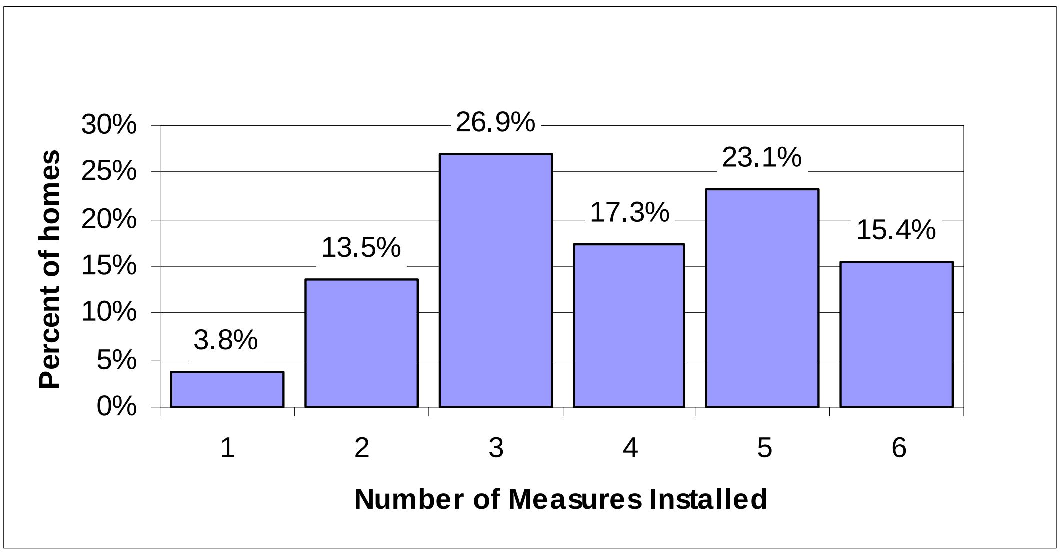
Figure 21 shows the distribution of the number of measures installed per home. Twenty-seven percent of the homes in the sample had three measures installed and 23% had five.

Table 23. Number of Measures Installed and Verified

	No. Measures Installed	No. Measures Verified	Percent Verified
Air Leakage	46	45	98%
Water Heater Insulation	42	36	86%
Tune-Up and or Repairs	35	29	83%
Attic Procedures	29	26	90%
Sidewall Procedures	14	13	93%
Duct Insulation	13	11	85%
Heating System Work	10	9	90%
Floor Procedures	8	7	88%
Secondary Window Procedures	2	2	100%
Replacement Door	2	2	100%
Replacement Sash Window Unit	1	1	100%
Total	*202*	*182*	*90%*

Note: "Number of Measures Installed" is the quantity reported in the Program tracking database. Our sample included 52 homes.

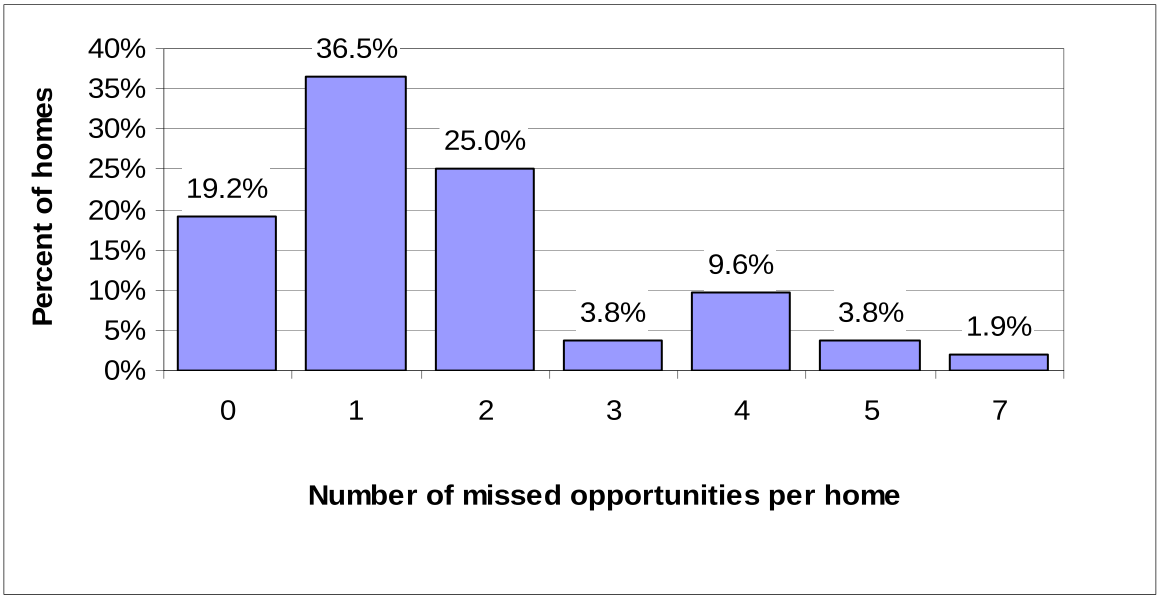
Figure 21. Number of Measures Installed



As noted earlier, we defined missed opportunities as weatherization measures that were not listed as installed in a home, but, in the judgment of our field technicians, would have been effective if installed. As stated earlier, some of the measures we identified were window and door measures that might not have met the Program's qualification criteria. This issue is discussed below.

Figure 22 shows the distribution of the number of missed opportunities per home. Ten homes (19%) had no missed opportunities that we were able to identify that could cause the poor performance observed in the analysis. Nineteen homes (37%) had one, and 13 (25%) had two opportunities for efficiency improvements that were not selected for the homes and could be contributing to poor performance.

Figure 22. Number of Missed Opportunities



Our field technicians also rated the potential energy savings of each missed opportunity identified on a scale from 1 to 5, with 5 being the largest energy savings potential. The assessment was a subjective judgment based on professional experience. Table 24 shows the number of missed opportunities and their energy-saving potential. Although the number of missed attic insulation performance measures was small, they had the highest mean rating for potential savings. Air sealing, heating system, sidewall[35] and floor insulation measures followed as the next four highest ranking missed opportunities. Of these four, however, only heating system performance factors that could lead to reduced savings occurred very frequently (27% of the homes).

Table 24 includes window sash replacement and secondary window replacements missed opportunities although some might not have been qualified under the terms of the Program. When the prime window is intact, window replacements are not an allowable measure under HWAP. The Program permits replacements only where window sashes cannot be repaired or are missing. Similarly, replacement doors rarely qualify under HWAP. We elected to include these measures in our assessment, however. The counts for these measures are based on the technician's observations that replacements could have been completed and could possibly have caused poor energy performance in these homes.

35 Sidewall insulation was observed with an infrared camera. The objective was to identify voids, and not to determine the density of the insulation installed.

Table 24. Savings Potential Ranking of Missed Opportunities

	No. Homes	Minimum Rating	Maximum Rating	Mean Rating
Attic Insulation	3	4	5	4.3
Air Sealing	4	2	4	3.5
Heating System	14	2	5	3.4
Floor Insulation	7	2	5	2.7
Sidewall Insulation	8	1	4	2.3
Duct Insulation	5	1	3	2.0
Tune-Up or Repairs	2	2	2	2.0
Replacement Window	17	1	2	1.7
Water Heater Insulation	4	1	2	1.7
Replacement Sash Window	12	1	2	1.5
Replacement Door	14	1	3	1.3

The field technicians recorded comments about the conditions observed for measures that were installed and reasons that might have led to low energy savings. Comments were recorded for each measure examined. Some comments referred to more than one problem for each measure. For example, if air sealing was inadequate for rim joists and was not present around a chimney bypass, the comment was recorded under both rim joists and air sealing.

Table 25 summarizes comments and groups them by topic. The most common comments (42) were about air sealing. Typical air sealing problems included air sealing missing or inadequate around chimney and plumbing bypasses, wall tops, windows, and kneewall bottoms. These comments help to explain the quality rating for each measure discussed later.

Table 25. Field Technician Comments

Type of comment	Number of comments
Air sealing inadequate or not installed: chimney bypass, plumbing bypass, attic wall tops, kneewall bottoms, attic hatch, duct boots. Leaky windows or windows with inadequate air sealing	42
Furnace old & inefficient, would benefit from replacement	15
Windows broken (4) or single pane windows that could have had a storm window installed (11)	15
Rim joist insulation missing or inadequate	14
Doors in poor condition	14
Weatherstripping missing or poorly installed	10
Floor insulation inadequate, not installed, or improperly installed	8
Sidewall insulation voids, missing altogether, or improperly installed	7
Attic insulation missing or inadequate	7
Duct leaks, incomplete duct insulation, no duct sealing	6
Water heater insulation improperly installed, tape problems	6
Tune-up & repair-no evidence	5
Kneewalls not insulated, or inadequate insulation	4

Findings by Measure

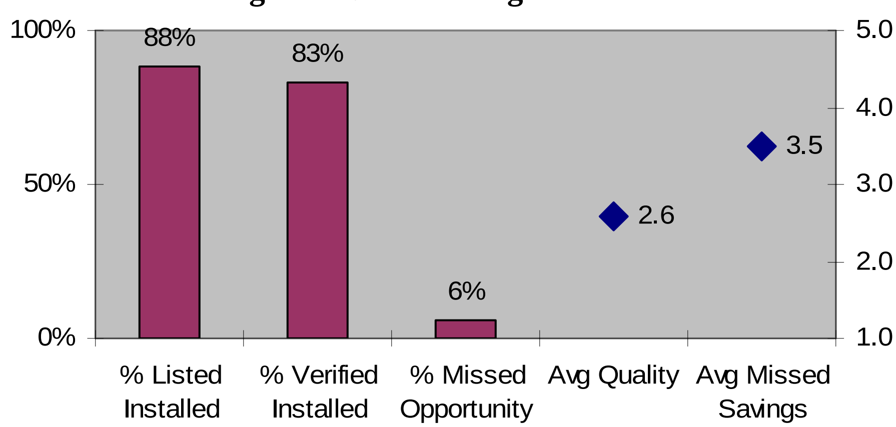
The following sections discuss site visit findings for each measure at these selected poorly performing homes. The measures are discussed in the order listed in Table 23, starting with the measures most commonly installed.

Discussions for each measure include the count of the measures installed and verified, factors that could lead to poor performance, and the ranking for energy savings potential from these factors. The graphs summarize the information for each measure. The values shown for "% Missed Opportunity" are based on our field technicians' estimates of the number of homes that, in their judgment, could have benefited from including the measure even though it was not listed as one of the measures installed in the home through the Program. For each measure, the discussion and quantification are based on the measure as a whole. Comments recorded by the field technician are also provided.

Air Leakage and Blower Door Findings

Figure 23 shows that air leakage measures were listed as installed in 88% of the homes. We were unable to verify that the measures had been installed in about 5% of the homes. On a scale from 1 to 5, the average rating for the air leakage work quality was just average at 2.6. Three (6%) of the homes in our sample were identified as additional homes that could have benefited from air leakage measures. The potential for energy savings in the missed opportunity cases was relatively high, a 3.5 average on a scale from 1 to 5.

Figure 23. Air Leakage Results



The main factor lowering the installation quality score was rim joist problems. Fourteen of the homes were determined to have rim joist sealing problems, usually missed sealing at penetrations. The second most common quality problem was weather stripping; six houses were identified where weather stripping was either incomplete or poorly done. Five of the homes had problems associated with windows and air leakage. The problems included broken windows and poor sealing around windows. Only one house was observed that had duct leakage problems.

Results from the original blower door tests were available for 47 of the 52 homes. We were able to conduct follow-up tests on 40 of these homes to compare leakage rates now with those measured earlier. The follow-up blower door tests were conducted with the home in the same configuration as the original pre and post tests. Where both basement-door-open and basement-door-closed tests were conducted, the door-open results were used to compute the percent change from the original pre-test.

Table 26 shows cases where data were available for both the original and follow-up tests. When the weatherization work was done, the blower door tests showed a 31% reduction in CFM50 on average. In our follow-up tests, blower door results showed, on average, a 21% reduction from the original pre-weatherization result.[36] The Program also establishes leakage reduction targets called OVERALLS; based on our tests, 22 of the 40 homes met these targets when we tested them.

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36 A blower door is used to test how leaky a home is. CFM50 is the airflow, measured in cubic feet per minute, needed to create a change in building pressure at 50 pascals. The larger the CFM50, the more airflow through the building. Leakiness is often computed as the number of air changes per hour. Air changes per hour at 50 pascals is computed as (CFM50 x 60) / building volume in cubic feet.

Table 26. Pre-Weatherization and Post Blower Door Results

Original Blower Door Tests		Follow-up Blower Door Tests		Percent Change in cfm50 from Original Pre Test		OVERALLS
Pre Test cfm50	Post Test cfm50	Basement Door Open cfm50	Basement Door Closed cfm50	Original Pre to Original Post Test	Original Pre to Follow-up Post Test	Does follow-up test meet OVERALLS?
7054	2328	5625	.	-67%	-20%	No
2001	1738	1700	.	-13%	-15%	Yes
3655	2712	3800	.	-26%	4%	No
4090	4106	3600	.	0%	-12%	No
1499	995	2030	.	-34%	35%	Yes
2704	2240	2700	.	-17%	0%	Yes
2066	1921	2000	.	-7%	-3%	Yes
1800	1497	2000	.	-17%	11%	Yes
6930	5441	6900	.	-21%	0%	No
6683	3578	4250	.	-46%	-36%	No
3651	1135	.	3100	-69%	-15%	No
4030	1990	.	2000	-51%	-50%	Yes
1215	1093	.	1250	-10%	3%	Yes
4826	3743	4400	3750	-22%	-9%	No
7012	5183	6400	5800	-26%	-9%	No
5617	2529	2150	2300	-55%	-62%	Yes
3780	2587	.	1920	-32%	-49%	Yes
3122	1893	1950	1830	-39%	-38%	Yes
3038	2226	.	2200	-27%	-28%	No
2450	1907	1650	1575	-22%	-33%	Yes
4480	2980	4600	4200	-33%	3%	No
4829	3076	3800	2900	-36%	-21%	No
4215	3412	2800	2400	-19%	-34%	Yes
1914	1395	1400	.	-27%	-27%	Yes
3009	2610	2000	.	-13%	-34%	Yes
3038	2591	2300	2240	-15%	-24%	No
8125	7231	6500	5500	-11%	-20%	No
2595	1382	2975	1720	-47%	15%	Yes
1990	1555	1600	.	-22%	-20%	Yes
12063	4919	5100	.	-59%	-58%	Yes
3107	2423	2500	2230	-22%	-20%	No
5271	2119	2300	.	-60%	-56%	Yes
3177	2376	2200	.	-25%	-31%	Yes
2635	2311	2300	.	-12%	-13%	Yes
4339	3418	3300	.	-21%	-24%	No
3038	2635	3100	.	-13%	2%	No
3713	2455	2240	2100	-34%	-40%	Yes
5764	2009	6100	5300	-65%	6%	No
9503	5255	6000	5800	-45%	-37%	No
4196	1798	1550	.	-57%	-63%	Yes

To better understand what factors might have contributed to an increase in leakage, we reviewed the technician's comments for the 25 homes where the blower door results degraded. For most of these homes, the comments identified missed air sealing opportunities. In other homes, windows and knee wall hatches were not closing properly. One home had open windows in the conditioned attic and the thermostat was set to 85 degrees. Another home had a hole in the ceiling. The fireplace damper was missing at one home and there was significant leakage around the glass doors. At other homes where the blower door readings degraded there were no apparent explanations; the work was done well, or there was minimal work to do.

Table 27 shows the percent reduction in 10% ranges of the blower door results from the pre-weatherization to the post weatherization periods. The "Original" column refers to the change in the blower door reading just after weatherization work was done on the home. The "Follow-Up" column refers to the measurements during our site visits and shows the change from the pre-weatherization result to the follow-up site visit result. The data suggest overall that the leakage in the homes had gradually increased since the original tests were done after weatherization. The table includes all homes with both the original and follow-up test results.

Table 27. Original and Follow-Up Blower Door Results

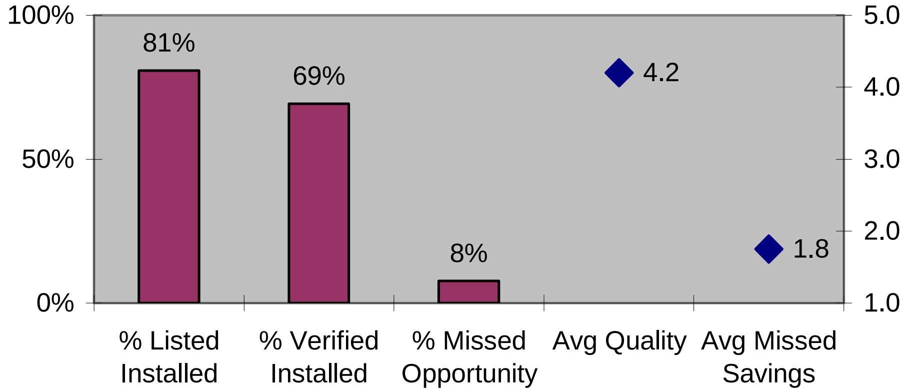
Reduction in CFM50 Reading	Original	Follow-Up
<=10%	3	10
>10% and <=20%	10	6
> 20 and <= 30%	11	7
> 30 and <= 40%	6	8
> 40 and <= 50%	3	5
> 50 and <= 60%	5	4
> 60 and <= 70%	3	1
Total	*41*	*41*

Water Heater Insulation Findings

Figure 24 shows that 81% of the homes in our sample were listed as having had water heater insulation installed. We verified water heater insulation was present in 69% of the homes. The average quality of the work was rated quite high at 4.2 on the 5-point scale. An additional 8% of the homes were determined to have missed opportunities in water heater insulation, but the likely energy savings were considered to be relatively small.

A small number of wrapped water heaters exhibited problems with the tape holding the blanket coming off either partially or completely. Only part of the water heater was wrapped in other installations. In a couple of homes, the technicians noted that the water pipes were wrapped as well.

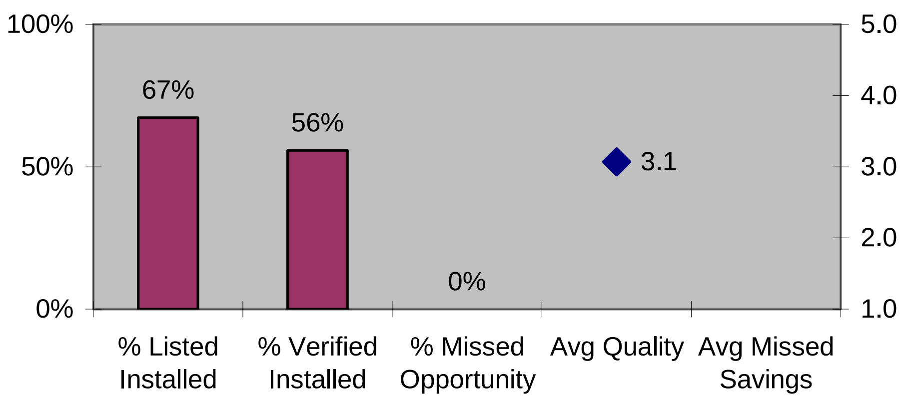
Figure 24. Water Heater Insulation Results



Tune Up and Repairs

Figure 25 shows that 67% of the sample homes (35) were reported to have tune ups or repairs done to the heating system. We verified that procedures were completed in 56% of the sample (29 homes). Where the tune up or repair could not be verified, the field technician noted there was no evidence of work being done. Where the procedure could be verified, the average quality of the work was rated 3.1 on a scale of 1 to 5. In one case the field technician recorded health and safety concerns noting the existing chimney needed modification. There were no missed opportunities identified.

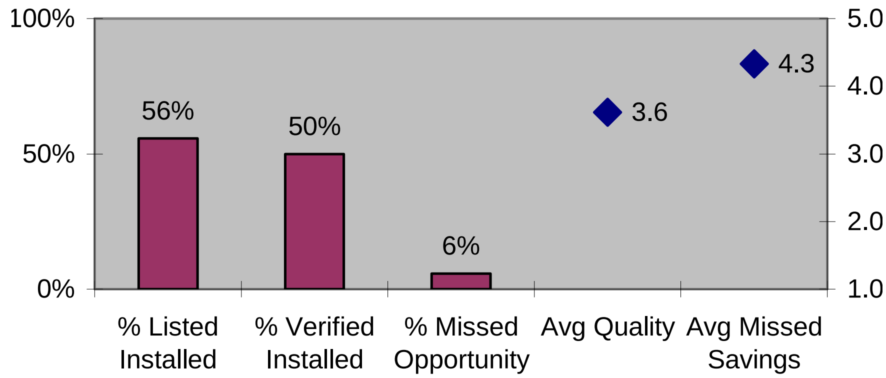
Figure 25. Tune Up and Repair Procedures Results



Attic Procedures Findings

A little over half (56%) the homes we visited were listed as having attic measures (basically ceiling insulation) installed. As shown in Figure 26, we were able to verify that exactly half the homes had ceiling insulation installed. The average quality of the work was a little above average. We found an additional 6% that, in our technicians' judgment, could have benefited from ceiling insulation. The energy savings potential was considered to be relatively high (4.3 on a 5-point scale).

Figure 26. Attic Procedures Results

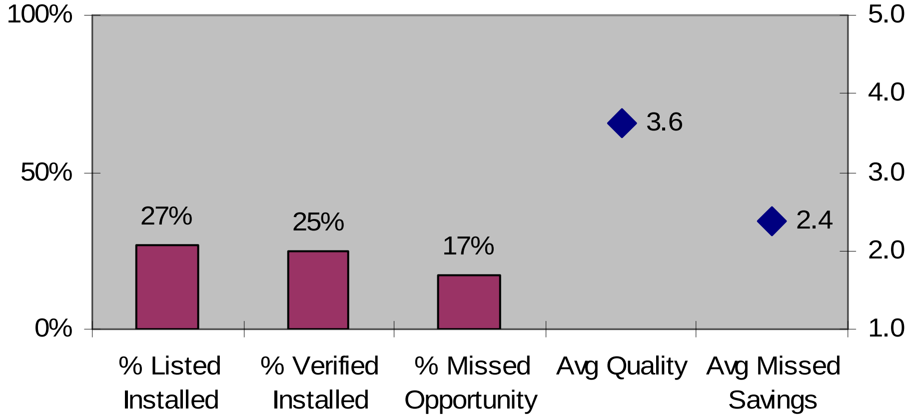


Although most of the field technician's comments about the quality of the attic work were positive, there were a few problems identified. There was no pattern to the defects observed. In one case, knee walls were not insulated. In another, the insulation was observed to not be uniform in the attic. There were a couple cases with poor overall work quality. In one case of especially shoddy work, the crew blew insulation about 4 to 6 inches above the floor without moving anything and put holes in the knee walls and did not repair them. One homeowner reported that they had refused to let the workers insulate the attic since the installers had left a big mess from their other work. In some cases, the weather stripping was not adequately installed around access hatches.

Sidewall Procedures Findings

Figure 27 shows that about one-fourth of our sample homes were reported to have sidewall measures. As noted earlier, sidewall insulation was observed with an infrared camera. The objective was to identify voids, and not to determine the density of the insulation installed. We verified installation in all but one of the cases. The one exception was a home with solid brick walls where wall insulation was impossible, and there was no evidence of rim joist insulation. Overall, the quality of the sidewall work was rated to be above average. In 17% of the homes, our field technician identified sidewall missed opportunities. The average estimated energy savings benefits associated with these potential missed opportunities were ranked relatively low, however, at 2.4 on the 5-point scale.

Figure 27. Sidewall Procedures Results

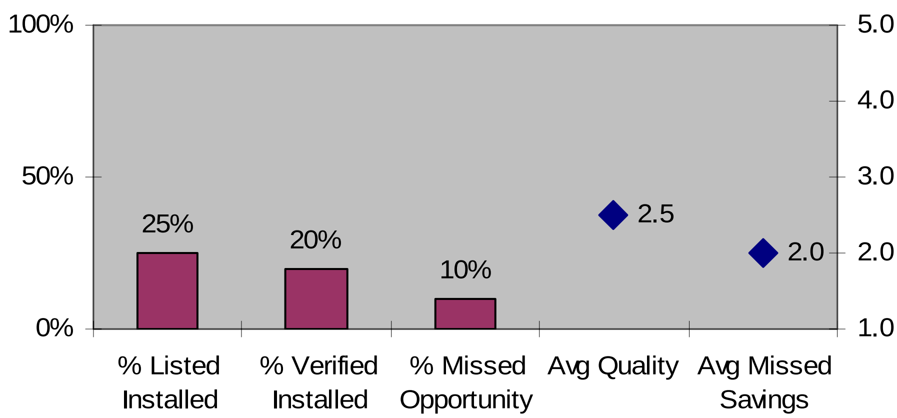


Although the sidewall procedures work received above average quality ratings, we identified specific defects in 5 of the 13 homes with wall insulation added. Our technicians used an infrared camera to identify voids in the insulation. Two had gaps near windows and the others had voids in a variety of locations, including, for example, the upper portion of a second floor wall.

Duct Insulation and Duct Sealing Findings

As shown in Figure 28, 25% (13) of the homes in our sample were reported to have duct insulation installed. Duct insulation was verified in 20% of the homes; we were unable to verify installation in three homes. Overall the average rating for the quality of the work was only 2.5 on the 5-point scale. An additional 10% of the homes were identified as having missed opportunities for installing duct insulation. We estimated that for those cases where duct insulation was a missed opportunity the probable savings from the measure were relatively low - an average of 2.0 on the 5-point scale.

Figure 28. Duct Insulation Results



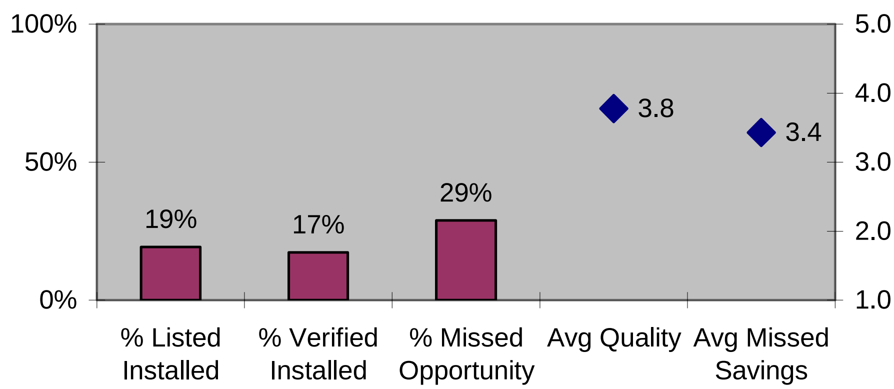
The main problem with duct insulation was incomplete work. For example, one home had the ducts in the attic insulated, but those in the crawlspace were not. The field technicians did not conduct duct leakage tests, but reported three cases where there was no duct sealing observed at all.

Heating System Findings

As noted in the earlier discussion about energy savings in this report, heating system replacements were much more likely among the high energy savers than the low savers. In our sample of low savers, 19% were listed as having heating system work done including replacements, as shown in Figure 29. We verified that 17% had heating system work completed. The average quality of the work received a high rating of 3.8 on the 5-point scale. We identified an additional 29% of the homes that, in our field technicians' judgment, could have benefited from heating system work and estimated that the savings from this measure would have been relatively high, 3.4 on the 5-point scale.

Most of the cases identified where our field technicians observed that there were missed opportunities with the heating system were homes with very old and inefficient heating systems. One was described as "an old floor unit to heat the entire house" and another was described in the field notes as follows: "Ancient gravity furnace. No blower." The remaining missed opportunities were cases where replacing the existing standard-efficiency furnace with a high-efficiency unit would have been justified in the opinion of the technician who conducted the on-site verification.

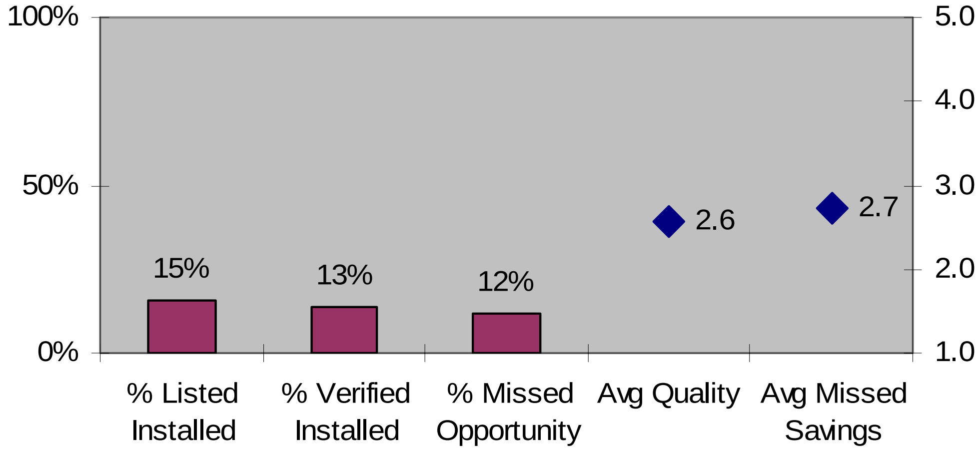
Figure 29. Heating System Work Results



Floor Procedures Findings

Figure 30 shows that floor procedures (typically insulation) were listed as installed in 15% of our sample homes. We were able to verify the procedures in all but one home. Overall, the quality of the work was below average. An additional 12% of the homes were identified as missed opportunities that could have benefited from application of floor insulation procedures. For example, our technician observed an uninsulated crawlspace and uninsulated cantilevered floors in some cases.

Figure 30. Floor Procedures Results

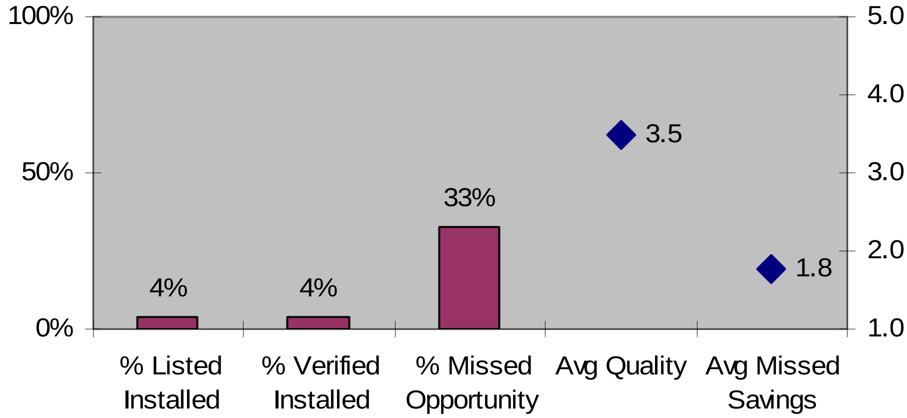


Most of the houses had one or more defects in the floor insulation. Most common was insulation that was not installed over the entire floor area, often because of accessibility problems. In one house with a basement, our field technician felt that the basement was not really part of the conditioned space and should have been insulated. In another case, R-11 batts were installed when R-19 would have been justified. In addition, the batts were installed incorrectly.

Secondary Window Procedures Findings

As Figure 31 shows, only 4% (2) of the homes in our sample were listed as having secondary window procedures and we verified these during the site visits. Secondary window procedures include repairs to broken windows or installation of storm windows on single-pane windows. The verified installations received relatively high quality ratings. The field technicians noted that they believed an additional 17 sites (33%) would have benefited from secondary window procedures. Comments typically said that the existing windows in these cases were single-pane wood framed windows. As noted previously, however, replacement of a window just because it was single-paned was not a qualified measure under the Program. Average missed savings for window missed opportunities were ranked low at 1.8 on a scale of 1 to 5.

Figure 31. Secondary Window Procedures Results

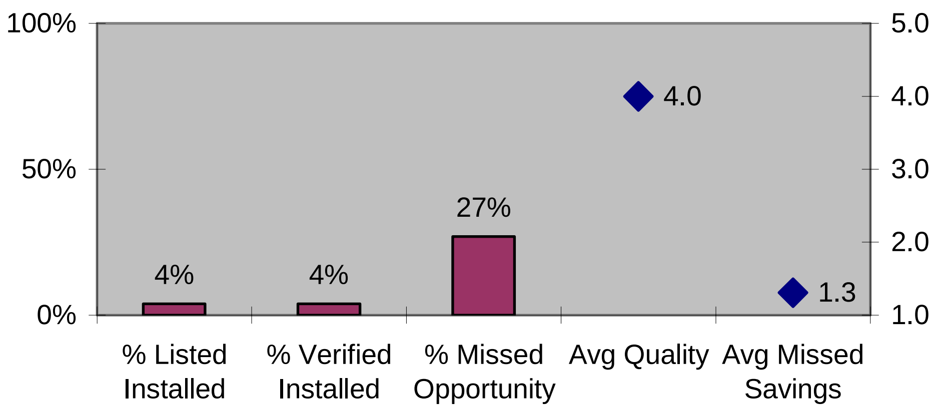


Replacement Door Findings

As shown in Figure 32, door replacements occurred in only 4% (2) of the houses in our sample. The work was considered to be of relatively high quality. Replacement doors rarely qualify for replacement in the Program; however, we identified another 27% of the homes that could have benefited from replacement doors based on our field technicians' observations. The likely energy savings from replacement doors were relatively small.

The missed opportunities were mostly doors that were very old, in poor condition, and leaky. In two cases, repairs had been made to the doors, but the repairs were inadequate.

Figure 32. Replacement Door Results

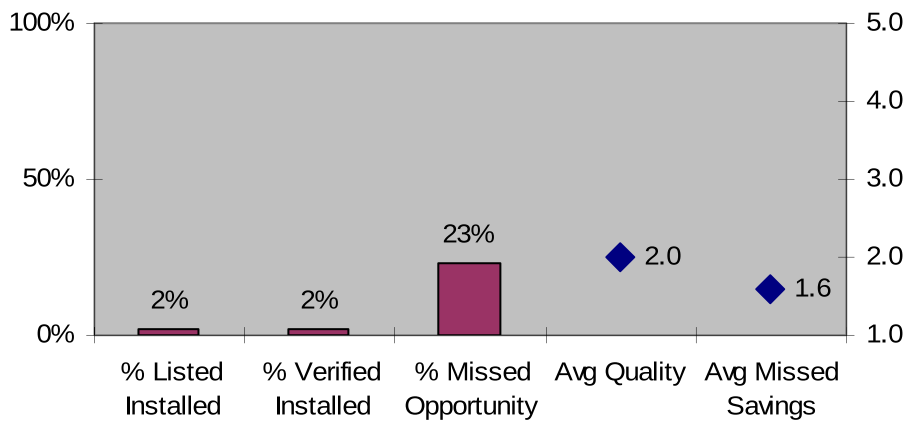


Replacement Sash Window

As noted earlier, when the prime window is intact, window replacements are not an allowable measure under HWAP. The Program permits replacements only where window sashes cannot be repaired or are missing. For the homes in our sample, one window sash was listed as replaced and our technician verified the installation. However, the field technicians identified 12 additional sites where windows were in poor condition and they believed a case could have been made for replacing them. Of course, the condition of these windows could have deteriorated since weatherization had occurred; for purposes of our study, however, it was important to identify these cases as possible contributors to poor energy performance.

The site visit results are shown in Figure 33. The 12 cases are shown as potential missed opportunities, comprising 23% of our sample. Despite the large number of such cases, the technicians rated the energy savings potential to be quite small (1.6 on the 5-point scale). The quality of the one window replacement was given a low rating.

Figure 33. Replacement Sash Window Results



10. Comparison to Other Low Income Weatherization Programs

This chapter summarizes HWAP results and compares them to similar programs in terms of energy savings and cost effectiveness.

Gas Savings

Table 28 presents findings from other WAP evaluations from around the United States for gas-heated, single-family homes.[37] The table shows that the results from this evaluation compare favorably to similar studies and that half of the programs with higher savings also had higher pre-use, which will tend to drive up savings.

Table 28. National WAP Gas Savings Results, Single-Family Homes

Study	Year	# Units Analyzed	Pre-Use (therms)	Savings (therms)	% Savings
Current Evaluation	2003	1,825	1,290	268	21%
National	1989	3,873	1,334	173	13%
Oak Ridge National Meta Evaluation	1993-2003	n/a	1,330	305	23%
Colorado	1994	3,431	1,230	185	15%
Illinois	2003	2,056	1,551	198	13%
Iowa	2004	633	1,194	295	25%
Kansas	1993	165	1,283	191	15%
North Dakota	1992	182	1,200	160	13%
Ohio	1994	2,209	1,395	324	23%
Vermont	1998-2000	25	1,116	145	13%
Washington	1997	71	852	230	27%
Wisconsin	2001-2003	8,252	1040	156	15%

Figure 34 and Figure 35 provide graphical representations of percent net savings and absolute net savings, respectively. These figures show again that Ohio has one of the most successful programs in the nation in terms of energy savings. Due to the recent rise in gas rates, the best comparisons are likely with the most recent studies, namely Iowa, Wisconsin (2001-2003), and Illinois.

The results of this evaluation are also close to the national meta evaluation estimates of 23% savings and 305 therms saved.

37 Most of the values shown are from a presentation by Michael Blasnik at the U.S. DOE National Weatherization Conference in Atlanta, Georgia, December 12-16, 2005.

Figure 34. Comparison of Gas Percent Savings in Current Evaluation to Other Programs

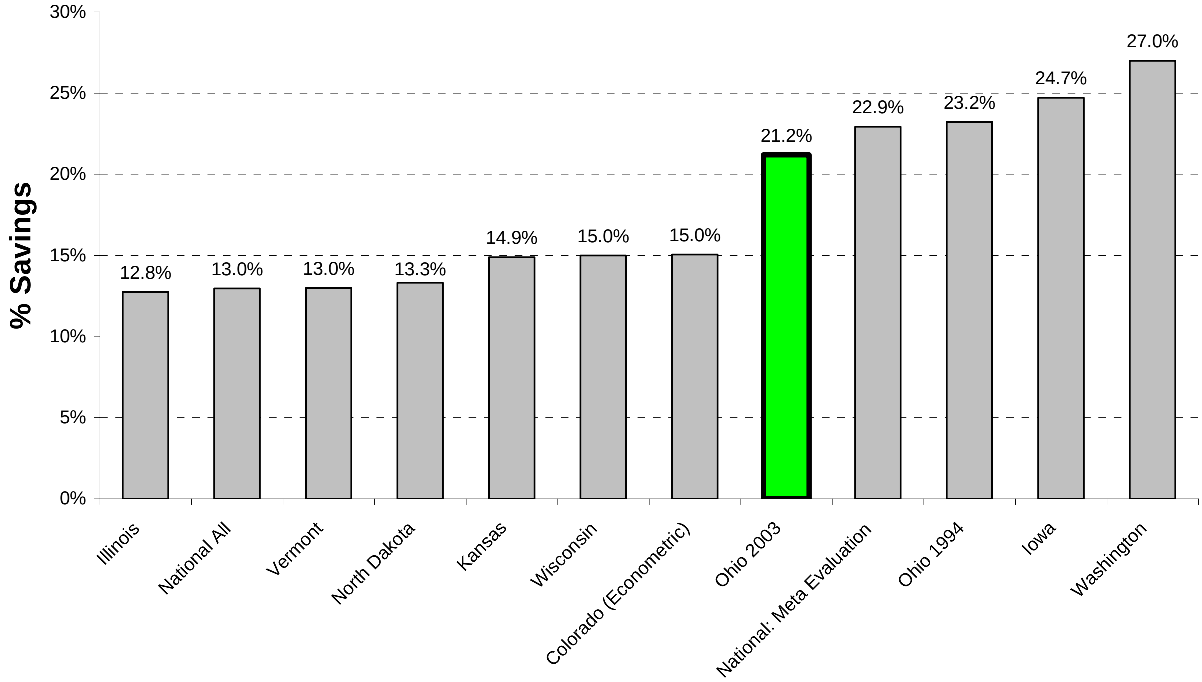
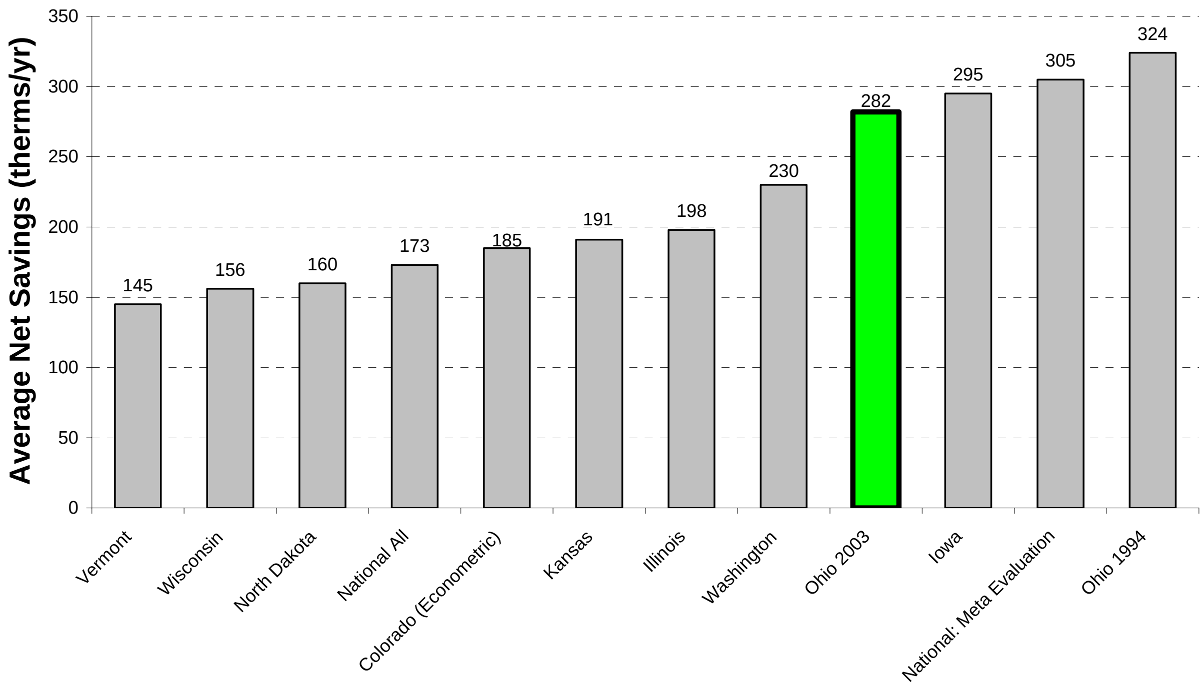


Figure 35. Comparison of Gas Net Savings in Current Evaluation with Other Programs



Electricity Savings

Table 29 summarizes total electric heat savings results from this evaluation as well as similar programs. Single-family homes with electric heat saved 1,473 kWh or 7% of pre in the current evaluation. Based on previous evaluations, the Ohio PY03 weatherization program single-family electric savings (electrically heated) are lower than other evaluations both in terms of net percent savings (Figure 36) and absolute net savings (Figure 37). However, the 7% percent savings estimate is relatively close to the 9% estimated in the HWAP PY94 evaluation.

Table 29. Comparison of Electric Savings Results

Study	Year	# Units	Pre-Use (kWh)	Savings (kWh)	% Savings
Current Evaluation	2003	213	22,282	1,473	6.6%
National	1989	426	14,972	1,830	12.2%
Oak Ridge National Meta Evaluation	1993-2003	n/a	19,919	2,153	10.8%
Ohio	1994	150	21,542	2,002	9.3%

The estimates from our evaluation, are also lower than the National WAP Evaluation with an estimate of 11% savings and 2,153 kWh saved. The savings are lower in magnitude than the 1,830 kWh estimated in the National Meta Evaluation conducted by Oak Ridge National Laboratory study.

Figure 36. Comparison of Electric Percent Savings in Current Evaluation with Other Programs

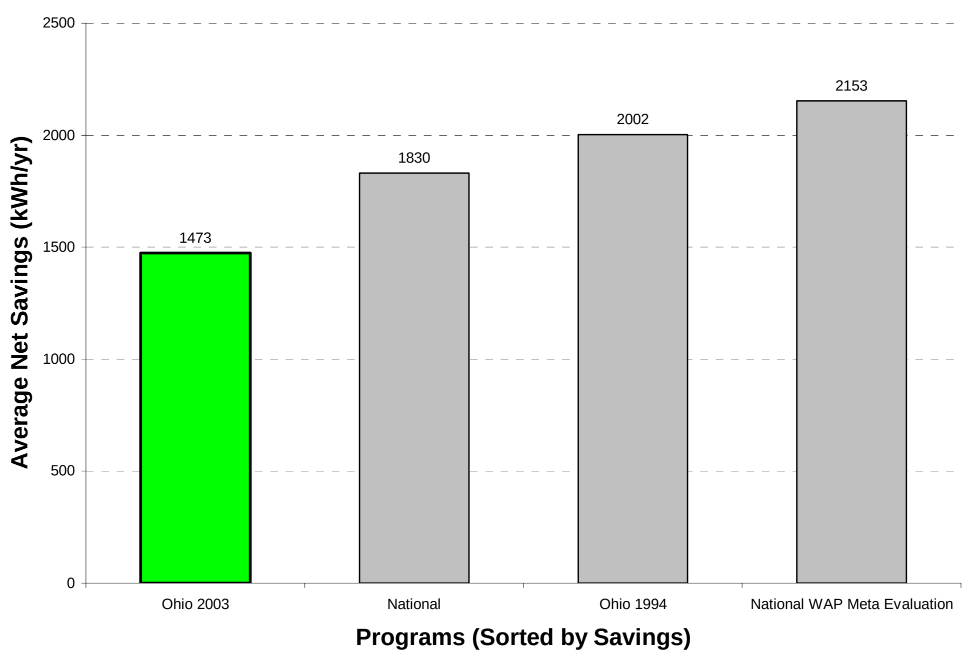
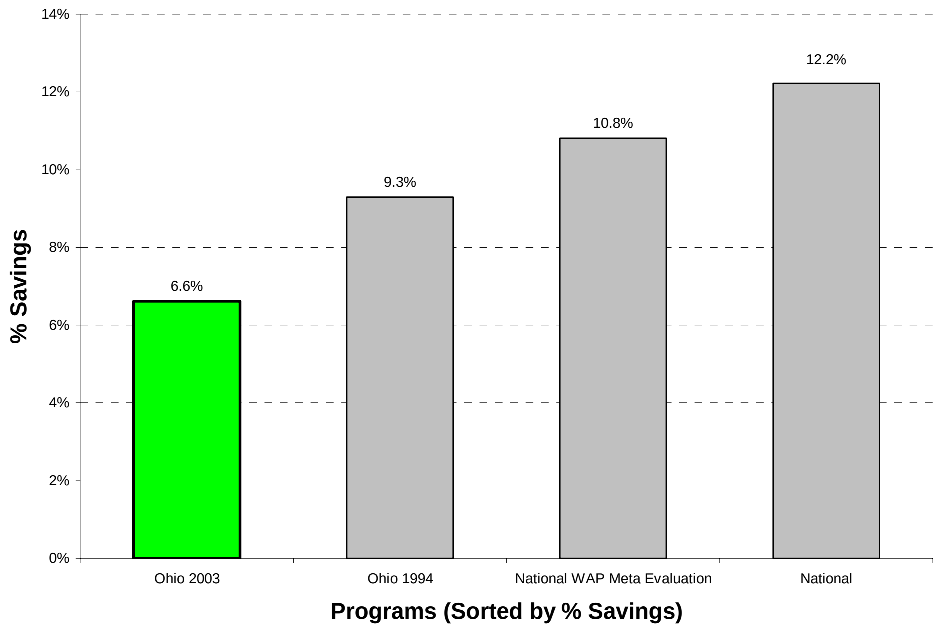


Figure 37. Comparison of Electric Net Savings in Current Evaluation with Other Programs



Cost Effectiveness

As described in Chapter 8, cost effectiveness was computed from several different perspectives. Results for single-family gas-heated homes are compared to similar programs in Table 30. This evaluation compares very favorably to the other studies, particularly from the program perspective. The benefit-cost ratios are higher for the current Program than the estimates from the 1994 evaluation based on both tests. From the societal perspective, the current evaluation produced a lower benefit-cost ratio than the national meta evaluation. The current Ohio evaluation showed both higher Program costs per home and larger energy benefits than the national study.

Table 30. Comparison of Cost Effectiveness Results for Gas-Heated Single-Family Homes

Program	Year	Program Perspective	Societal Perspective
Current Evaluation	2003	1.10	1.87
Oak Ridge National Meta Evaluation	1993-2003	1.30	2.70
Ohio	1994	0.88	0.90*
Washington	1997	0.74	1.20

* Includes only energy and disconnection benefits.

11. Recommendations

As a result of the findings presented in earlier chapters of this report, recommendations were generated with regard to the questions posed in the RFP. These recommendations are intended to provide a guide to OEE on potential Program improvements to maximize the impact of HWAP dollars.

Obtaining Applicant Energy Histories

Many studies have shown (including this one) that pre-consumption is the biggest factor in energy savings potential through weatherization. In light of this, it would be worthwhile for OEE to acquire applicant energy usage histories and group them based on pre-consumption with the highest consumers being the top priority.

This would require some extra work on the part of OEE to contact utilities, but Quantec was able to obtain a very high percentage of requested records from utilities, and the Ohio Department of Development already tracks energy consumption for PIPP participants on HEAP.

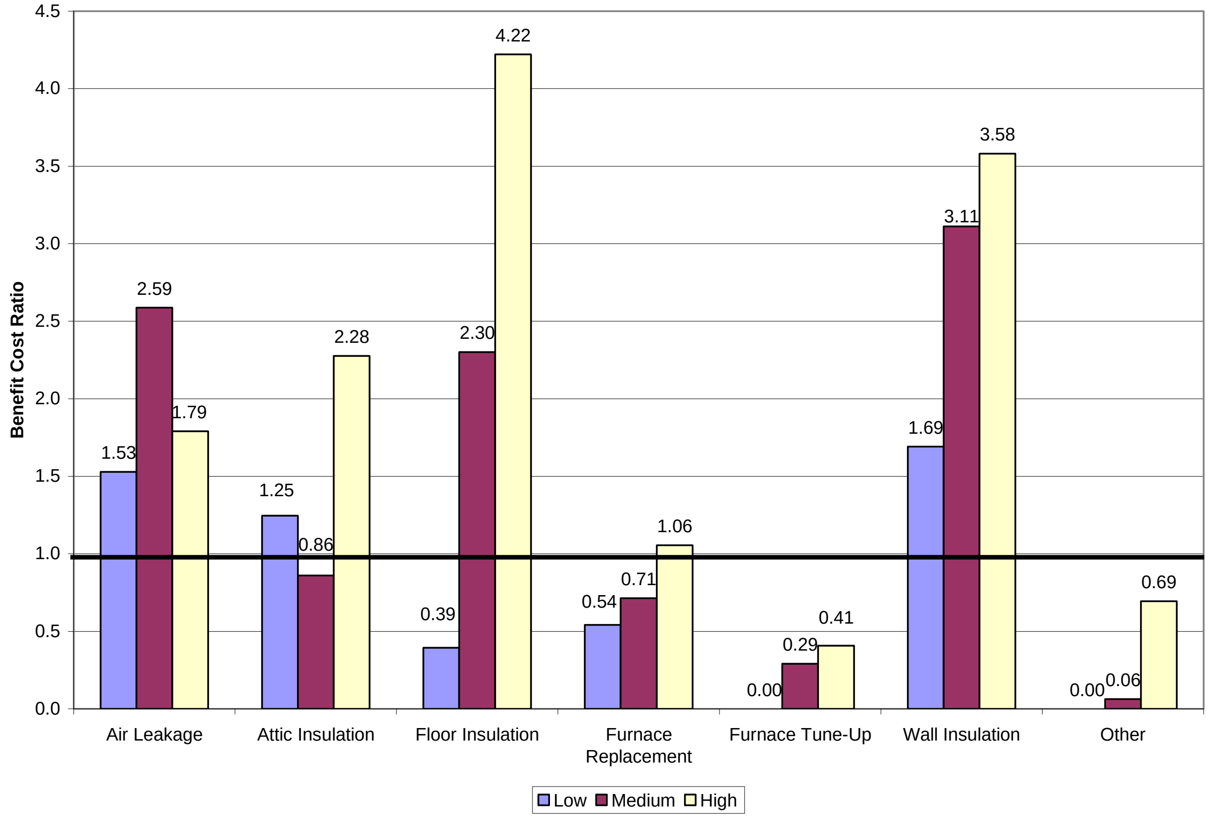
In addition, OEE might consider proactively seeking utility data for low-income families and using this information to let agencies know which homes to target to maximize energy savings through weatherization. The mechanism and implications of doing this should be investigated further.

Measure Installation Based on Pre-Consumption

Figure 38 (also presented in Chapter 8) displays the measure-level cost effectiveness by pre-consumption for single-family gas homes and provides a guide for determining which measures should be installed once billing histories are obtained. All measures, except furnace tune-up, are worth installing in high-usage houses when deemed necessary, however, fewer measures are cost effective for medium- and low-consumption homes. Furnace replacement, tune-up, and other measures (water heater and duct insulation) were not found to be cost effective for medium consumption homes and only air leakage reduction and wall and attic insulation were found to be cost effective for low consumers. By following this guide to measure installation, OEE should be able to maximize energy saved per dollar spent.[38]

[38] Please note that the results for attic insulation in medium-usage homes did not appear to be consistent with the observed trends in the benefit-cost ratio. The low benefit-cost ratio resulted from the relatively low savings estimated for this measure in medium-usage homes. We thoroughly reviewed these values and reestimated them using different samples, but the results did not change. Although they appeared to be stable, we do not believe they provide sufficient evidence to question the cost effectiveness of attic insulation in medium-usage homes.

Figure 38. Measure-Level Cost Effectiveness



Combo Job Tracking

It is currently extremely difficult to determine if a weatherization job received money jointly from HWAP and a utility. Data must be received from both OEE and the given utility and then merged together based on home data (account number, social security number, etc.). Altering the BWR to include either a "combo job" checkbox or a field to capture the utility name would allow for much easier tracking of these jobs. This information could be stored in the OATS database and would be readily available to compare joint weatherization to HWAP-only weatherization.

Labor Cost Tracking

In order for an accurate calculation of measure cost effectiveness, the full cost of a measure's installation must be tracked. Currently, the BWR records material costs by measure, but all labor costs are combined. In this evaluation, a regression was required to estimate labor costs by installed measure, but this estimation could be avoided with measure-level labor cost tracking.

Appendix A: GIS Data by County

In an effort to provide a new perspective on HWAP, Quantec utilized ArcGIS, a geographic information systems (GIS) mapping program. Using GIS, it is possible to assess the spatial relationships of HWAP elements such as eligibility, participation, and Agency location. Specifically, this aspect of the evaluation sought to understand where the need for HWAP services is greatest, what percentage of those eligible have been served, and how the Program Agency locations and service territories spatially relate to areas exhibiting high or low levels of saturation. This section offers a series of county-level maps exploring these relationships, as well as a brief analysis of the findings and suggestions for the future application of GIS.

Data

To develop maps, data from the following sources were utilized:

- ***OATS Database***: The Program database provided historical data used to map participation by county.
- ***2000 United States Census***: The Census was utilized to access county-level population, income, and poverty information.
- ***GIS Data:*** These data provided geographical information for the state of Ohio, including its counties, and cities.

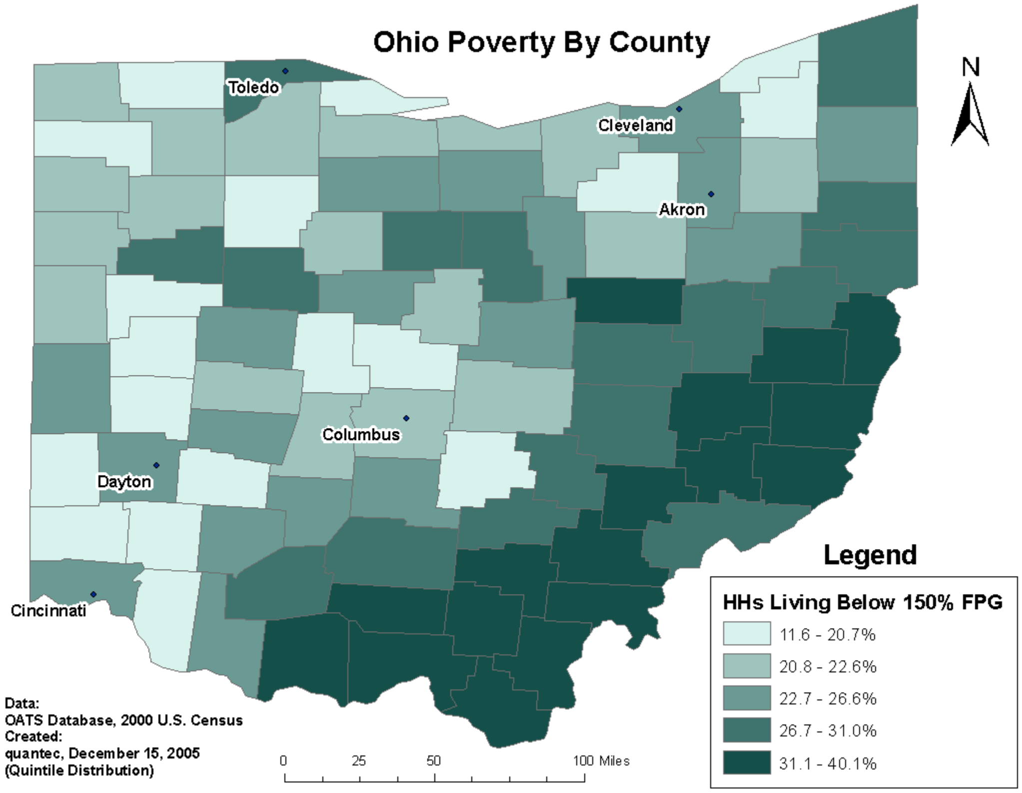
Methodology

To calculate the percentage of eligible households HWAP has served to date, it was necessary to first determine the number of households in each county that meet the Program's income eligibility requirements. While the 2000 United States Census identified the number of households living at or below 100% of the Federal Poverty Guideline (FPG), precise Census data are not available regarding the severity of household poverty at the Program's eligibility threshold of 150%. To overcome this, Quantec utilized other Census data available on the distribution of households by income stratum and average household size, to extrapolate the number of households at 150% of the FPG for each county.

Results

Map 1, which presents the percentage of total households in each county meeting the Program's income eligibility standards, provides an overview of how poverty differs across the state. As evident in the map, the percentage of eligible households ranges dramatically by county, with a low of 11.6% in Delaware County and a high of 40.1% in Athens County. Generally, the highest percentages of Program-eligible households were exhibited in the Appalachian counties of southeastern Ohio. In addition, with the exception of Franklin County, each of the counties containing larger metropolitan cities have Program eligibility rates exceeding 22.7%. A table providing the precise eligibility rate for each county is provided at the end of this appendix.

Map 1. Percent of Households Eligible for HWAP by County



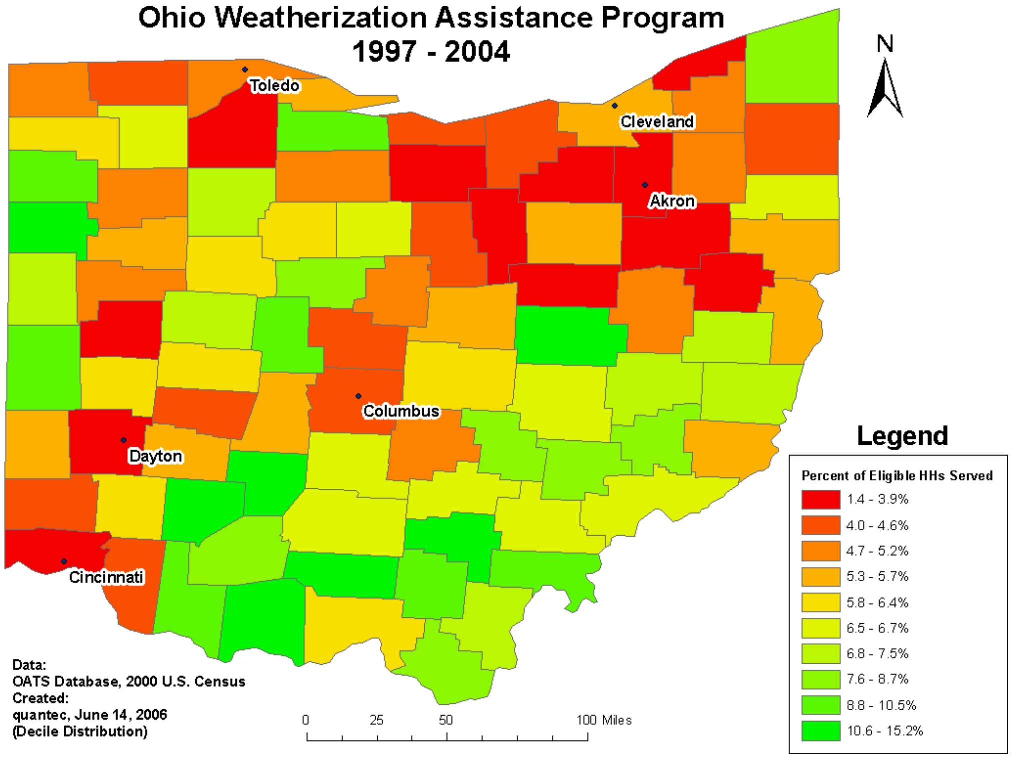
By combining the findings presented in Map 1 and data from OATS regarding participation from 1997 to 2004, it is possible to determine the percent of Program-eligible households served by HWAP during this eight year period. Since valid data regarding their county of residence were not available for 17% of the participants in the OATS database, participants without county data were assigned to a county based on their Agency's distribution of weatherization jobs by county. Assuming the occurrence of missing data is equally distributed across counties at the Agency level, this approach accounts for data deficiencies and calibrates the findings to represent the actual level of service in each county. The results of this analysis are provided in Map 2.

Similar to Map 1, the percentage of eligible households served differs greatly by county, ranging from 1.5% to 15.2%. To highlight this variation, Map 2 indicates counties exhibiting low percentages of households served with warmer colors, such as red, orange, and yellow, and those that have reached a greater percentage of such households with cooler colors, such as yellow and green. Utilizing this color approach allows for quick identification of activity in each county and also provides insight into the severity of the issue.

Generally, it appears that HWAP has been more successful reaching higher percentages of eligible households in the state's rural counties. While this makes intuitive sense since those counties have fewer eligible households, they are also more geographically dispersed. The Program's success in such counties constitutes a clear effort to reach the rural poor. Conversely, there remains a higher percentage of un-served eligible households in more populated counties.

In particular, there appears to be a cluster of counties in the northeast portion of the state that exhibit lower levels of Program saturation. Similar to eligibility by county, a table providing the exact percentage of eligible households served in each county is provided at the end of this appendix.

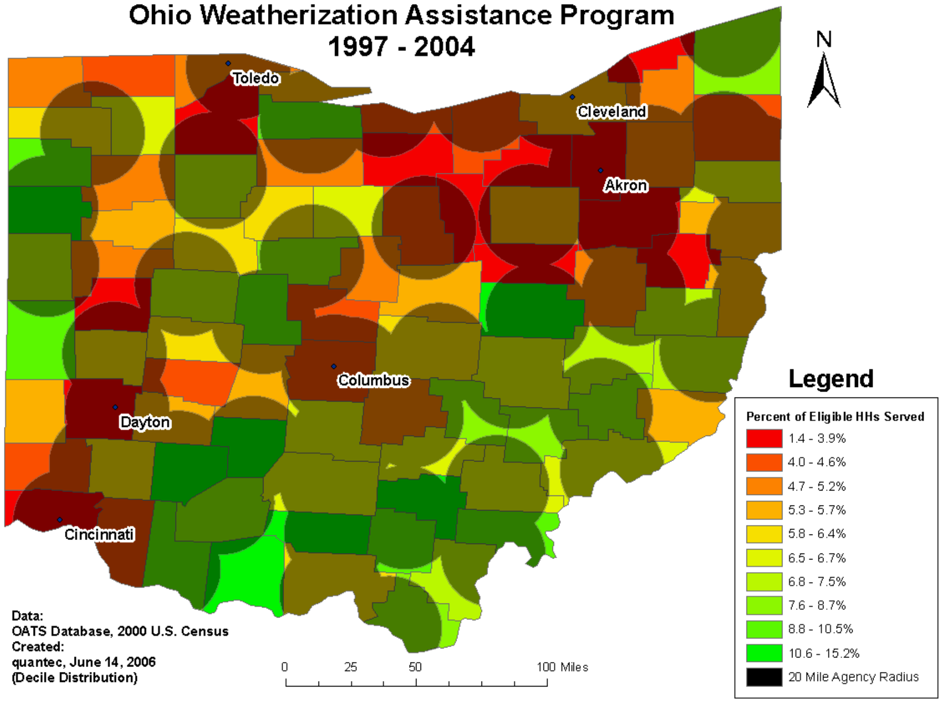
Map 2. Program Saturation (1997-2004) by County



To assess how levels of Program saturation relate to Agency location, each of the participating agencies were added to Map 2. Once located, a 20-mile radius was generated around each Agency to simulate that Agency's approximate service territory. Aggregating each of the Agency radii yields an estimated assessment of the portion of the state within 20 miles of a participating Agency. The aggregated radii can be geographically placed on top of Map 2. It should be noted that metropolitan areas with multiple agencies within 20 miles will produce overlapping radii.

Overall, as seen in Map 3, the resulting Agency radii clearly cover a significant portion of the state. While there appear to be few areas of low Program saturation not within 20 miles of an Agency, there are also several areas outside the same range that are well-served.

Map 3. Program Saturation (1997-2004) and Approximated Agency Coverage



Potential Future Applications

As demonstrated, GIS offers a new perspective from which to assess this Program. GIS has many possible applications for program evaluation. The following is a brief list of possible uses for this tool in evaluating HWAP:

- Investigate Program saturation and Agency coverage at a smaller scale in metropolitan areas, utilizing geo-coding (block group or census tract level)
- Collect any additional historic Program data not included in the OATS database, and determine overall Program saturation
- Geographically represent other Program attributes, such as funding allocations, participant types, and weatherization measures received
- Calculate the number of eligible homes within a specific distance of agencies
- Utilize Agency-specific radii for the creation of a more accurate assessment of Program reach
- Use maps to replace large, cumbersome tables for reporting and presentation, where appropriate

Table A.1. County Data

County	Percentage of Total Households Eligible for HWAP	Percentage of Eligible Households Served
Adams	38.1%	12.5%
Allen	28.1%	5.3%
Ashland	24.7%	3.0%
Ashtabula	28.9%	8.7%
Athens	40.1%	6.7%
Auglaize	20.6%	4.8%
Belmont	35.8%	7.2%
Brown	26.6%	9.9%
Butler	19.7%	4.6%
Carroll	29.1%	3.7%
Champaign	21.7%	6.4%
Clark	24.6%	4.4%
Clermont	18.6%	4.3%
Clinton	23.6%	15.2%
Columbiana	30.5%	5.6%
Coshocton	28.8%	15.0%
Crawford	27.4%	6.6%
Cuyahoga	26.7%	5.7%
Darke	25.0%	9.0%
Defiance	19.7%	6.1%
Delaware	11.6%	4.6%
Erie	22.4%	4.5%
Fairfield	18.6%	5.0%
Fayette	25.3%	12.8%
Franklin	22.2%	4.4%
Fulton	18.5%	4.0%
Gallia	36.8%	7.3%
Geauga	13.4%	5.2%
Greene	19.5%	5.6%
Guernsey	35.4%	7.5%
Hamilton	25.1%	3.9%
Hancock	20.6%	6.9%
Hardin	30.6%	6.1%
Harrison	33.8%	7.4%
Henry	21.0%	6.7%
Highland	30.3%	8.4%
Hocking	31.0%	6.7%
Holmes	37.7%	3.9%
Huron	23.4%	3.1%
Jackson	35.8%	9.8%
Jefferson	33.8%	5.7%
Knox	25.8%	5.3%
Lake	17.0%	1.4%
Lawrence	38.1%	8.3%
Licking	21.6%	6.1%

County	Percentage of Total Households Eligible for HWAP	Percentage of Eligible Households Served
Logan	23.4%	7.4%
Lorain	21.8%	4.0%
Lucas	27.9%	4.7%
Madison	20.8%	5.4%
Mahoning	30.1%	6.7%
Marion	25.4%	8.0%
Medina	14.4%	3.1%
Meigs	39.9%	10.5%
Mercer	22.0%	6.8%
Miami	20.8%	6.4%
Monroe	34.6%	5.7%
Montgomery	24.5%	3.9%
Morgan	38.3%	8.1%
Morrow	22.5%	5.2%
Muskingum	29.6%	6.5%
Noble	33.0%	8.7%
Ottawa	19.8%	5.7%
Paulding	22.6%	8.8%
Perry	30.1%	8.4%
Pickaway	23.2%	6.5%
Pike	35.7%	10.9%
Portage	21.7%	5.1%
Preble	20.7%	5.5%
Putnam	20.8%	4.8%
Richland	26.9%	4.6%
Ross	28.3%	6.6%
Sandusky	22.3%	9.7%
Scioto	38.8%	6.4%
Seneca	25.4%	4.7%
Shelby	19.9%	2.9%
Stark	24.6%	3.3%
Summit	23.5%	3.9%
Trumbull	26.2%	4.3%
Tuscarawas	27.6%	5.0%
Union	16.9%	9.0%
Van Wert	21.3%	10.8%
Vinton	37.2%	11.2%
Warren	13.7%	6.0%
Washington	29.5%	6.5%
Wayne	22.5%	5.3%
Williams	22.2%	5.2%
Wood	22.0%	3.8%
Wyandot	22.5%	5.8%

Appendix B: Methodology Details

The billing analysis methodology included the following steps:

A. Collect participant and non-participant billing data from utilities
B. Clean & prepare billing data & weather data
C. Establish pre and post periods
D. Weather-normalize consumption and aggregate to annual level
E. Select non-participant group by utility
F. Compare participants to non-participants to calculate Program savings

Each of these steps is described in more detail below.

A. Collect Participant and Non-Participant Billing Data from Utilities

For the gas analysis, data were received from Dominion, Columbia Gas, Vectren, and Cincinnati Gas & Electric (Cinergy). These utilities represented 98% of the gas billing data from the utilities. Figure B.1 summarizes the distribution of gas-heated homes.

Figure B.1. Distribution of Gas Utilities for Gas-Heated Homes

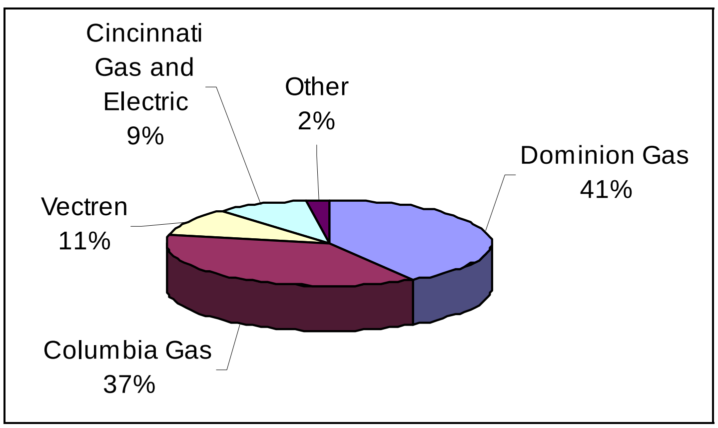


Figure B.2 summarizes the distribution of electrically heated homes by electric utility. For the electric (electrically heated) analysis, data was received from AEP and Cincinnati Gas & Electric (Cinergy). The electric analysis was performed using the AEP customers, since this utility was the only one that had sufficient non-participants for non-participant selection. AEP represents 74% of the electric billing data for electrically heated homes from the utilities.

Figure B.2. Distribution of Electric Utilities for Electrically-Heated Homes

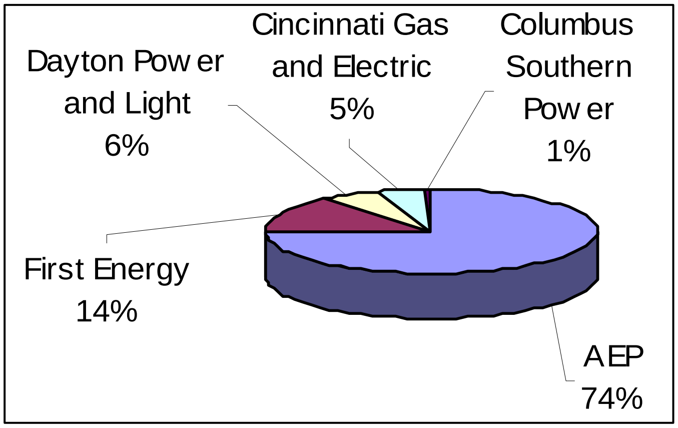
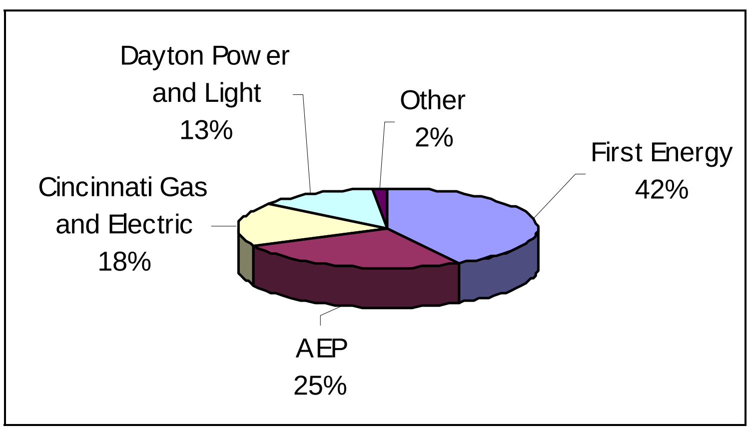


Figure B.3 summarizes the distribution of participating gas-heated homes by electric utility. For the electric (gas-heated) analysis, we received data from AEP and Cinergy. These two utilities represent only 33% of the gas-heated accounts. The analysis was, however, augmented with HEAP billing data for PIPP participants for First Energy and Dayton Power & Light. This allowed a 36% matching rate for Dayton and First Energy (i.e. 1,000 accounts out of 2,779 accounts requested). [39]

Overall, electric billing data was available for 53% of gas heat accounts. Even with the small percentage there are plenty of sites available for the analysis since natural gas heating is predominant - representing about 80% of electric accounts.

Figure B.3. Distribution of Electric Utilities for Gas-Heated Homes



[39] The savings for this group was similar to the AEP/Cinergy savings.

B. Clean and Prepare Billing Data

This is one of the most complex tasks of the billing analysis. It involves examining the billing data, cleaning the data, imputing missing readings, examining vacancies, and estimating readings.

The tasks below summarize typical data cleaning methods that were employed.

1. Plot usages by account to find unusual readings
2. Check for estimated readings
3. Impute missing readings
4. Check for vacancies
5. Check for disconnections
6. Test for completeness of billing data

In Test 1, the average daily consumption is plotted against time at the monthly level. If there are outliers, missing readings (Test 3), prolonged vacant periods (Test 4), or periods of disconnections (Test 5) then this check will find these readings.

Test 2 is a check of estimated readings. Sometimes a reading will be classified as an estimated reading. These will usually cause a spike in usage relating to the estimated reading, after which the subsequent reading may either be too low or too high. In order to solve this problem, the estimated reading and the reading following were averaged. In effect, this is equivalent to combining the two readings into one reading spanning approximately 60 days.

Test 3 is a fill with missing readings. If there were missing readings, typically they were filled in with the average of the average daily consumption (ADC) of the readings before and after the missing period.

Test 4 is a check for vacancies. Sometimes it is evident from the plots that there is a vacant period. Such readings would show a large drop in usage in either the post or pre period exaggerating or diminishing savings. These gaps in the data are assigned to missing values.

Test 5 is a test for disconnections. Sometimes a customer will be disconnected, or choose to be disconnected. These readings may be coded either as 0 usages or gaps in the billing data. These may confound the billing analysis results. A test was performed on the models, and an indicator variable was included to test for the effects of disconnections. The savings were not affected by disconnections.

Test 6 is to check for completeness of data. This is performed after the data have been cleaned as much as possible. There still may be extended missing periods in the pre or post periods. One of the data attrition screens required all accounts to have at least 300 days in both the pre and post periods. This is necessary, because, for example, if the entire winter usage bills are missing from the pre period, this can cause the average normalized annual consumption (NAC) to be unusually low – confounding the analysis.

Weather Data. The daily weather data were obtained from weather stations for the period from January 1999 through July 2005. Accounts were mapped to their nearest station based on zip code. We used the following 10 Ohio weather stations in our analysis: Akron, Cincinnati, Cleveland, Columbus, Dayton, Findlay, Mansfield, Toledo, Youngstown, and Zanesville.

Base-65 heating degree days and cooling degree days were computed from the average daily temperature. In the billing analysis, these were matched to the billing data periods to obtain the exact total for each billing period.

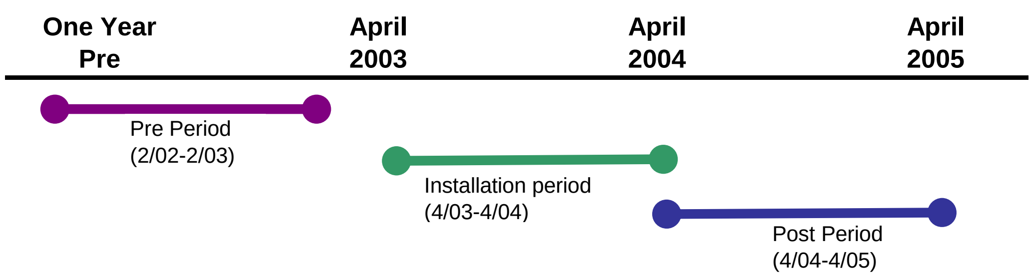
Thirty year normal weather data were obtained from the NOAA (TMY) database for the period 1961 through1990 for the weather stations used in our study.[40]

C. Assigning Pre and Post Analysis Period Dates

The recorded 2003 Program installation dates varied by participant from April 2003 to April 2004. Figure B.4 summarizes the definitions for pre and post that we used in our analysis. Typically, billing data during a 60 day window before and after the recorded installation dates are not used because of possible inaccuracies in the recorded installation dates. This was possible for the pre period because billing data were obtained for at least a year prior to the beginning of the PY03 Program. For the post period this was not always possible, however, since some of the billing data were received early. As a result, we started the post period immediately after the last installation for some of the utilities.[41]

Our definition of pre and post periods assures perfect comparability between participants and non-participants, which can be a problem with other methods of adjusting the pre and post periods.

Figure B.4. Pre and Post Period Definitions



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40 We used this historical weather data because we had a zip code mapping tied directly to these 1961-1990 normals. These normals are very close to the 1970-2000 normals. On average there is a only 0.5% difference between the two series for the 10 Ohio Stations.

41 For some utilities where we received the billing data later, we were able to provide a 60 day window in the post period as well. Even so, a small percentage of participants actually installed in 3/04, 4/04, so this is not a big problem to begin with. Since our non-participant group is not selected from previous or future year participants as in the 1994 analysis, and pre and post periods are defined identically between participants and non-participants, the post period differences of a few months should not affect the savings.

D. Weather-Normalize Consumption and Aggregate to Annual Level

The weather normalization models varied by fuel and heat source.

Gas - Gas Heat Model. For the gas modeling, our approach is equivalent to a PRISM model, with the fixed heating reference temperature (tau) at 65 degrees. In this modeling approach - account level models are run for the pre period and post periods. For each customer i and calendar month t,

$ADC_{it} = \alpha_i + \beta_1 AVGHDD_{it} + \varepsilon_{it}$

Where,

- α_i is the intercept for each participant (or non-participant). This represents the base load (non-heating usage) in the pre or post period
- β_1 is the heating slope in the pre or post period
- ADC_{it} is the average daily consumption during the pre (post) program period
- $AVGHDD_{it}$, is average daily heating degree days (base 65) pre (post) period based on home location
- ε_{it} is the error term

From the model above, the weather normalized annual consumption (NAC) for the pre or post period is computed as follows:

$$NAC_i = \alpha_i * 365.25 + \beta_1 * LRHDD_i + \varepsilon_{it}$$

Where, for each customer i,

- α_i is the base load for each participant (or non-participant). This represents the average daily base load (non-heating usage) from the model
- β_1 is the heating slope in the pre or post period from the model
- NAC_i is the pre(post) period normalized annual consumption
- $LRHDD_i$, is the annual long run heating degree days (base 65) based on home location
- ε_{it} is the error term

Electricity – Electric Heat Model. For the electricity, electric heat model we used a PRISM heating and cooling model – with fixed tau at 65 degrees. This model is not as reliable as the heating-only model because of the complexity in separating out the cooling and heating usage. If the customer does not have cooling usage then the cooling coefficient will be nearly 0.

Again account level models are run for the pre period and post periods. For each customer i and calendar month t,

$$ADC_{it} = \alpha_i + \beta_1 AVGHDD_{it} + \beta_2 AVGCDD_{it} + \varepsilon_{it}$$

Where,

- α_i is the intercept for each participant (or non-participant). This represents the base load (non-heating usage) in the pre or post period
- β_1 is the heating slope in the pre or post period
- β_2 is the cooling slope in the pre or post period
- ADC_{it} is the average daily consumption during the pre (post) Program period
- $AVGHDD_{it}$, is average daily heating degree days (base 65) pre (post) period based on home location
- $AVGCDD_{it}$, is average daily cooling degree days (base 65) pre (post) period based on home location
- ε_{it} is the error term

From the model above, the weather normalized annual consumption (NAC) for the pre and post periods is computed as follows:

$$NAC_i = \alpha_i * 365.25 + \beta_1 * LRHDD_i + \beta_2 * LRCDD_i + \varepsilon_{it}$$

Where, for each customer i,

- α_i is the base load for each participant (or non-participant). This represents the average daily base load (non-heating usage) from the model
- β_1 is the heating slope in the pre or post period from the model
- β_2 is the cooling slope in the pre or post period from the model
- NAC_i is the pre(post) period normalized annual consumption
- $LRHDD_i$, is the annual long run heating degree days (base 65) based on home location
- $LRCDD_i$, is the annual long run cooling degree days (base 65) based on home location
- ε_{it} is the error term

Savings for the PRISM type models for a given participant (non-participant) are obtained as the difference in NAC (DNAC) between the pre period or post period.

Electricity - Gas Heat Model. For the electricity gas-heat model, account level normalization would not be appropriate since the PRISM models detect savings related to temperature-sensitive components (heating and cooling), and these are not expected. Instead fixed effects pooled panel models were developed by grouping together the participants and non-participants, and accounting for overall weather differences in pre and post usages.

Using energy consumption during the post-installation period as the dependent variable and weather and a pre post dummy as independent variables, this approach involves estimating a regression model for both the participant and non-participant groups with the following specification:

$$ADC_{it} = \alpha_i + \beta_1 AVGHDD_{it} + \beta_2 AVGCDD_{it} + \beta_3 POST_{it} + \beta_4 EPP\_POST_{it} + \varepsilon_{it}$$

Where, for each customer i and calendar month t,

- α_i is a unique intercept for each participant (or non-participant), derived by estimating the relationship using the ANCOVA (fixed-effects) procedure
- ADC_{it} is the average daily consumption during the pre- and post-Program periods
- $AVGHDD_{it}$, is average daily heating degree days (base 65) based on home location
- $AVGCDD_{it}$ is the average daily cooling degree days (base 65) based on home location
- $POST_t$ is a dummy variable that represents the savings - change in usage from pre to post period is (1 in the post period, and 0 in the pre period).
- EPP_POST_t is a dummy variable that accounts for savings due to participation in the EPP program. This removes the EPP related savings from the POST variable - change in usage from pre to post period for EPP customers is (1 for EPP customers in the post period, and 0 otherwise).
- ε_{it} is the error term

The net savings are then calculated as the difference between participant and non-participant savings.

E. Select Non-Participant Group by Utility

After the weather normalization was complete, the average pre usage for the non-participants was found to be significantly different than the participant usage – even at the average level. There was no opportunity to screen the non-participants initially to match the participants because billing data were not available at the time of the data request.

In order to address this issue, single-family participants were assigned to quartiles at the utility level based on their pre period NAC (PRENAC) or raw usage (gas heat in the case of electric utilities). The non-participants then were assigned to the corresponding participant quartile. Finally, a random sample of non-participants was chosen that then matched the usages in the participant groups.

We note that the non-participant group may include some multifamily homes in the smallest quartiles because home type is not identified in the HEAP database from which non-participants were drawn and, thus we could not exclude them. This, however, is not likely to have had much effect on the analysis, since the probability of selecting a multifamily home is relatively small. We do have housing type for the participants and this group is composed of 81% single-family/mobile home units.

Some of the characteristic differences between participants and non-participants are illustrated in Table B.1. The process described above matched non-participants' average pre usage almost identically to participants' average usage. The non-participants were different in other ways.

There were some differences in the characteristics of the two groups: non-participants tended to have fewer occupants, lower incomes, and a smaller percentage of people with a disability.

Table B.1. Comparison of Participants to Final Non-Participants, Gas Heating

Characteristics	Sample Participants	Non-Participants
# Units	1,625	2,644
Pre-Use (therms/yr)	1,290	1,288
Number of Occupants	2.25	1.84
Average Income	$10,731	$9,454
% On PIPP program	20%	24%
% With Handicapped Occupant	2.7%	1.8%
% With Disability	16.6%	12.8%

F. Compare Participants to Non-Participants to Calculate Program Savings

After the non-participant matching was complete, the savings were obtained from the regression models (either PRISM or the fixed effects model as described in section D of Appendix E:). The gross savings were obtained straight from the models. Next, the gross participant savings were adjusted for changes in non-participant usage to yield net savings estimates.

In most cases, we applied the overall non-participant net-to-gross ratio to calculate net savings estimates. The only exceptions were in the case of utility-level results and the comparisons of pre Program consumption by usage range. In both these situations, the data were available to make the net-to-gross adjustment for the specific groups being investigated.

Furthermore, in order to develop the final electric savings estimates; regression models were run that removed the impact of EPP. Otherwise the savings would be biased upwards by the effect of EPP on electricity usage.

Appendix C: Data Collection, Cleaning, and Sample Attrition

Data attrition estimates were obtained for the three models. A balance between obtaining and retaining good quality data and keeping the data as unmodified as possible was maintained. The following screens were used in the analysis:

- *Utility did not participate in the evaluation.* Either the billing data were not available, or the utility data did not have enough accounts to merit a data request.
- *Accounts were not matched by the utility.* In these cases, we requested the data, but never received the data for the accounts because the utility could not find selected account based on matches of account number, social security number, or address.
- *Insufficient usage data in the pre or post period.* Accounts with less than 300 days in either pre or post periods were dropped (less than 10 months of data).
- *Infeasible PRISM parameters or usage.*[42] This screen includes negative heating slope, negative cooling slope, or negative baseload (intercept). In the gas analysis NACs under 400 therms or over 5000 therms were dropped. For electricity models with electric heat NACs under 5000 kWh were dropped. For electricity analysis with gas heat any account with raw annual usage over 30000 kWh was dropped.
- *Outliers, defined as cases with percent savings more than 2.2 interquartile ranges (i.e., the distance between the 75th and the 25th percentiles) from the median savings for the analysis group.* This is equivalent to a 3 standard deviations cutoff in normally distributed datasets. For the electricity, gas heat model any accounts that showed savings of more than 30% of pre were dropped instead, since normalized annual consumption was not available.[43]
- *Non-participants only – data matching to participant quartiles.* These are non-participants that were not matched with participant quartiles.

Tables C.1 and C.2 summarize the attritions for participants and non-participants. For the gas heat analysis, almost half of participants are kept in the analysis. In Table C.1 about 25% of electric gas heat participants remain, and 31% of electric: electric heat remain in the analysis. Table C.2 drops many cases in the participant quartile matching process.

[42] An R-square screen of 0.75, used in the 1994 evaluation, was not used in our analysis. In the current evaluation, applying this screen causes a 6% reduction in net savings, but drops 30% of the participants. This suggests that this is a very restrictive screen. If the screen is relaxed to an r-square of 0.5, the savings are almost identical, but about 10% of the participants are dropped. In the end, this screen was not employed, because this screen removed too many accounts.

[43] Since the measures only affect the baseload, it was very improbable that a 30% reduction in usage would occur. Less than 5% of cases were dropped by this screen.

In general, most of the attrition is caused by having insufficient data in the pre or post periods due to missing data or vacancies. Not many cases, however, are dropped out as outliers or due to infeasible PRISM parameters or usages.

Table C.1. Participant Attrition

	Gas: Gas Heat		Electric: Gas Heat*		Electric: Electric Heat	
	Removed	Remaining	Removed	Remaining	Removed	Remaining
Population (total units)	4,535		4,535		926	
Utility Not Requested or Bills Not Available From Utility	247	4288 (95%)	1032	3503 (77%)	307	619 (67%)
Accounts Not Matched by Utility or Usage	889	3399 (75%)	500	3003 (66%)	86	533 (58%)
Insufficient Billing Data Pre or Post	996	2403 (53%)	1796	1207 (27%)	182	351 (38%)
Infeasible PRISM Parameters	59	2344 (52%)	0	1207 (27%)	41	310 (33%)
Outliers	195	2149 (47%)	131	1076 (24%)	20	290 (31%)
Final Analysis Sample**	2,149 (47%)		1,076 (24%)		290 (31%)	

Table C.2. Non-Participant Attrition

	Gas: Gas Heat		Electric: Gas Heat*		Electric: Electric Heat	
	Removed	Remaining	Removed	Remaining	Removed	Remaining
Sample Requested (Total Units)	8,304		8,304		1,466	
Utility Not Requested or Bills Not Available From Utility	415	7,889 (95%)	1907	6,397 (77%)	486	980 (67%)
Accounts Not Matched by Utility or Usage	557	7,332 (88%)	597	5,800 (70%)	191	789 (54%)
Insufficient Billing Data Pre or Post	1744	5,588 (67%)	2934	2,866 (35%)	284	505 (34%)
Infeasible PRISM Parameters	121	5,467 (66%)	0	2,866 (35%)	14	491 (32%)
Outliers	627	4,840 (58%)	370	2,496 (30%)	34	457 (31%)
Participant Usage Quartile Matching	1320	3,520 (42%)	1071	1,425 (17%)	352	105 (7%)
Final Analysis Sample**	3520 (42%)		1425 (17%)		105 (7%)	

Appendix D: Benefit-Cost Analysis Tables

Table D.1 provides a detailed summary of PY03 actual state spending, not including utility weatherization expenditures.

Table D.1. PY03 Spending

Cost Category	Amount
Agency Direct Admin	$1,445,975
Agency Indirect Admin	$626,129
Agency Additional Admin	$225,763
Agency Liability	$236,051
Agency Labor	$15,264,062
Agency-Other Support	$2,632,667
Agency Indirect	$36,648
Agency Materials	$3,544,508
Agency T&TA	$285,250
Agency Single Audit	$71,180
Agency Health and Safety	$2,739,626
OWTC	$542,517
OEE T & TA	$384,102
OEE Admin Costs	$674,694
Total Program Spending	$28,709,172

Table D.2 presents the results of the monetary savings results of the billing analysis. Gas and electric rates are based on monthly PUCO utility rate surveys, while propane and fuel oil rates are from the Northeast-Midwest Institute.

Table D.2. Summary of Participant Avoided Energy Payments

	Single-Family	Mobile Home	Multifamily	All Buildings
Number of Gas Heated Participants	3,090	500	945	4,535
Net Gas Savings per participant (therms)	282	90	83	
Total Gas Savings (therms)	871,380	45,000	78,435	994,815
Lifetime Avoided Gas Payments (2003 dollars)				$24,070,580
Number of Non-Electrically Heated Participants	3,470	962	947	5,379
Electric Savings for Non-Electrically Heated Homes	326	105	201	
Total Electric Savings for Non-Electrically Heated (kWh)	1,131,195	101,034	189,918	1,422,147
Lifetime Avoided Electric Payments for Non-Electric Heat (2003 dollars)				$2,269,010
Number of Electrically Heated Participants	276	430	222	928
Net Electric Savings per participant (kWh)	1,251	1,584	705	
Total Electric Heated Electricity Savings (kWh)	345,189	680,919	156,510	1,182,618
Lifetime Avoided Electric Payments for Electric Heat (2003 dollars)				$1,886,845
Number of Propane Heated Participants	173	351	0	524
Net Propane Savings per participant (gallons)	316	101	93	
Total Propane Savings (gallons)	54,753	35,454	0	90,206
Lifetime Avoided Propane Payments (2003 dollars)				$3,393,017
Number of Fuel Oil Heated Participants	207	111	2	320
Net Fuel Oil Savings per participant (gallons)	206	66	61	
Total Fuel Oil Savings (gallons)	42,738	7,314	122	50,174
Lifetime Avoided Fuel Oil Payments (2003 dollars)				$2,208,387
Total Lifetime Avoided Payments (2003 dollars)				$33,827,839

Appendix E: Regression Based Measure Level Results

Table E.1 summarizes the results of the regression model approach with dummy variables for each measure. This approach tended to overstate the savings associated with air sealing and attic insulation. This problem occurs because the installation rates for these measures is relatively high (over 80%), and the model cannot differentiate sufficiently among the effects of air sealing, attic insulation, and wall insulation. This problem, known as collinearity, results from high correlations between independent variables and leads to inaccurate savings estimates and increases the error of the estimates.

Table E.1. Measure Level Regression Savings Estimates by Pre Group

	Low Usage		Medium Usage		High Usage	
	Savings	% of Pre	Savings	% of Pre	Savings	% of Pre
Air Leakage Reduction	71	8.6%	137	11.1%	286	15.0%
Attic Insulation	50	6.1%	51	4.1%	109	5.7%
Duct Insulation	6	0.7%	-21	-1.7%	51	2.7%
Floor Insulation	11	1.3%	46	3.7%	78	4.2%
Heat Replacement	74	8.8%	118	9.4%	217	11.1%
Furnace Tune-Up and Repair	-4	-0.5%	26	2.1%	46	2.4%
Wall Insulation	61	7.4%	108	8.8%	105	5.5%
Water Heater Insulation	-16	-2.0%	26	2.1%	0	0.0%

The regression approach did not yield accurate measure savings impacts for measures such as air leakage and air sealing, because the installation rate was over 85% for both of them, and the model could not separate the effect for the two measures correctly due to collinearity.

To get around this problem, a Monte Carlo regression analysis approach was used to estimate the measure level impacts for measures with high installation rates. In this approach, 500 (Monte Carlo) random samples were drawn from the group of homes installing a measure for each usage category. The sample size for each of the 500 samples of those installing a measure was equal to the sample size of those that did not install the measure. Samples were drawn by measure and by pre consumption level group. A separate measure level regression model was then run for each of 500 sub-samples, and the coefficients were saved. Finally, the coefficients for the measure of interest were averaged across the 500 samples to obtain the savings estimate.

As an example, in the high consumption group, there were 513 participants. Of these, 458 (89%) received air leakage reduction measures and 55 (11%) did not. The savings were developed by running the measure-level regression model with all measure dummy variables included; the 55 who did not receive the air leakage measure were combined with a random sample of 55 participants that did receive the air leakage measure. This process was repeated 500 times by varying the random sample of participants receiving the air leakage measure. We used the average coefficient of the air leakage measure across the 500 samples as the Monte Carlo regression estimate; this value was 286 therms.