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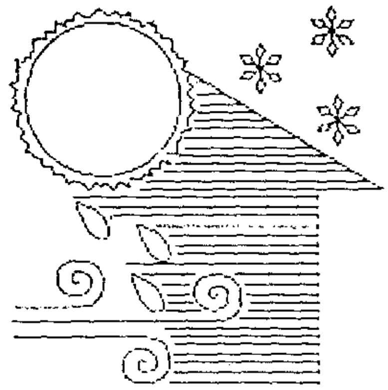

Progress Report of the National Weatherization Assistance Program

Linda G. Berry
Marilyn A. Brown
Laurence F. Kinney

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LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

WEATHERIZATION ASSISTANCE PROGRAM

Schedule - 10

ORNL-27 (3-96)

ORNL/CON-450

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* Synertech Systems Corporation

September 1997

Prepared for the
Office of State and Community Programs
Office of Building Technology, State and Community Programs
U. S. Department of Energy
Under the Direction and Supervision of
Jeanne Van Vlandren
Director, Office of State and Community Programs

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Managed by
Lockheed Martin Energy Research Corp.
for the
U. S. Department of Energy
Under Contract DE-AC05-960R22464

INCREASES IN PROGRAM ENERGY SAVINGS AND COST EFFECTIVENESS (1989-1996) AT A GLANCE

ENERGY SAVINGS IN GAS-HEATED HOMES

First-year savings	Savings per dwelling	Percent of total gas consumption	Percent of gas space heat consumption
1989 (PRISM analysis of billing data for homes in the representative national sample that heat with gas)	17.3 Mbtu	13.0%	18.3%
1996 (national estimate derived from Metaevaluation of 17 state-level evaluations of savings in gas-heated homes)	31.2 Mbtu	23.4%	33.5%

VALUE OF GAS ENERGY SAVINGS (in 1996 dollars)

	First year	20 years
1989	$107/dwelling	$1,707/dwelling
1996	$193/dwelling	$3,047/dwelling

COST EFFECTIVENESS

	1989	1996
Program Benefit/Cost Ratio [a]	1.06	1.79
Installation Benefit/Cost Ratio [b]	1.58	2.39
Societal Benefit/Cost Ratio [c]	1.61	2.40

[a] The program benefit/cost ratio compares the discounted value of the energy savings to total program costs with an assumed lifetime of 20 years and a discount rate of 4.7%.

[b] The installation benefit/cost ratio compares the discounted value of energy savings to installation (labor and materials) costs with an assumed lifetime of 20 years and a discount rate of 4.7%.

[c] The societal benefit/cost ratio compares the discounted value of both energy and nonenergy benefits (such as employment and environmental impacts) to total program costs with an assumed lifetime of 20 years and a discount rate of 4.7%.

CONTENTS

The National Weatherization Evaluation of the 1989 Program Year and the Metaevaluation of 1996 are described in two ways in this summary document. The text on the right-hand (odd) pages summarizes the results of the two evaluations conducted by the Oak Ridge National Laboratory. The photographs and explanations on the left-hand (even) pages illustrate weatherization operations and tactics.

Even Pages

Odd Pages

"I have seen first hand how many jobs weatherization programs create and also how much good they can do . . . A lot of this weatherization work for poor people, especially for a lot of elderly people who are stuck in these old houses that have holes in the walls . . . or in the floor, not only makes them warmer in the winter and cooler in the summer, they also save money on their utility bills. [Weatherization] conserves energy and puts more money in the pockets of people who have just barely enough to get by. So I strongly support [weatherization programs] . . . It's a kind of hard sell in the Congress now because the price of oil is so low and energy is so cheap--it's much cheaper in America than it is in any other major country. But if you just have enough to get by on, [if] you're living on a Social Security check or you're living on a minimum wage, [utility bills] are still very, very expensive and a big part of your budget."

President Clinton's remarks concerning the Department of Energy's Weatherization Assistance Program at the Summer of Service Forum held at the University of Maryland, August 31, 1993.

"By implementing energy-saving measures in low-income homes, the Weatherization Program works to correct the disproportionate energy burden faced by low-income Americans who often face the difficult choice between buying food or fuel. Consequently, weatherization helps low-income residents gain financial independence, thus offering a hand-up not a hand-out."

Excerpt from Secretary Peña's testimony before the Senate Committee on Energy and Natural Resources, May 13, 1997.

Progress Report of the National Weatherization Assistance Program

I. OVERVIEW

The U.S. Department of Energy's (DOE) Weatherization Assistance Program (the Program) has long served as the nation's core program for delivering energy conservation services to low-income Americans. The Program reduces the heating and cooling costs for low-income families -- particularly the elderly, persons with disabilities, and children -- by improving the energy efficiency of their homes and ensuring their health and safety. In combination with closely related programs sponsored by the Department of Health and Human Services (HHS) and supplemental funding from other sources, the DOE Weatherization network is operated by state entities in all 50 states and is managed by the DOE Office of State and Community Programs (OSCP). This network has weatherized more than *four and one-half million* households since its inception in 1976.

In 1990, DOE sponsored a comprehensive evaluation and assessment (the National Evaluation) of the Weatherization Program under the supervision of Oak Ridge National Laboratory (ORNL). The National Evaluation concluded that the Program meets the objectives of its enabling legislation and fulfills its mission statement. Specifically, it

- saves energy,
- lowers fuel bills, and
- improves the health and safety of dwellings occupied by low-income people.

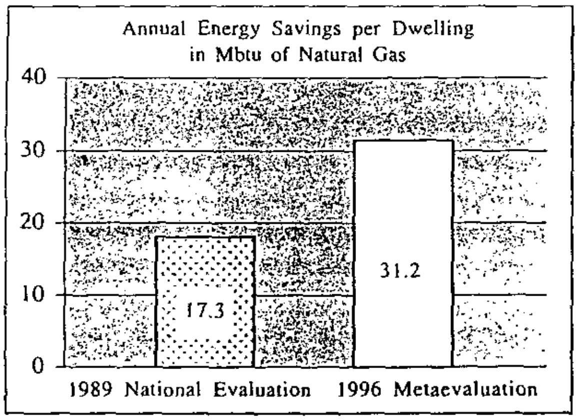
In addition the National Evaluation concluded that, based on 1989 data, the Program has been achieving its mission in a cost-effective manner, with benefits exceeding costs according to all three standards employed by the evaluators. Annual savings for households heated with natural gas, the predominant home heating fuel, were estimated to average 17.3 Mbtu per weatherized dwelling. This constituted a reduction of 18.3 percent in natural gas consumption for space heating, or a 13.0 percent reduction in natural gas consumption for all end uses. The National Evaluation also pointed to several promising approaches and practices that could further improve the overall performance of the Program in future years.

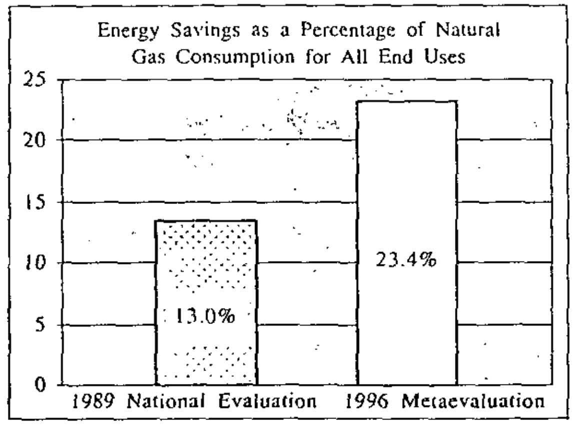
A 1996 Metaevaluation of 17 state-level evaluations (the Metaevaluation) suggested that improved practices have indeed produced 80 percent higher average energy savings per dwelling today as compared to the measured savings in 1989. The Metaevaluation, which developed a regression-based national estimate of savings, indicated that average savings in homes using natural gas as the primary heating fuel were 31.2 Mbtu, which was 33.5 percent of natural gas space heating consumption. The savings constituted a reduction of 23.4 percent in consumption of natural gas for all end uses.

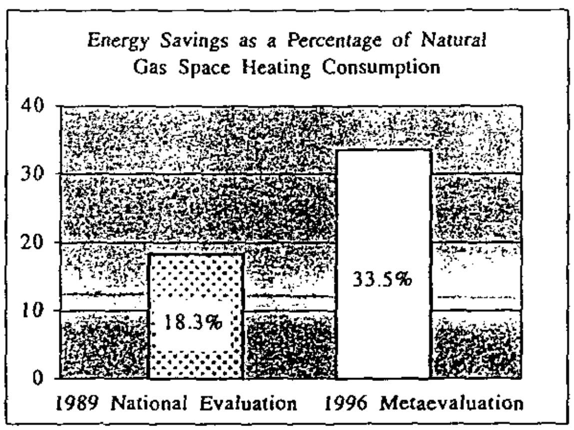
References are at the end of the text on pages 74-75.

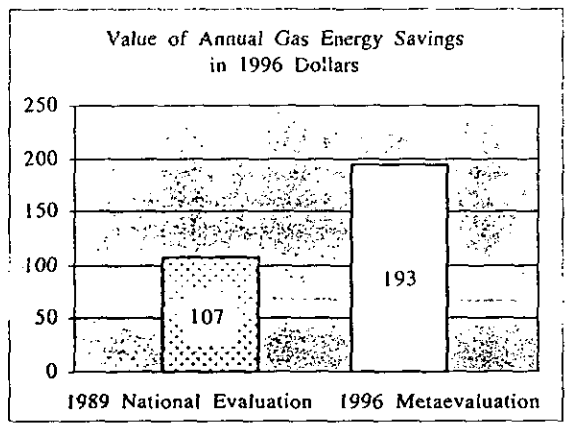
1996 INCREASES IN PROGRAM PERFORMANCE

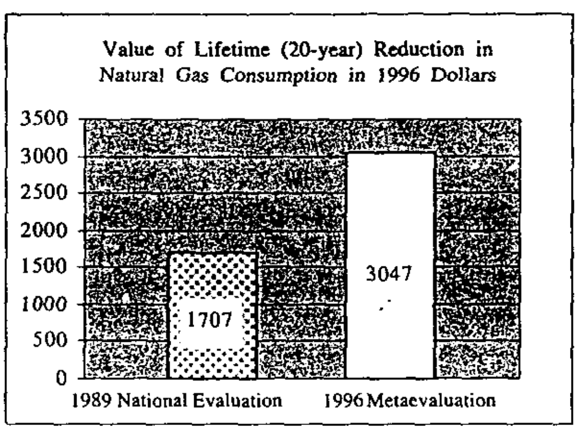
The Metaevaluation in 1996 showed an 80% increase in energy savings, greater reductions in CO_2 emissions, and increased cost effectiveness since 1989

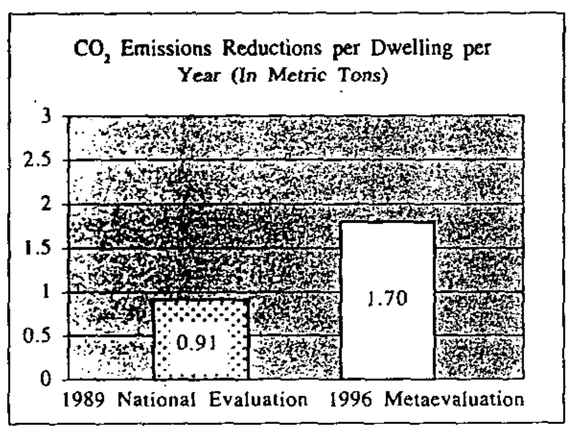










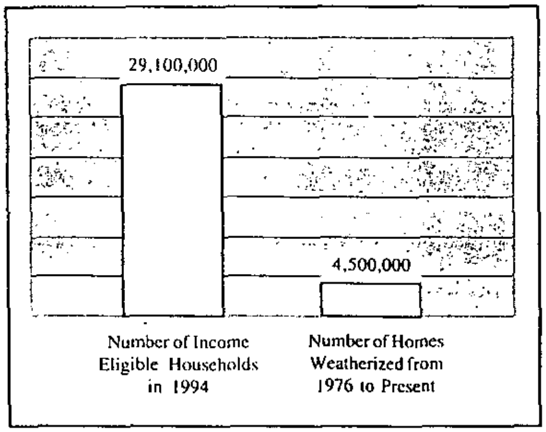


Cost-Effectiveness Results for Gas-Heated Homes:
Benefit/Cost Ratios[a] from Three Perspectives in 1989 and 1996

	Program	Installation	Societal
National Evaluation 1989	1.06	1.58	1.61
Metaevaluation Results 1996	1.79	2.39	2.40

[a]See page 29 for an explanation of the calculation procedures and a definition of the three perspectives.

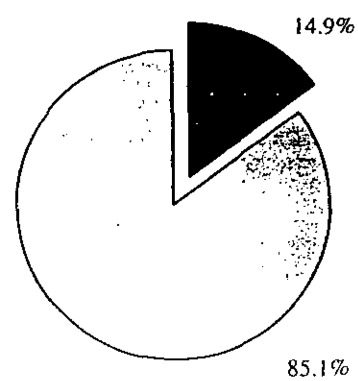
With the increased energy savings, the value of annual avoided energy costs per gas-heated household also increased from an average of $107 to $193, and the benefit/cost ratio for the Program rose from 1.61 to 2.40.



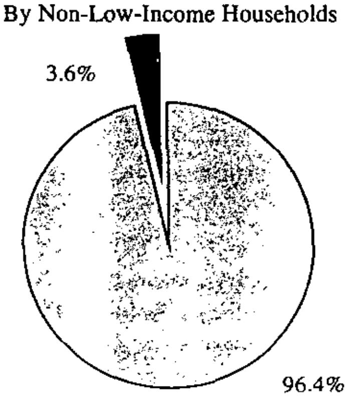
Although the Weatherization Program has successfully accomplished a significant portion of its mission, additional activities need to be undertaken to meet the ongoing need for low-income weatherization. The Department of Health and Human Services has reported that, based on Energy Information Administration data, there were 29.1 million households with incomes near or below the federal poverty guidelines for Weatherization eligibility in 1994. These households were spending an average of 14.9 percent of income for residential energy. This compares to an average expenditure of 3.6 percent of income for residential energy by non-low-income households. The most recent Residential Energy Consumption Survey indicates that 1.5 million households experienced heating interruptions because of their financial situations during one year.

From Program Year (PY) 1985 through PY 1995, the Program's network of 1,100 local agencies weatherized an average of 200,000 dwellings per year. Substantial budget reductions for Weatherization Assistance in PY 1996 and PY 1997 have forced a reduction in the number of agencies performing weatherization and have cut the number of dwellings weatherized to approximately 70,000 annually. This downsizing is the most recent challenge to carrying out the Program's mission in an efficient and effective manner.

Percent of Income Spent on Residential Energy By Low-Income Households

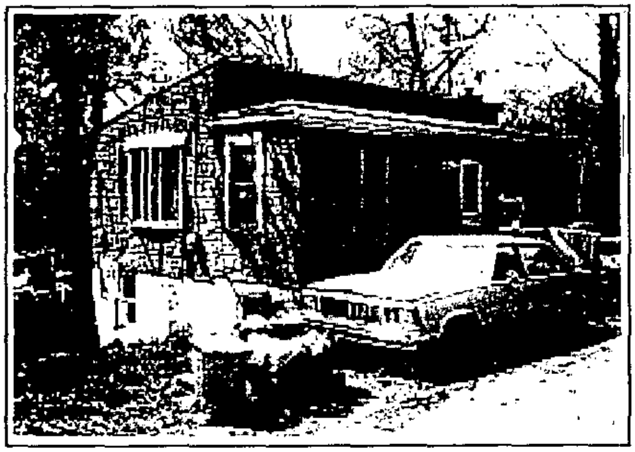


Percent of Income Spent on Residential Energy By Non-Low-Income Households

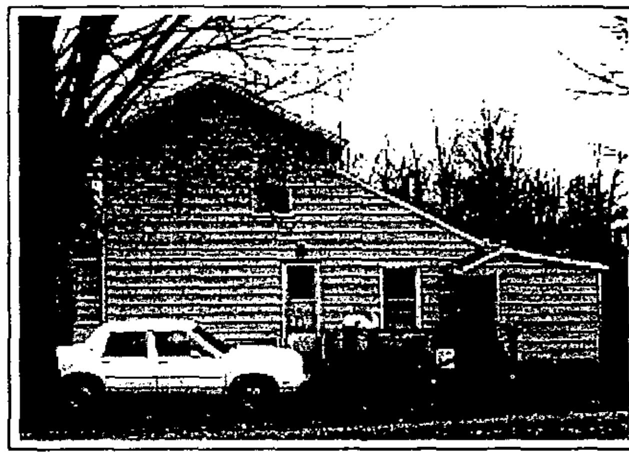


SINGLE-FAMILY DETACHED HOMES

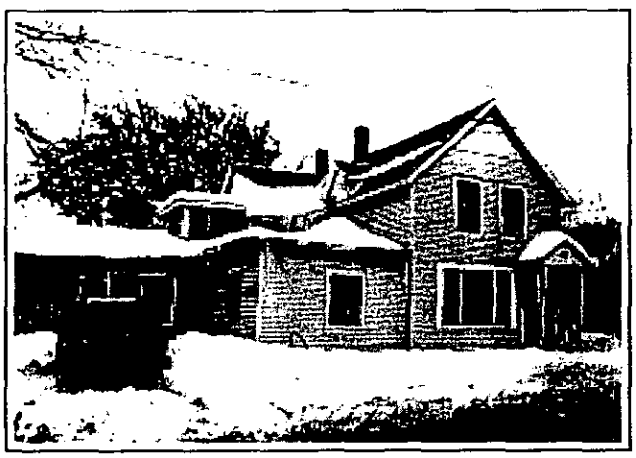
This series of photographs illustrates the age and diversity of single-family homes weatherized by the Program.



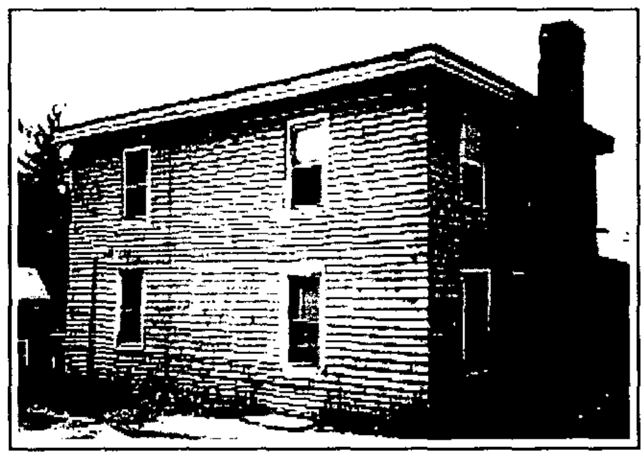
The weatherization job on this house will include foundation wall repair.



This roofline suggests complex paths for air leakage.



Patterns of snow and ice indicate a leaky, poorly insulated attic.

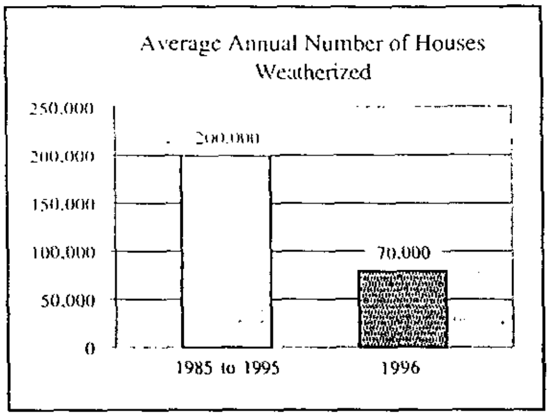


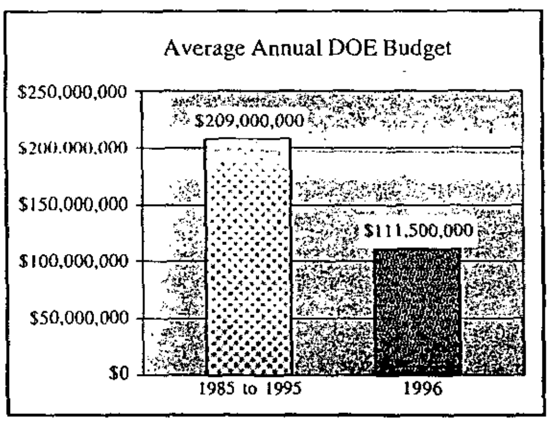
A good candidate for wall insulation.

This concrete block house is typical of homes that are weatherized in rural Georgia.

II. PROGRAM HISTORY

Most Americans were dramatically affected by the 1973 oil crisis. Huge home heating bills were a heavy burden on some household budgets, sinking many families into debt. Low-income families in cold climate states, who received high heating bills, suffered the most severe consequences. In Maine, where nine out of ten homes are heated with oil, state officials and community action agencies worked with homeowners and renters to seal house leaks (where costly heated air poured out and cold air entered). Retrofitting cut bills and saved oil. Out of this effort, the Nation's first weatherization program was born. Congress created the DOE's Weatherization Assistance Program in 1976 under Title IV of the Energy Conservation and Production Act.





The Program initially emphasized emergency and temporary measures, including caulking and weatherstripping of windows and doors, and low-cost measures such as covering windows with plastic sheets. By the early 1980's, the emphasis had turned to more permanent and more cost-effective measures, such as installing storm windows and doors and insulating attics. In 1984, regulations were passed to allow Weatherization Assistance funds to be spent on space and water heating system efficiency changes. In 1985, spending for the replacement of defective furnaces and boilers was approved.

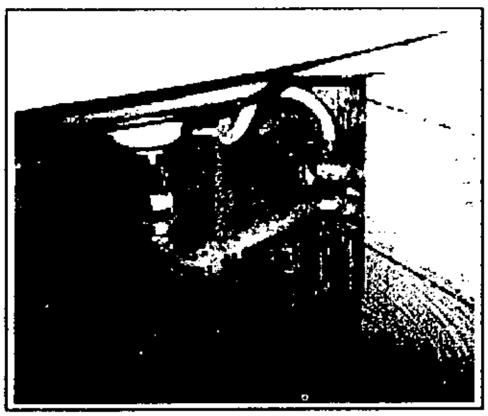
In the 1990's, the trend toward emphasizing more cost-effective measures continued with the development and widespread adoption of advanced audits. Advanced audits are now used in 37 states. By 1996, the Program's performance had improved significantly because of the implementation of many of the recommendations of the National Evaluation and of other DOE-sponsored research. In spite of funding reductions, technical advances produced 80 percent higher energy savings per dwelling. Increases in energy savings were achieved through better training, audit tools, and management practices with little increase in cost.

Among the new DOE regulations implemented in 1994 were changes that promote the use of advanced audits, and that permit the use of cooling efficiency measures such as air conditioner replacements, ventilation equipment, and screening and shading devices. In warm climates, where cooling costs may be higher than heating costs, cooling measures can now be installed when appropriate. Barriers to performing work on heating systems and mechanical equipment have also been removed. The requirement that 40 percent of Program funds be spent on materials is waived in states that adopt approved advanced audits, thus ensuring audit-driven cost-effectiveness tests of investments. With increased flexibility, better measure selection procedures, and more advanced diagnostics (such as blower-door directed air sealing), the Program now installs more cost-effective combinations of measures tailored to the needs of particular dwellings and climates.

ADVANCED AIR SEALING

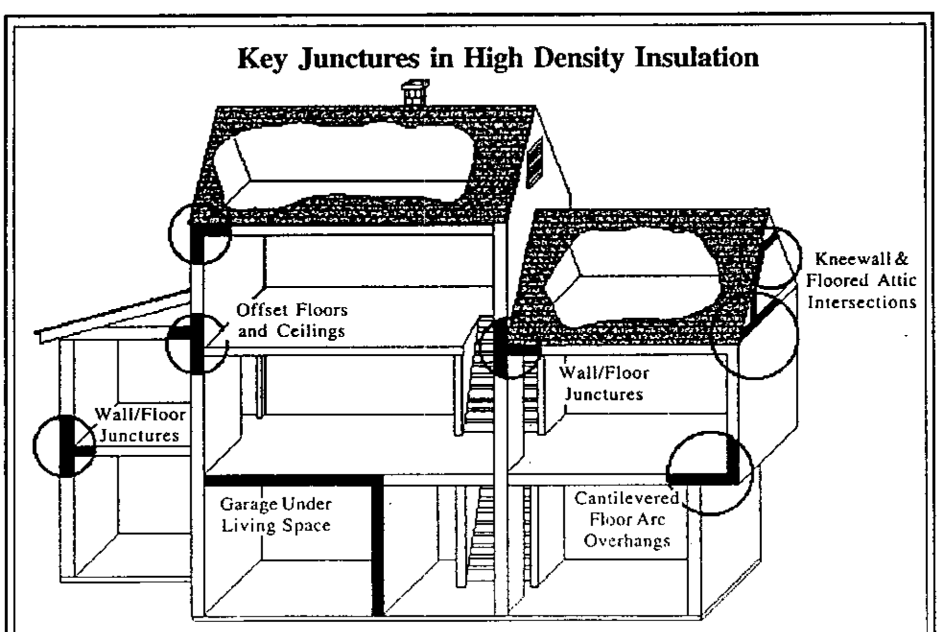
In the last several years, it has been shown that some previously ignored areas of dwellings can be potent sources of convective losses. If such losses are found and treated, they offer high potential for savings. As illustrated in the figures, these include interstices between floors, spaces between the conditioned envelope and such buffer zones as porches and garages, and areas between old and new portions of dwellings. The blower door, in conjunction with a gauge that measures differences in pressure, is a valuable tool in identifying leakage to or from these areas, helping both in identifying the magnitude of the leakage and in verifying when such measures as the blowing of high-density cellulose or other air-sealing measures will solve the problem. Weatherization agencies that integrate these tests and tactics into routine operations achieve excellent savings.

As revealed by a blower door and a pressure gauge in a test that takes only several minutes, the area under this porch is directly connected to the envelope through floor joists between the first and second floor. High-density insulation is being used to air seal this largest hole in the dwelling.



Note the infiltration area under the bathroom sink, which connects to the attic via a stud cavity in an interior wall.

Air sealing a plumbing chase on the first floor that corresponds with both attic and basement. Sealing holes in inconspicious and hard-to-get-to places are frequently those which result in good, cost-effective weatherization jobs.



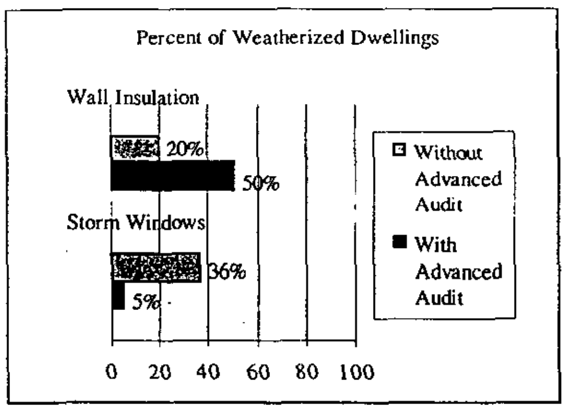
III. THE SCOPE OF WEATHERIZATION

A. Types of Measures Used

A variety of weatherization measures are used by DOE's Weatherization Program to improve the energy efficiency of dwellings occupied by low-income people. Although audit methods to optimize the type and amount of weatherization measures have improved, the set of measures that is typically considered has remained relatively constant between 1989 and 1996. Detailed results from the National Evaluation indicated that the following measures were those most commonly used in 1989:

Air leakage control was the most common type of weatherization measure installed in single-family and small multifamily dwellings. General caulking and weatherstripping around windows and doors were by far the most common of these measures at the time of the National Evaluation. Today, blower-door directed air sealing and air leakage control measures for distribution systems are used frequently. These techniques reduce air leakage much more effectively.

Advanced Audits Select More Insulations, Fewer Storm Windows



Insulation was the next most common type of energy conservation measure installed. Attic insulation was either used for the first time or added to existing insulation in the majority of homes receiving insulation. Wall insulation was installed in less than 20 percent of homes. Today, with the use of advanced audits, attic and, especially, wall insulation are installed much more frequently.

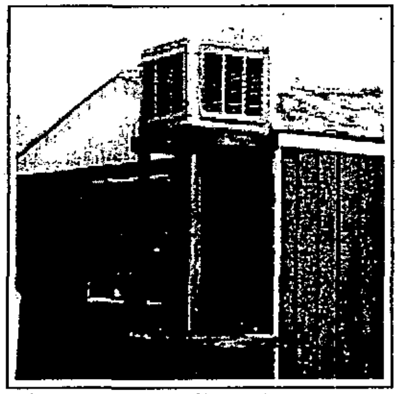
Energy-efficiency improvements to **water heater systems** were made in 56 percent of the weatherized homes in 1989. Most of these retrofits involved tank or pipe insulation. Today an even larger majority of homes receive water heater measures. In addition, water temperatures are reduced and low-flow showerheads are added in a higher percentage of homes.

Energy-efficiency improvements to **windows and doors** occurred in 42 percent of homes weatherized at the time of the National Evaluation. Additional window and door work was conducted primarily for repair purposes. By far, the majority of these improvements involved the addition of storm windows (36 percent) or the replacement of entire windows (37 percent). Advanced audits are unlikely to recommend storm windows or window or door replacements in most homes. Therefore, these measures are installed less frequently today.

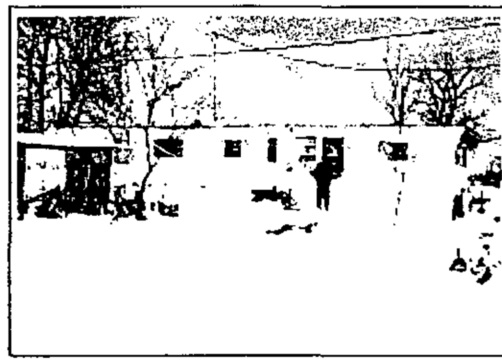
Nearly one-third (30 percent) of the homes weatherized had energy-efficiency improvements made to their **space heating systems**. Most of these improvements involved tune-ups, during which heating systems were cleaned, controls adjusted, and filters replaced. Increased attention to space heating measures probably characterizes the Program

MOBILE HOMES

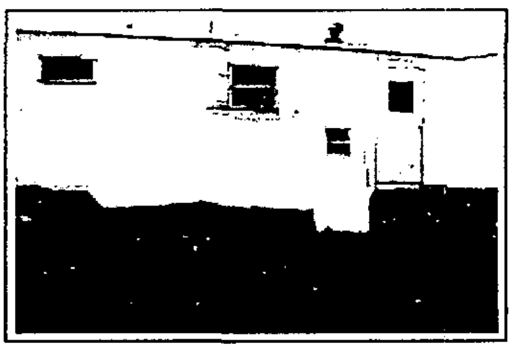
Due to the economic realities of affordable housing, *many low-income families live in mobile homes.*



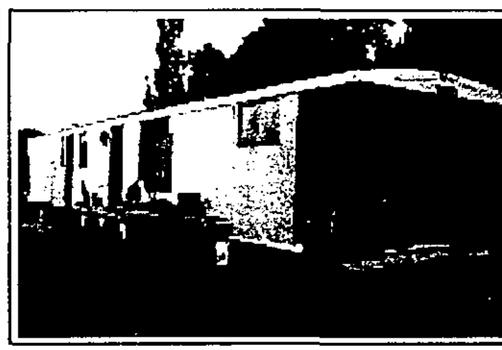
Evaporative chillers (swamp coolers) often mean large leaks.



This home used over $1,000 of fuel oil per heating season before weatherization tightened it up and installed a more efficient oil burner.



New doors and windows sometimes save energy, but air sealing ducts in mobile homes are usually a more cost-effective retrofit.



Mobile homes with poor foundations often develop major structural problems.

Very poor insulation causes major problems with mobile homes built before HUD's energy standards were adopted in 1976.

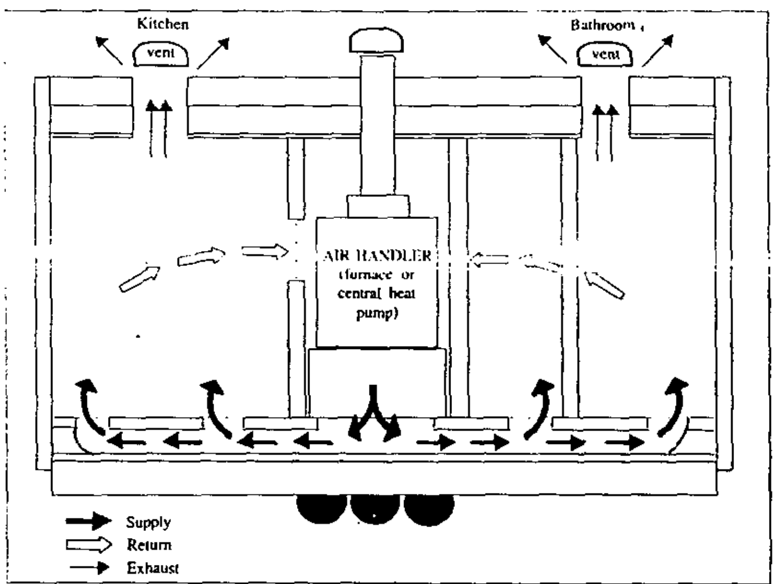
Skirting under a mobile home is not as important for the heating bill as belly board insulation, which can be blown in by weatherization crews.

today because barriers to performing work on heating systems and mechanical equipment have been removed. Distribution systems also now receive increased attention for both heating and cooling applications. In addition, new regulations implemented in 1994 allow for the use of **cooling efficiency measures** including air conditioner replacement, ventilation equipment, and screening and shading devices. These measures enable the Program to more effectively address the energy efficiency needs of homes in warm climates.

The requirement that 40 percent of Program funds be spent on materials is waived in the 37 states that have adopted approved audits, thus ensuring that the most cost-effective package of investments will be selected. These and other Program updates allow increased flexibility to select the most appropriate measures for specific dwellings in particular regions.

Measures for Mobile Homes

There are seven million "manufactured homes" in the United States and the number is growing. Well over half were constructed before 1976, when HUD initiated its mandatory national standards on manufactured home construction. These older units, which tend to be occupied by lower-income people, suffer from a variety of ills. Energy problems stem from shoddy construction, improper site set ups, and poor maintenance. As a result, many are leaky, uncomfortable, and have high energy bills.



Mobile Home Heating System Distribution System

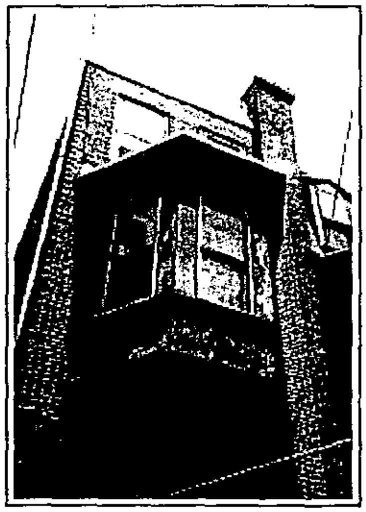
The profile of weatherization measures installed in mobile homes differed from that of other housing types. In 1989, mobile homes were much less likely to receive any type of insulation than the average home (20% vs. 62%), and nearly all mobile home insulation consisted of floor insulation. Blowing the space between the belly board and the floor of older mobile homes with insulation, in combination with attention to air sealing and duct leakage, solves many conductive and convective problems so that less heat is wasted.

Blower-door-assisted air sealing is becoming a more prominent part of mobile home weatherization. Quite frequently, major leaks are found in unobvious places, such as main electrical boxes, plumbing chases, and ducts. The combination of leaks in mobile home ducts and belly boards results not only in low heating and cooling efficiency, but also in uncontrolled air leakage. This wastes energy and can affect indoor air quality, raise moisture levels, and cause structural deterioration.

In 1989, water heating measures were installed less frequently (48% vs. 56%) in mobile homes than in other types of structures, while window and door measures (50% vs. 42%) were installed more frequently. Installation of inside storm windows covering leaky jalousie-type win-

Although most dwellings weatherized are single-family detached structures, other dwelling types are also common.

ROW HOUSES (SINGLE-FAMILY ATTACHED DWELLINGS)

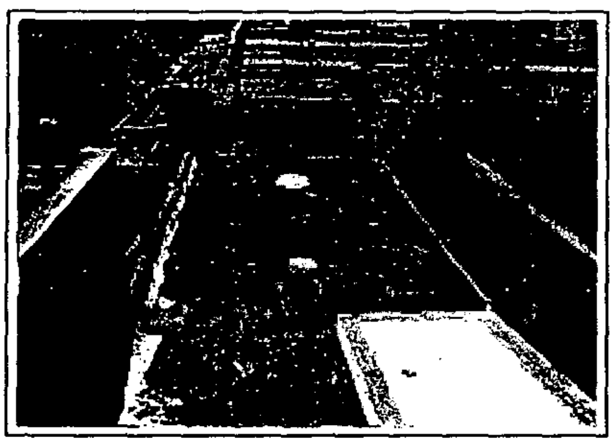


The space under these bay windows may cause more energy waste than the windows themselves.

Row houses, which predominate in many older American cities in the Northeast, can be extremely wasteful of energy. Leaky flat roofs cause falling ceilings and massive air leakage.

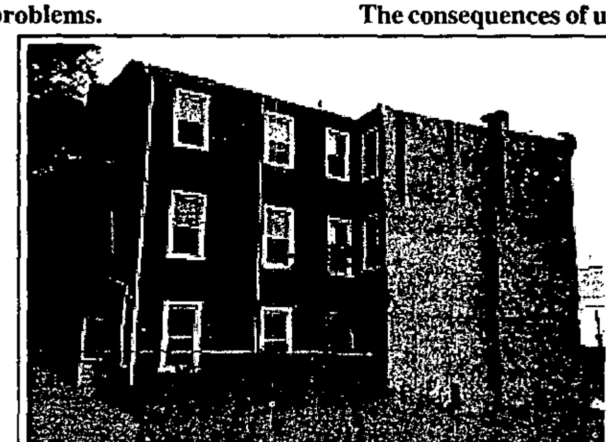
The space above porch ceilings is often connected to the inside of the front wall.

A solid exterior may conceal inner decay.



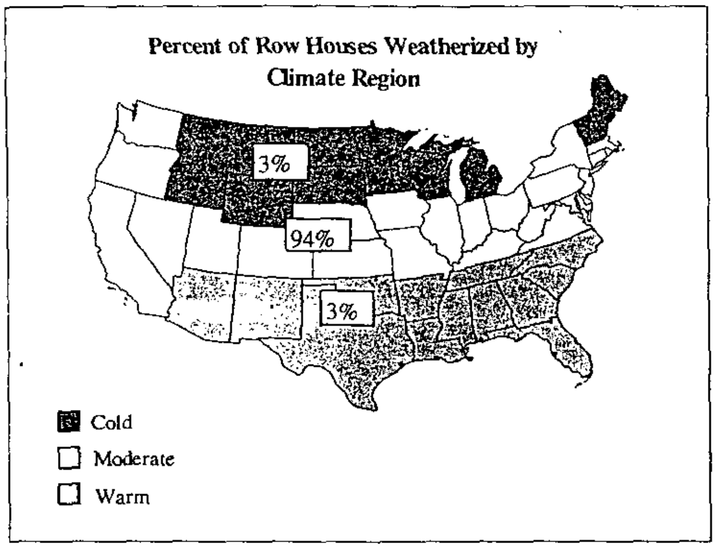
Leaky roofs pose big problems.

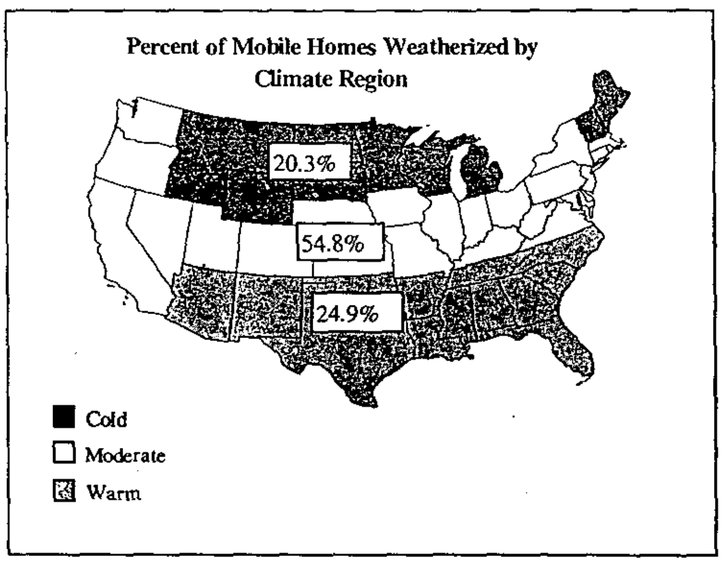
The consequences of unrepaired roof leaks.



Newly missing next-door neighbor causes major air infiltration.

Weatherized Row Houses and Mobile Homes Are Concentrated in the Moderate Climate Region





dows was especially common in mobile homes. Most mobile homes received one or more measures that were especially suitable for this type of dwelling, including underpinning, skirting, cool seals on the roof, and belly board insulation.

An audit designed specifically for mobile homes is being developed for the Program's use. This advanced audit will improve the auditor's ability to select the most cost-effective packages of measures for mobile homes.

Measures for Row Houses

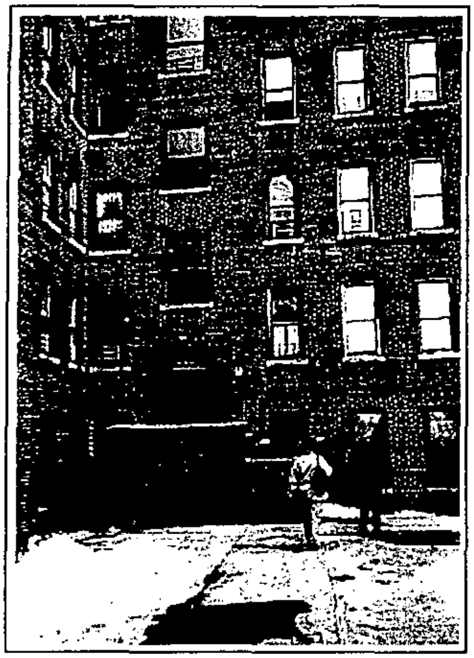
Row houses tend to be among the most wasteful and leaky housing stock in the country. Accordingly, extensive air sealing measures were undertaken on virtually all weatherization jobs performed in 1989. The work is complicated in that some air leakage may be conditioned air from an adjoining house, a fact that affects both energy use and indoor air quality. In addition, part of the inherent architectural charm of row houses, including such details as porches and bay windows, can mask subtle convective and conductive problems. Thus, air sealing these homes requires special care and sealing techniques.

In 1989, "first time" attic insulation was installed at higher rates in row houses than in any other type of housing, pointing out their poor thermal condition. In addition, roof repairs were used more frequently for row houses than for other housing types. A major source of energy waste in older row houses occurs when their flat roofs leak water, ultimately causing ceilings to fall. This allows stack-effect infiltration to have devastating effects on the fuel bill. As explained on page 30, stack-effect infiltration results from the rising of warm air in the interior, pulling in air at the bottom of the conditioned envelope and exhausting warm air at the top. Pressure differences at the top and bottom are at their maximum, which makes holes in these areas critical to repair.

Measures for Large Buildings

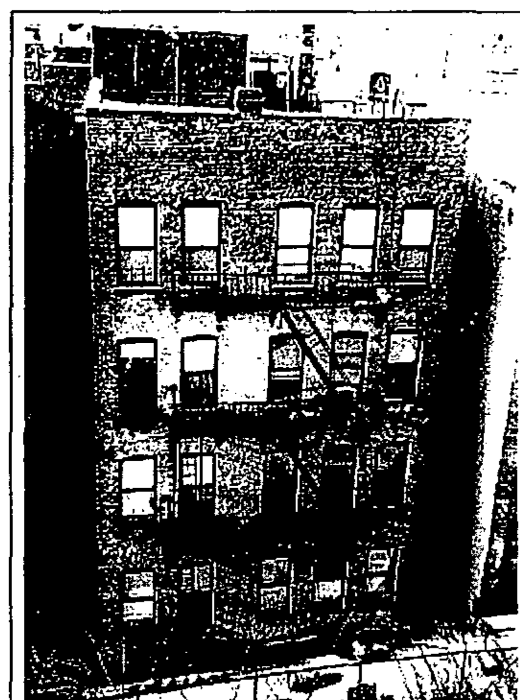
The weatherization of large multifamily buildings, those with five or more units, presents local agencies with challenges different from those presented by smaller dwellings. Most of the work is accomplished in distressed urban areas where both buildings and much of the surrounding communities suffer from maintenance problems and even abandonment. Consequently, facade facelifts in the form of window repair and replace-

LARGE MULTIFAMILY BUILDINGS



This large building in the Bronx was almost ready for abandonment when weatherization played a key role in its restoration.

This is a large multifamily dwelling in Holyoke, Massachusetts, which was weatherized by HAP Inc., from Springfield, Massachusetts.

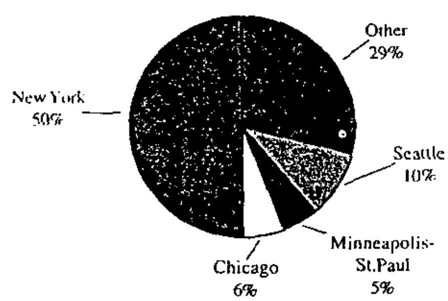


This is the back of a four-story building in Brooklyn. After air sealing, boiler, and window replacements, the energy expenditures for this building are approximately 40 percent less than the previous year's fuel expenditures.

ment has been the focal point of most large multifamily operations, accounting for 80 percent of material expenditures in Program Year 1989 in which 20,000 units in multifamily buildings were weatherized (MacDonald, 1993). In rental units, which dominate in multifamily buildings, local agencies have special safeguards in place to ensure that energy saving benefits are passed along to the tenant. In addition, a significant landlord financial contribution to the project is often required.

The diversity of housing stock and approaches to weatherization found in single-family housing also holds true in the multifamily sector, where the unique features of the urban environment require especially creative responses. This diversity is illustrated by findings from three case studies summarized below (Kinney et al., 1994).

50 Percent of Multifamily Weatherizations Take Place in New York and the Rest in Other Large Cities



Multifamily Weatherization Takes Place in Large Cities

The New York City weatherization operation, with its 22 local agencies, accomplishes over half of the multifamily weatherization work done nationally by the Weatherization Program. The need for such services is apparent. New York City has 126,000 multifamily buildings with more than 1.9 million apartments. An average apartment uses over 865 gallons of fuel oil (or its equivalent) annually for heat and domestic warm water, a startlingly large number for the climate and average apartment size. This inefficiency makes multifamily buildings very good targets for cost-effective conservation retrofits.

The trend in current multifamily weatherization operations in New York City is to concentrate on the heart of the building, the boiler room, and on its arteries, the distribution system. Poorly designed, controlled, and maintained heating systems are a major culprit in causing some buildings to consume five to six times as much energy as their neighbors. In response, professional energy auditors using state-of-the-art testing equipment and EA-QUIP analytical software undertake building audits that result in detailed work orders. These include computations of costs and benefits of all retrofit measures anticipated and specifications of each element of the proposed work. These work orders, most of which are accomplished by the staff of the New York City Weatherization Coalition, are instrumental both in ensuring that resulting weatherization work meets rigorous standards and in leveraging funding from building owners.

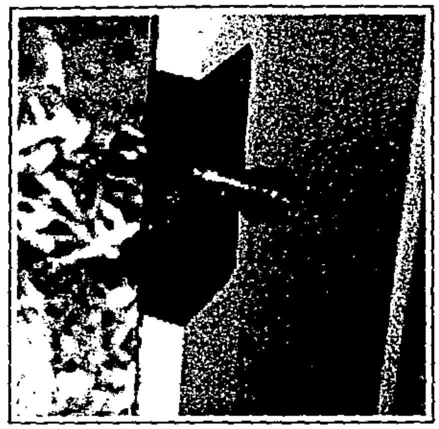
In Chicago, the City government administers the Weatherization Program, serving single-family, smaller, privately owned multifamily buildings (typically three and four story walk-ups), and larger public housing projects managed by the Chicago Housing Authority. Because of the Program's excellent reputation for quality performance, a waiting list of over one year for weatherization services has resulted. Buildings on the waiting list are served on a first-come, first-served basis.

Past weatherization measures were concentrated at the apartment level with strong emphasis on storm and replacement windows.

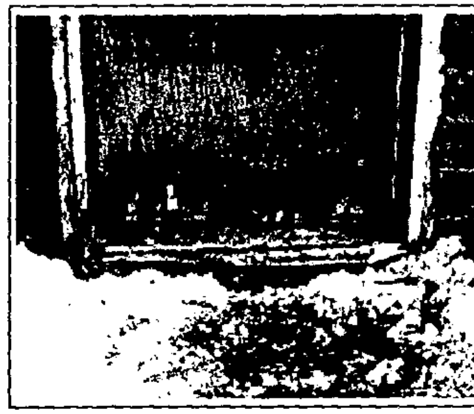
DOORS AND WINDOWS

Although most dwellings require air sealing, insulation, furnace retrofits, and at least minor repair work, exactly which tactics to employ is a decision that depends on the circumstances of the dwelling, the funding of the agency, and the **know-how of the auditor and crews**. The National Evaluation, plus testimony from experienced practitioners in the field, has shown that cookbook procedures employed in the early days of the Program—weatherstripping, caulking, and storm windows—were only marginally effective. Audits using advanced diagnostics direct crews to the real problems in a dwelling and usually result in more cost-effective work.

Window and door repair is a necessary part of most weatherization operations, but many agencies have abandoned the practice of routinely installing storm windows and exterior doors because they have found these measures do not save as much as many other less costly conservation measures.



A new lock set is only marginally cost effective as a weatherization measure (it can aid in air sealing), but since it supplies a measure of security, this repair can be the most important one for a client. Sometimes a new door performs a similar security function.



When doors and frames are in this condition, weatherization jobs include replacement of both.

Although this storm window is still functional, missing window trim and a rotten sill plate have done substantial damage. The sash weight is visible from the outside of this dwelling.

Glass replacement is inevitably time consuming but necessary. Most agencies rebuild the sash to ensure good air sealing.

When window frames are out of square in an older home—usually due to foundation problems—some agencies try to repair the primary window and install new storm windows.

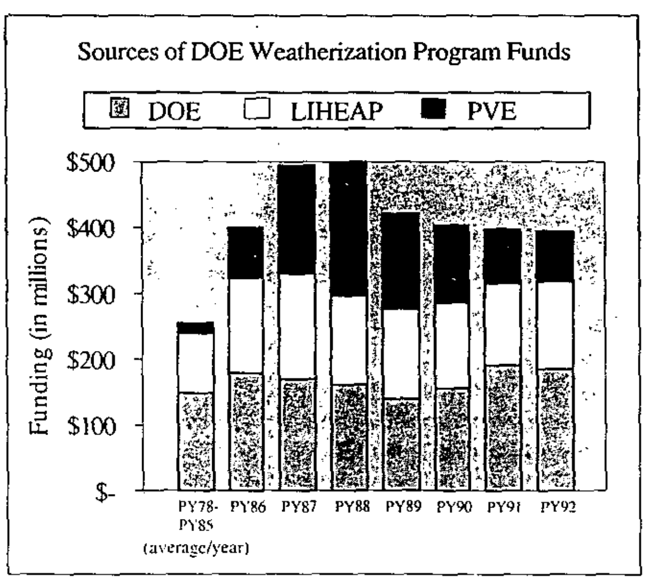
This basement window will be replaced by fixed-board insulation sealed in place by foam.

The new policy in Chicago is to weatherize whole buildings, which allows for working on heating systems before treating thermal losses in apartments. Frequently, the new policy results in the replacement of large, inefficient boilers and the integration of modern electronic controls. In all cases, whenever major measures such as boiler replacements or large-scale window replacements are undertaken, building owners are required to bear 50 percent of the costs. In smaller buildings where tenants can control their own heat, digital thermostats are frequently installed.

Weatherization agencies in Minnesota weatherize about 1,000 large multifamily units each year, most of which are in the Minneapolis-St. Paul area. These units range from row houses to 20-story high-rise buildings, but the most common are two- and three-story frame walk-ups with brick facades. Larger building work concentrates on boiler repair, controls, and distribution systems, with little emphasis on window repair work or even air sealing. Smaller buildings are air sealed (with emphasis on attic bypasses) and insulated like single-family dwellings. Multifamily work is guided by information from fuel bills and instrumented audits.

Weatherization of large buildings in our nation's largest cities is a complex process. There is a growing cadre of technically competent engineers and contractors that is involved in the Weatherization Program's large multifamily retrofits. These individuals practice such important crafts as making single-pipe steam systems work efficiently. When their practical wisdom is communicated clearly to building supervisors, systems tend to be maintained much better, with the consequence that savings endure. These long-term energy savings can play a key role in the revitalization of distressed neighborhoods in our nation's larger cities.

B. Sources of Funds

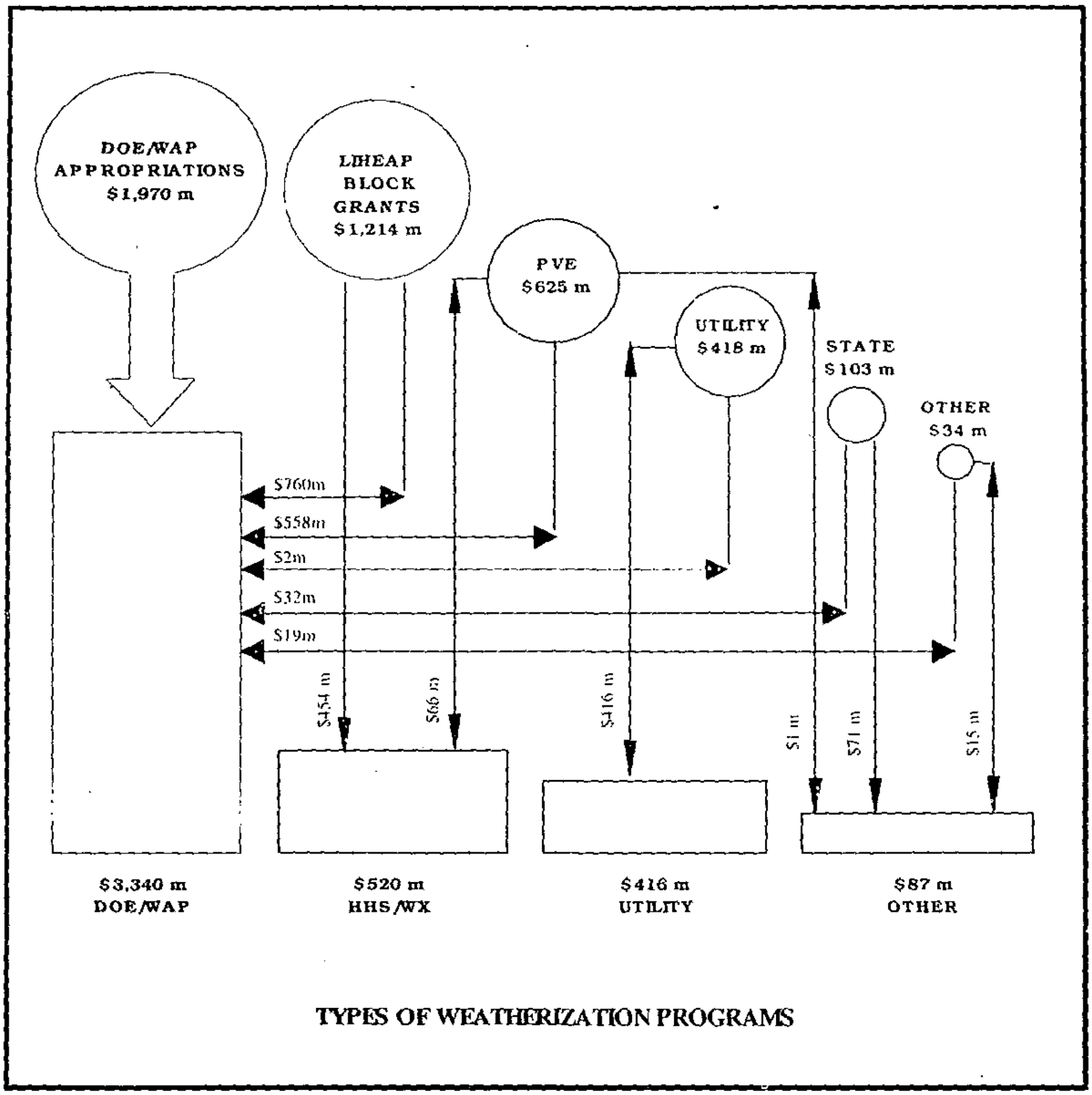


Three Major Sources of DOE Weatherization Program Funds, 1978 to 1992

To implement the Weatherization Program, DOE provides money to State Weatherization Agencies, more than 80 percent of which are located within executive departments responsible for human services, community development, or economic development. In turn, these agencies allocate funds to local agencies, of which 81 percent are private, nonprofit Community Action Agencies. Most of the remaining entities are local or county governmental agencies and Native American tribes. The weatherization work is done by employees of these local agencies or by contractors.

Although other organizations fund and implement low-income weatherization programs, DOE has been the dominant source of funding for low-income weatherization. Between 1978 and 1996, DOE provided 45 percent of total funding. More investment was made in low-income weatherization in the late 1980's than in earlier years, and considerably less in the 1990's than in the 1980's. More homes have been weatherized in cold states than in warm states, which partly reflects the formula used to allocate DOE's funds in the 1980's. That formula

SOURCES OF WEATHERIZATION PROGRAM FUNDS PY 1978-1989



Definitions of Program Types:

DOE/WAP = funds spent under DOE Weatherization Program rules and regulations.

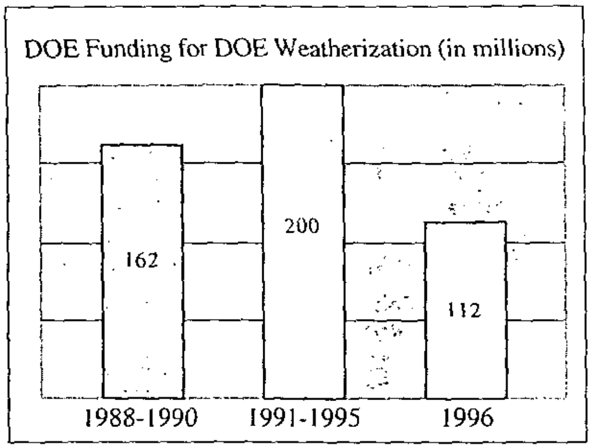
HHS/WX = funds spent under HHS LIHEAP guidelines and not DOE's rules and regulations.

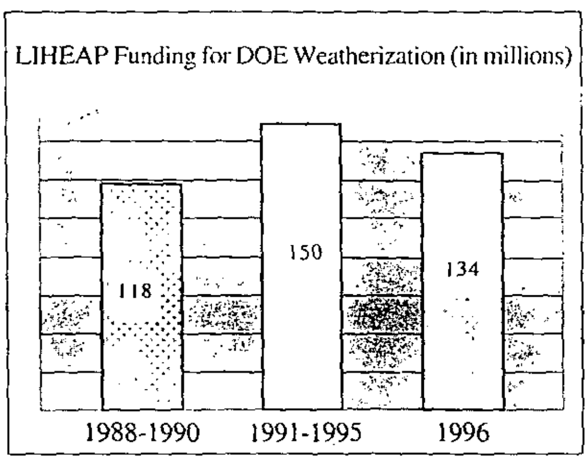
Utility = funds spent in utility programs independent of DOE's rules and regulations.

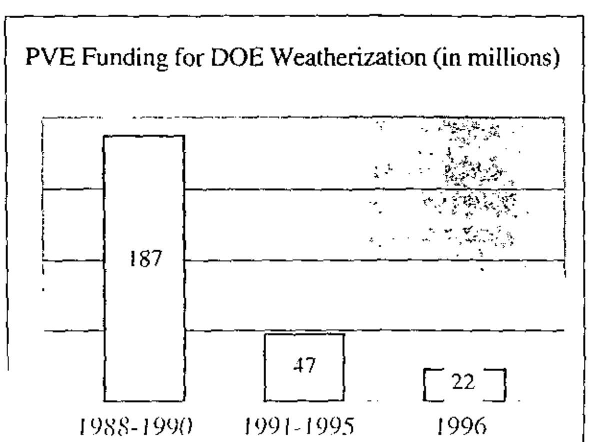
Other = funds spent in state weatherization programs or other independent programs.

weighted heating degree days much more heavily than cooling degree days. In 1995, the funding formula was changed to increase the proportion of funding going to warm climate states. The intent of the changes was to provide warm climate states with a greater share of the funding while protecting the Program capacity of the states with cooler climates. The revised formula emphasizes all residential energy expenditures (including heating and cooling costs). It provides states with a fixed base amount derived from the FY 1993 allocation. Funds in excess of those needed to meet the base amounts are allocated according to the revised formula. On a national level, DOE funding for its 1996 program totaled \$111.5 million, which compares to DOE funds of \$214.8 million in 1995. This nearly 50% reduction in funding in one year's time was the result of budget cuts passed by the 104th Congress.

Major Funding Sources for the DOE Weatherization Program Decreased Sharply in 1996



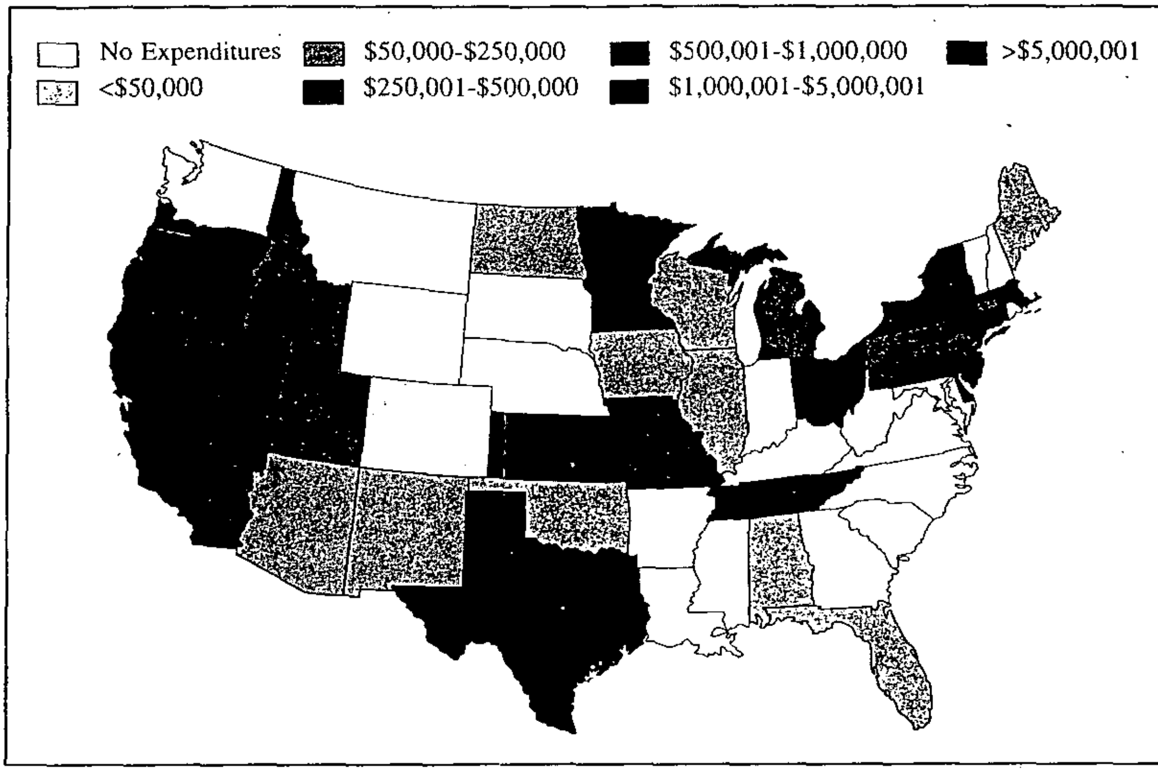




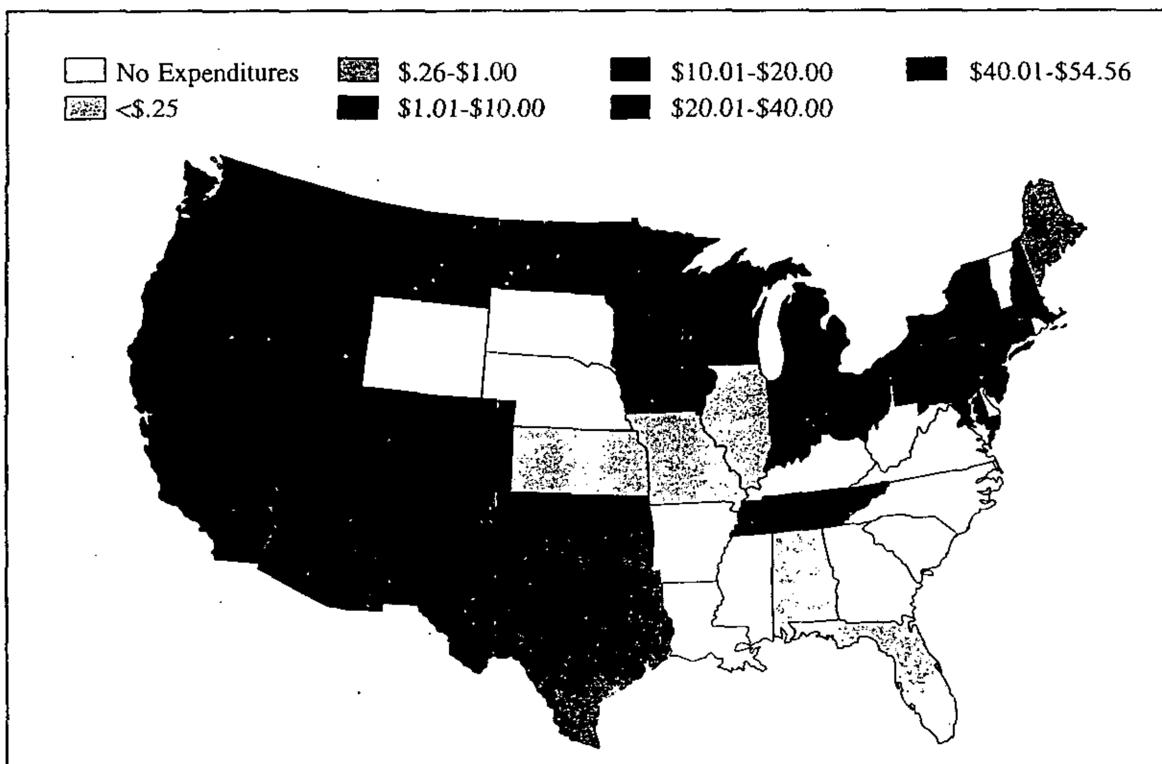
In the 1980s a major source of weatherization resources was the **Low-Income Home Energy Assistance Program (LIHEAP)**, administered by HHS. Since 1982, states have had the flexibility to allocate up to 15 percent of LIHEAP funds (now 25 percent after receiving a waiver) to energy conservation measures. Total LIHEAP funding peaked in 1987 and has since declined. In 1996, LIHEAP funds were about 72% of what they were in 1989. In spite of the reduction in total LIHEAP funding, however, the amount of LIHEAP funding spent on weatherization has actually increased. In 1989, \$106.1 million in LIHEAP funds were spent on weatherization. In 1996, \$134.0 million in LIHEAP funds were used for weatherization. This increase in LIHEAP contributions to weatherization, during a time when its overall budget declined, suggests that weatherization is seen as an especially effective way of producing a long-term reduction in the energy burdens of low-income households.

A third major source of weatherization money in the 1980s was the **Petroleum Violation Escrow (PVE) Fund.** These funds came from legal penalties assessed against oil companies convicted of violating price controls. The exhaustion of PVE funds devoted to low-income weatherization on a one-time basis was the most dramatic cause of the decline in total weatherization funding from 1987 to 1992. State program managers indicated that total funding for low-income weatherization dipped 30 to 40 percent between 1990 and 1994, primarily because of the exhaustion of PVE funds.

Utilities provided 9.6 percent of funding available for low-income weatherization between 1978 and 1989. Utility programs and funding were responsible for 22 percent of all units weatherized during that 12-year period. Among the 49 utilities that spent \$418 million on energy measures between 1978 and 1989 the average investment per unit was only about one-third as much as in the DOE Weatherization Program. A small amount of funding for low-income weatherization came



Geographic Distribution of Utility Expenditures on Low-Income DSM Programs in 1992

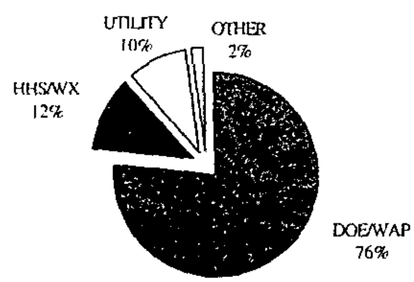


Geographic Distribution of Utility Expenditures per Low-Income Household in 1992

from miscellaneous other sources, including owners of rental housing weatherized under the Program and state weatherization programs, which in some cases emphasized comprehensive home repair or heating system retrofits.

The impending restructuring of the electric utility industry poses uncertain prospects for continued utility funding of low-income programs. Past programs to assist low-income households with energy efficiency have been funded through regulated utility rates, but obtaining low-income funding may become more difficult in a more competitive and less regulated industry structure. The Weatherization network has been actively presenting low-income interests and concerns to policymakers in state regulatory commissions and legislatures. As a result of these efforts, restructuring programs in states such as California and Massachusetts, which have been the first to initiate restructuring, have continued funding for low-income energy efficiency. The Weatherization network also continues to be successful in securing funding from utilities in other states where the pace of change is slower and traditional regulation remains firmly in place.

FULL SCALE WEATHERIZATION
BY PROGRAM PY1978-PY1989



$4.364 Billion

C. Uses of Funds: DOE Sets the Pace

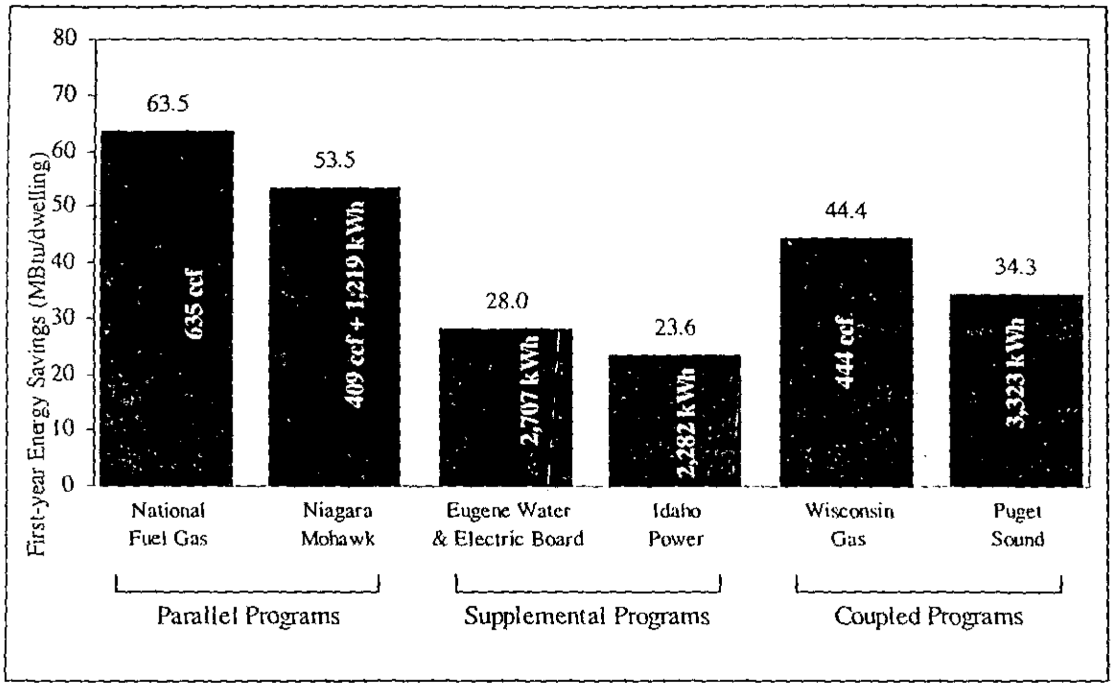
Regardless of its source, most funding for low-income weatherization has been spent according to DOE's Weatherization Assistance Program rules. By law, all funds appropriated to the Program by DOE are governed by DOE rules and regulations. In contrast, funds appropriated by LIHEAP can be spent by that program's much broader guidelines, which have allowed, for example, greater expenditures on furnace and boiler retrofits and replacements. Similarly, utility low-income DSM programs and state funding for weatherization can be spent as the funding agency deems appropriate.

In practice, 76 percent of all low-income weatherization money spent in the 12-year period between 1978 and 1989 was guided by DOE rules and procedures. Before 1989, about 12 percent was spent in programs under LIHEAP regulations. Today the percentage of funds spent under LIHEAP regulations has risen to 35 percent. DOE's central role in directing weatherization activities nationwide is underscored by the fact that the vast majority of non-DOE funds have been channeled through the Program. This distribution process also indicates the importance of the new Program rules in guiding future weatherization activities.

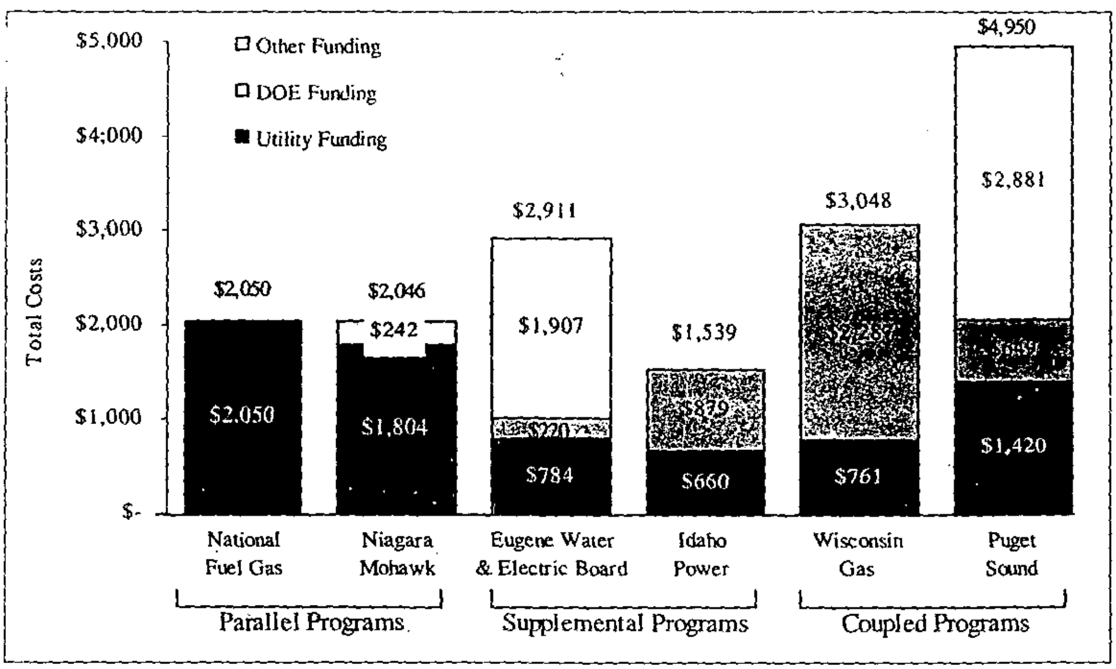
D. Utility Partnerships

Utility programs made significant contributions to the effort to weatherize low-income dwellings. According to Power et al. (1992), 102 utility low-income energy-efficiency programs operated in 1989, with investments totaling $97 million (or $109 million, expressed in 1992 dollars). By 1992, these numbers had increased to 132 programs with an annual expenditure of $141 million (Brown et al., 1994).

PROFILES OF SIX COORDINATED PROGRAMS



First-Year Energy Savings of Six Coordinated Programs



Costs of Six Coordinated Programs by Source of Funding

Utility programs tend to be concentrated in a few states where weatherization services for low-income customers have been mandated by regulatory bodies. On average, utility-sponsored low-income programs invest about one-third as much per dwelling as the DOE Program. Unlike the DOE Weatherization Program, many of the electric utility programs for low-income customers focus primarily on lighting and appliance measures. Water-heating measures (particularly low-flow showerheads) are common to both gas and electric utility low-income programs. "Major" measures such as attic, wall, and floor insulation and storm windows are less common in these utility programs than in DOE's Weatherization Program.

By pooling utility and government resources in "coordinated" programs, utilities are able to offer more comprehensive weatherization to their low-income customers. Three types of utility low-income partnerships exist, which involve varying degrees of coordination between government and utility cosponsors (Brown and Hill, 1994).

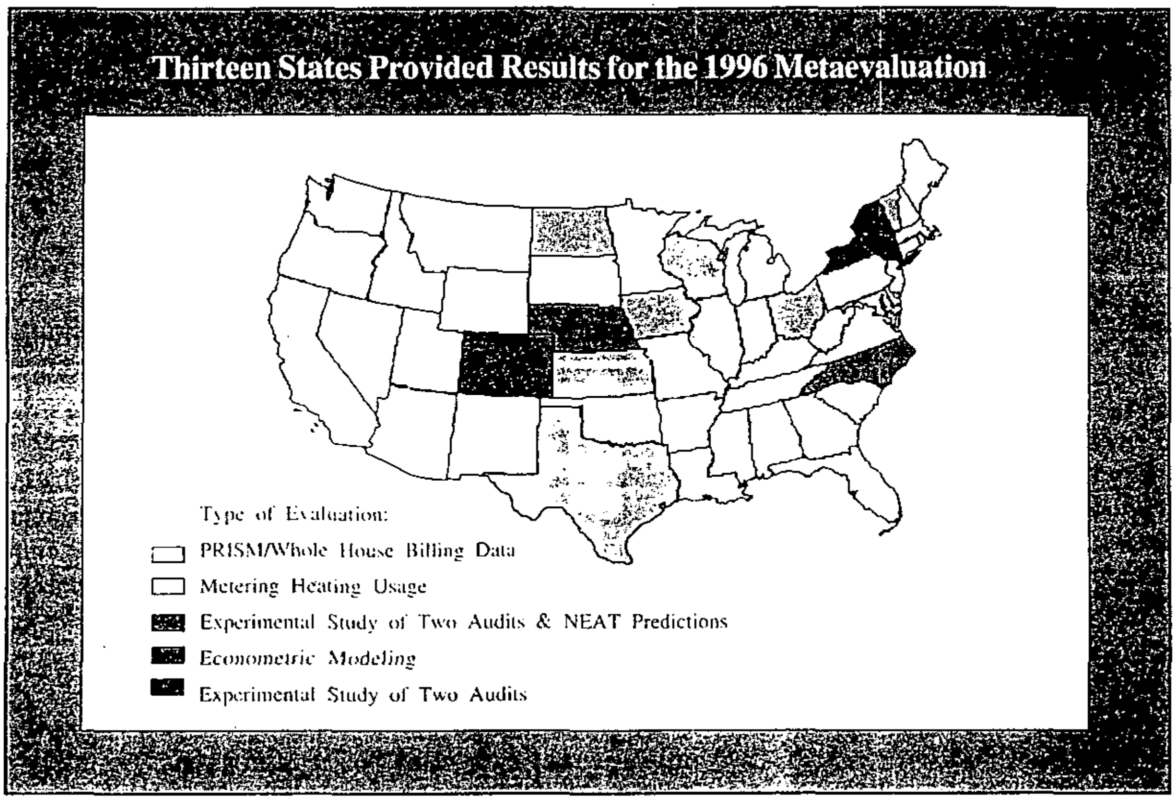
•**Parallel Programs.** In these cases, the local weatherization agency operates two parallel programs--one funded by government grants and the other funded by utility contracts. The utility simply employs the agency as a subcontractor to deliver energy-efficiency services to low-income households. The utility-funded program is coordinated in the sense that some of the same staff and equipment are used by both programs.

•**Supplemental Programs.** These programs use utility funds to supplement the agency's government-funded weatherization program, with no changes to the operation of that program. The result is more weatherized homes, more comprehensive weatherization, or both.

•**Coupled Programs.** These programs employ a combination of utility and government funds to deliver weatherization services as part of an integrated program that is distinct from the agency's preexisting government-funded program. This type of program has the potential to outperform parallel and supplemental programs by taking advantage of the unique capabilities of each cosponsor.

Each of these types of coordinated programs provides utilities with access to trained weatherization professionals and associated equipment, which is often quite sophisticated and conducive to high-quality weatherization. In many regions of the country, there is a scarcity of such capability. In addition, community action agencies are often uniquely qualified to tackle the problems associated with substandard shelter.

Brown and Hill (1994) conducted case studies of six coordinated low-income weatherization programs. All six programs achieved impressive levels of energy savings. For the three coordinated gas programs, annual savings ranged from 409 to 635 ccf (hundred cubic feet) per dwelling, and for the three electric utility programs, annual savings ranged from 2,282 to 3,323 kWh (kilowatt-hours) per dwelling. Costs for the six coordinated programs ranged widely from $1,539 to $4,950 per dwelling. This range of costs is high relative to the amount typically spent in the DOE Weatherization Program, which averaged $1,550 per dwelling in 1989. In



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

	Mbtu of Natural Gas Saved per Dwelling	Percentage Reduction in Natural Gas Consumption for Space Heating	Percentage Reduction in Natural Gas Consumption for All End Uses
National Evaluation Results for 1989	17.3	18.3%	13.0%
Metaevaluation Results for 1996 Based on Regression Model	31.2	33.5%	23.4%

Need to Update National Estimate of Savings

- National Evaluation estimated savings for homes weatherized in 1989.
- Program performance has improved during the last seven years.

Objectives of Metaevaluation

- Locate state-level evaluations
- Review evaluations
- Organize findings
- Develop method of applying state-level findings to nation
- Estimate regression models
- Apply model results to national inputs to develop national estimate

Ten States With One Evaluation

- Colorado (1993-1995)
- Indiana (1991-1992)
- Kansas (1992)
- Nebraska (1994)
- New York (1990)
- North Carolina (1990)
- North Dakota (1990-1992)
- Texas (1991-1992)
- Wisconsin (1992)
- Wyoming (1996)

Three States With More Than One Evaluation

- Iowa (1992-93) and (1995)
- Ohio (1990-91), (1993-94), and (1994-95)
- Vermont (1992-93) and (1993-94)

addition, it is much higher than the typical investment levels of stand-alone utility-operated low-income weatherization programs.

The utilities and community action agencies managing each of the six coordinated programs indicated that the benefits of coordination far outweighed the costs.

IV. METAEVALUATION METHODS AND RESULTS FOR 1996

A number of state Program offices conduct periodic evaluations of the energy savings produced by their efforts. With the help of these offices, a metaevaluation of 17 state-level evaluations conducted since 1990 was recently completed for DOE by Oak Ridge National Laboratory.

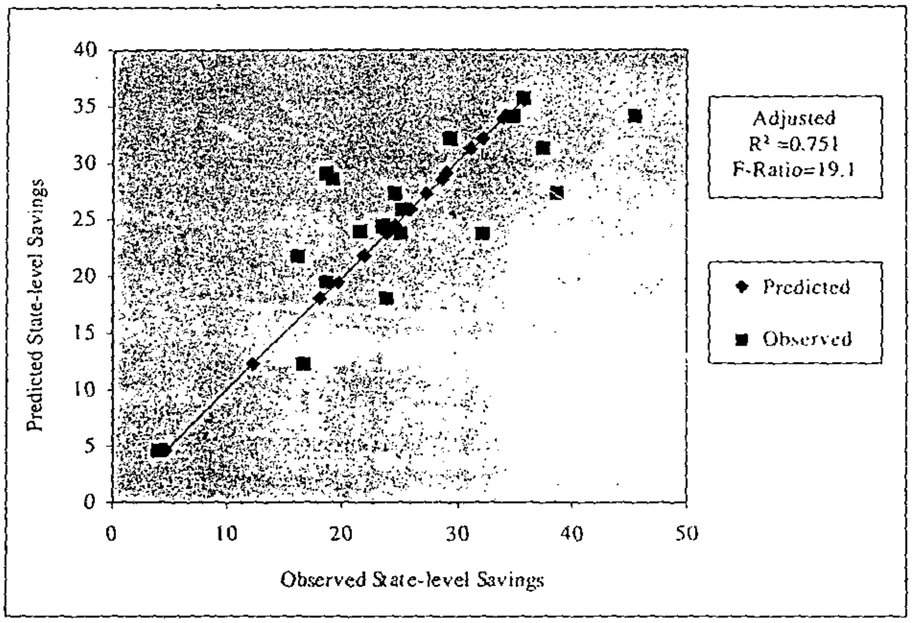
The state-level evaluation results were used to produce the estimate of national savings for 1996 discussed below (Section A). This estimate was developed by summarizing and integrating the findings of the state-level evaluations (Berry, 1997). The results are only for homes heating with natural gas, the only fuel for which all of the state-level evaluations provided results. Three of the thirteen states with evaluations conducted since 1990 had evaluated their Program more than once in the last seven years.

The approach chosen to estimate the 1996 national savings was to use regression modeling to develop the best linear equation for predicting savings. The data from the 17 recent state-level evaluations (1990-1995) were used to develop this predictive tool. Then the parameters of the best predictive model were applied to the appropriate average national input values for each predictor in the equation. For example, the average heating degree days for the available evaluations was 5,942. Nationally, the population weighted 30-year average of heating degree days is 4,499. Therefore, the national average of 4,499 heating degree days was used as the input to the regression model used to predict national savings. For the most part, national input values were taken from the National Evaluation, which was based upon a representative national sample. Details of model development and of the rationale for selecting specific national input values are given in Berry (1997).

A. Three Methods Show Trend Toward Higher Savings

Regression Analysis. The key finding of the Metaevaluation's regression analysis is that, in the last seven years, improved practices have produced 80% higher average energy savings per dwelling. The most recent comprehensive evaluation of the Program was based on an analysis of changes in pre- and post-weatherization energy consumption for a representative national sample of homes weatherized in 1989. This National Evaluation found that dwellings that heated primarily with natural gas, which made up over 50% of the national sample, had average savings of 17.3 Mbtu per dwelling, which was 18.3% of space heating consumption, or 13.0% of the total consumption of natural gas for all end

Predictive Value of Fit for the Three-Variable (Pre-Weatherization Consumption, Year, Audit Type) Regression Model



Literature Review Findings on Central Tendencies Characterizing the Percentage of Energy Savings in 1981-1989 and in 1990-1996

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

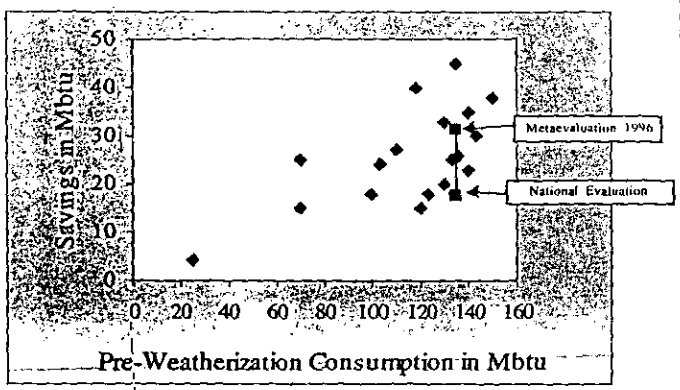
Upward Trends in Energy Savings in Ohio, Vermont, and Iowa

Ohio			Vermont			Iowa		
	Mbtu	Percent		Mbtu	Percent		Mbtu	Percent
1990-91	20.5	12.6%	1992-93	18	17.8%	1992-93	25.2	18.6%
1993-94	29.3	20.4%	1993-94	24.5	20.1%	1993-94	n/a	n/a
1994-95	31.0	22.5%	n/a	n/a	n/a	1995	27.3	21.7%

uses (Brown, Berry, Balzer, and Faby, 1993). The Metaevaluation of state-level evaluations of the Program, which developed a regression-based national estimate of savings, indicated that savings in 1996, in homes using natural gas as the primary heating fuel, were 31.2 Mbtu, which was 33.5% of natural gas space heating consumption, or 23.4% of the total consumption of natural gas for all end uses (Berry, 1997).

Literature Review Findings. In addition to the regression modeling results summarized above, two additional types of evidence (from a literature review and from comparisons within the same state over time) demonstrate the trend toward increased Program energy savings.

At Same Levels of Pre-Weatherization Consumption, Most Evaluations Completed Since 1990 Show Higher Savings Than in 1989



Six years before conducting the 1996 Metaevaluation, ORNL completed a similar task in preparation for the National Evaluation. That task was a literature review (which was completed in 1990) and is presented in Section 1.4 of Brown et al., (1993). Comparisons of findings from the 1990 and 1996 literature reviews show a trend toward increased savings. The 1990 literature review concluded that the state-level evaluations available at that time (covering the years of 1981-1989) showed typical energy savings (expressed as the percentage reduction in the total consumption of the primary heating fuel) of between 12% and 16%, with a range of 6% to 23% savings in various locations. The 1990 literature review also concluded that a number of demonstration projects indicated that the Program could potentially achieve much greater savings (25% to 40%). The similarity in findings from that literature review (i.e., expected average savings of 12% to 16%) and the results of the National Evaluation (13.0% of the total consumption of natural gas for all end uses or 18.3% as a percentage of consumption for space heating) created confidence that a review of the state-level evaluations conducted since 1990 would also yield a reasonably accurate current estimate of national savings. The 1996 review of state-level evaluations covering weatherizations performed in 1990 through 1996 showed typical savings of 18% to 24% (expressed as the percentage reduction in the total consumption of the primary heating fuel), with a range of savings from 13% to 34%.

1996 PROGRAM IMPROVEMENTS/NONENERGY BENEFITS

Some Reasons for Improved Program Performance in 1996

Shift From Priority Lists to Advanced Audits
- No advanced audits in 1980's
- 37 States used advanced audits in 1996

More Use of Blower-Door Directed Air Sealing

Increased Targeting of Dwellings With High Potential for Savings

Revised DOE Regulations That Promote More Cost-Effective Tailoring of Measures to the Specific Needs of Individual Dwellings and Regions
- Removed barriers to heating system efficiency measures
- Allowed cooling measures
- Promoted use of advanced audits

Nonenergy Benefits are Numerous and Important

Affordable Housing
- maintain or enhance residential property values
- extend the lifetime of low-income housing
- decrease homelessness and mobility

Improving Comfort, Health, and Safety
- improve livability and thermal comfort of homes
- prevent fires
- reduce CO hazards from defective and unvented heating systems

Impacts on Household Budgets
- increase resources for nonenergy expenditures

Utility Benefits
- reduce utility arrearages
- reduce utility terminations and reconnections

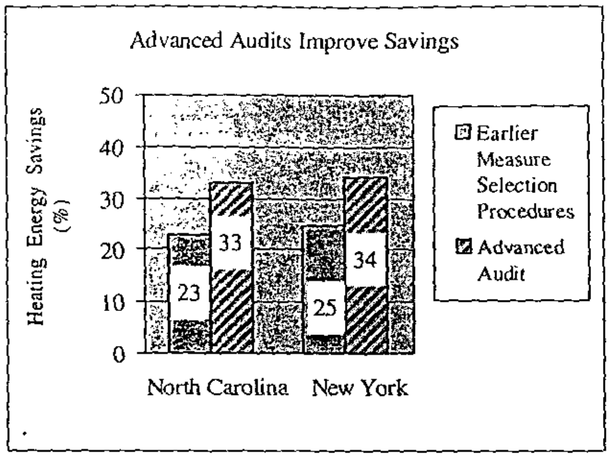
Employment and Economic Benefits
- increase economic output
- increase employment
- generate tax revenues

Environmental Benefits
- reduce emissions of combustion by products

Trends within States. Three states for which savings could be compared over time -- Iowa, Ohio, and Vermont -- all showed significant increases in savings. The trend toward increased savings over time in these states is unmistakable.

B. Reasons for Increases in Program Savings

Several reasons exist for the trend toward higher savings. Three important technical improvements are discussed below.



Advanced audits had not yet been introduced in 1989. Today 37 states use them. Two demonstration studies, one in New York and one in North Carolina, have shown the superior energy savings achieved with the use of advanced audit procedures (New York State Energy Research and Development Authority and New York State Department of State, 1993; Sharp, 1994). In North Carolina the introduction of an advanced audit increased heating energy savings from 23% to 33%. In New York, savings increased from 25% to 34%.

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

Targeting high-energy consumers is a Program management technique that produces higher savings. More agencies use this practice today. Many studies have shown that high pre-weatherization consumption is the best predictor of high energy savings (Brown et al., 1993; Columbia Gas of Ohio, 1995; Pennsylvania Public Utility Commission, 1994, Berry, 1997).

Additional reasons to expect a trend toward higher energy savings relate to the implementation of Program regulations designed to capture opportunities for improvement. Among the **revised DOE regulations** issued in 1994 were changes that promote the use of advanced audits and permit the use of **cooling efficiency measures** such as air conditioner replacements, ventilation equipment, and screening and shading devices.

C. Nonenergy Benefits of Weatherization

Most of the state-level evaluations did not address the issue of the nonenergy benefits of weatherization at all. Only one, the Iowa evaluation, gives much attention to nonenergy benefits. The Iowa evaluation notes that the potential benefits of weatherization include:

- improved client safety and health;
- reduced utility collection costs and write-offs;
- improved property value, longevity, and maintenance of affordable housing;

Summary of 1994 Regulatory Changes Governing DOE's Weatherization Program

	OLD RULES	NEW RULES[a]
Weatherization materials and measures	Services provided include: -air sealing -caulking and weather stripping -furnace and boiler tune-up, repair, and replacement -cooling system tune-up and repair -replacing windows and doors and adding storm windows and doors -insulating attics, walls, and foundations -client education	Added the following: -replacement air conditioners -ceiling, attic, and whole-house fans -evaporative coolers -screening -window films
Materials requirement	40% of funds must be spent on materials	Waiver of 40% requirement may be granted if an advanced audit procedure is used
Rental unit requirements and protections	Owner permission 66% of eligibility required for large multifamily units and 50% eligibility required for duplexes and four-unit buildings Weatherization benefits to accrue primarily to low-income tenants	Expanded renters protection -benefits and no rent increase even for renters paying for energy through rent -States may require financial participation from landlords
Eligibility and targeting	Up to 125% of poverty, or the state may elect to use LIHEAP eligibility criteria Special consideration given to the elderly and persons with disabilities	Special consideration also given to families with young children
Reweatherization	Allowed reweatherization of unit partially weatherized from September 30, 1975 to September 30, 1979	Cut-off date for reweatherization extended to September 30, 1985

[a]The final version of the new DOE rulemaking was published in the Federal Register of March 4, 1993.

- reduced environmental impacts from energy production and transport; and
- additional economic activity and jobs for Iowa.

Only the economic activity and job creation benefits were quantified in the Iowa study. Using an input-output analysis, the study concluded that each million dollars of Program spending produces about $240,000 worth of additional economic activity. This additional economic activity supports 5.6 additional jobs (The Statewide Low-Income Collaborative Evaluation (SLICE) of Iowa, 1994). The Iowa study did not assign a specific dollar value to any additional nonenergy benefits. However, it concluded that even conservative estimates of these nonenergy benefits would significantly increase the cost effectiveness of the Program.

In the National Evaluation, an effort was made to quantify the dollar value of some nonenergy benefits. The highest dollar values were assigned to employment and environmental benefits (Brown, Berry, Blazer, and Faby, 1993). The methods used to estimate the dollar value of the range of nonenergy benefits varied. These methods are explained in Chapter 6 of Brown et al. (1993). The final estimate of the net present value of all of nonenergy benefits that were monetized was set at $976 per dwelling in 1989 dollars. This is the estimate that is used in the next section to estimate Progam cost effectiveness from the societal perspective, which is the only perspective that includes nonenergy benefits.

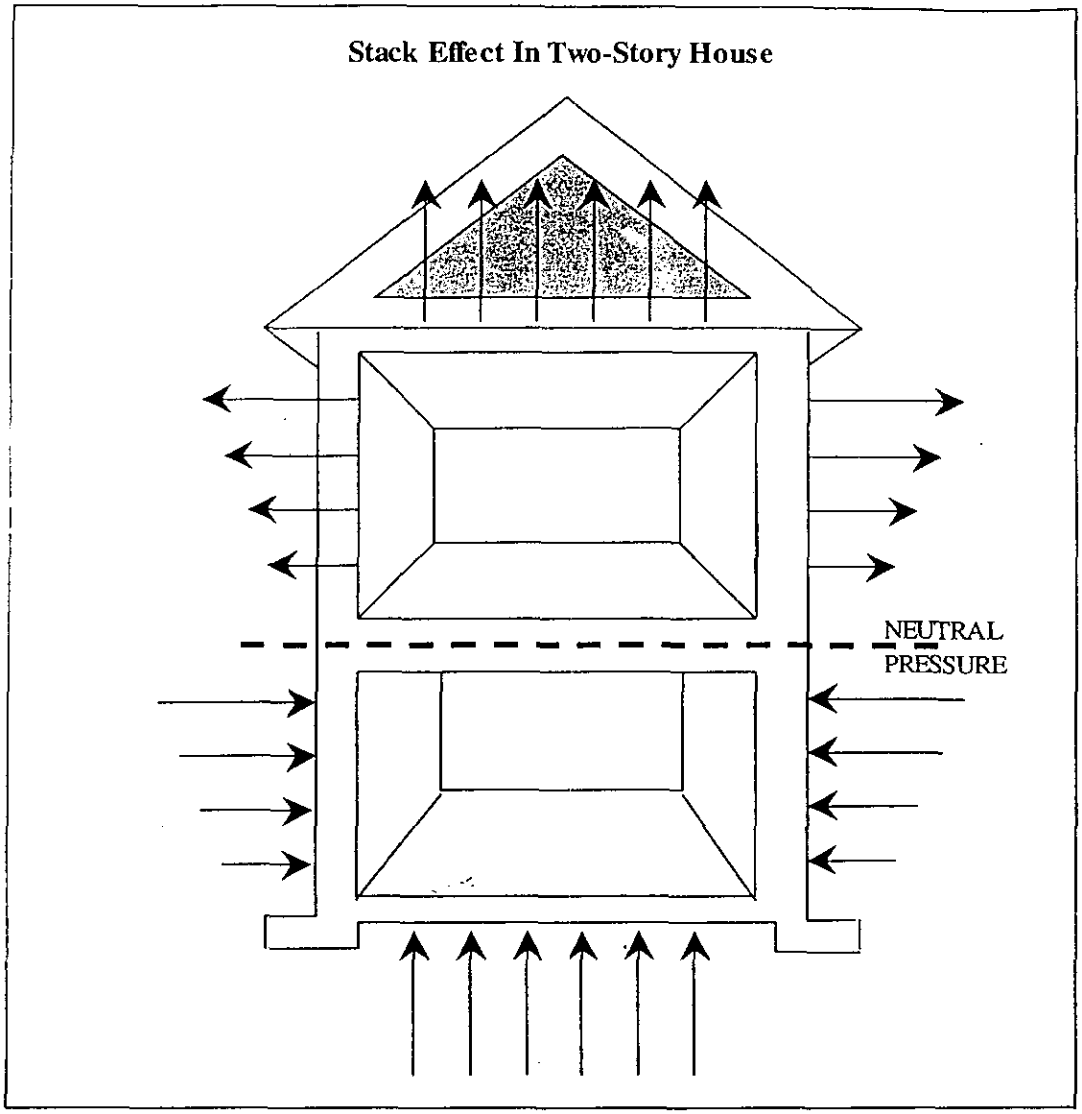
D. Cost-Effectiveness Results

Because of the higher average national savings estimated for the Program in 1996, cost-effectiveness estimates also increased. The National Evaluation used three perspectives[1] for estimating cost effectiveness:

- the program perspective, which compares energy benefits to total costs;
- the installation perspective, which compares energy benefits to installation costs; and
- the societal perspective, which compares energy and nonenergy benefits to total costs.

[1] In the National Evaluation, three perspectives were used to develop benefit/cost ratios: the program perspective, the installation perspective, and the societal perspective. The program perspective compares the discounted value of energy savings to total program costs (including labor, materials, overhead, administrative, and all other categories of both fixed and variable costs). The installation perspective compares the discounted value of energy savings to installation-related program costs (i.e., installation labor and materials costs). The societal perspective compares the discounted value of both energy and nonenergy benefits (such as employment and environmental benefits) to total program costs (including labor, materials, overhead, administrative, and all other categories of both fixed and variable costs). All three perspectives used an assumed measure lifetime of 20 years and a discount rate of 4.7%. To make the 1996 benefit/cost ratios comparable to the National Evaluation ratios the same definitions and assumptions were used.

AIR INFILTRATION/EXFILTRATION



Very leaky houses are uncomfortable and have high energy bills, so finding and curing infiltration problems is a high priority for weatherization operations. The rate of air infiltration in a home depends on many factors, the most important being the size and location of holes in the thermal envelope and the difference in temperature between inside and outside. Warm air inside a dwelling gives rise to "stack effect" infiltration as it tries to escape from the top of the envelope, sucking in cold air at the bottom. Wind and leaks in duct systems can also have a major effect on infiltration, but these effects are not usually as constant over the heating season as is stack-effect infiltration, which is at its worst on coldest days.

Note that in the middle of the heated envelope there is a neutral pressure zone where neither infiltration nor exfiltration occurs due to stack effect. This explains why caulking and weatherstripping in mid-envelope tends to save less energy than careful attention to the bottom and top of the envelope, where these natural driving forces are greater.

Benefit/Cost Ratio for Gas-Heated Dwellings in 1989 and 1996

PERSPECTIVE	BENEFITS INCLUDED	COSTS INCLUDED
PROGRAM	Energy Savings Only	All Costs
	1989 Benefit/Cost Ratio = 1.06 1996 Benefit/Cost Ratio = 1.79	
	BENEFITS INCLUDED	COSTS INCLUDED
INSTALLATION	Energy Savings Only	On-Site Installation Costs
	1989 Benefit/Cost Ratio = 1.58 1996 Benefit/Cost Ratio = 2.39	
	BENEFITS INCLUDED	COSTS INCLUDED
SOCIETAL	Both Energy and Nonenergy Benefits	All Costs
	1989 Benefit/Cost Ratio = 1.61 1996 Benefit/Cost Ratio = 2.40	

E. Conclusions from the 1996 Metaevaluation

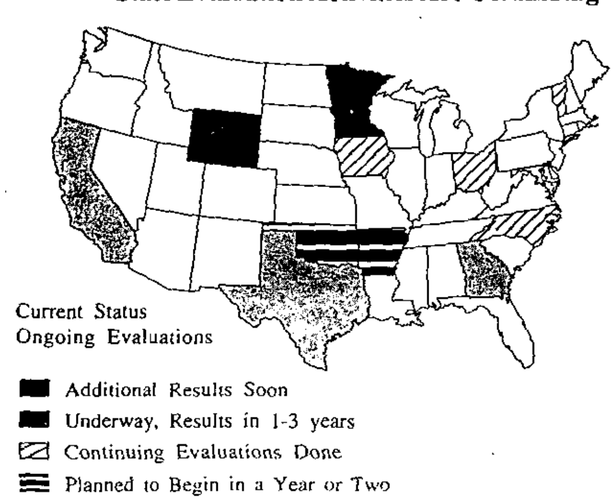
All aspects of the Metaevaluation point to improved performance during the past seven years. **In spite of funding reductions, technical advances have produced 80% higher energy savings on a per dwelling basis. Increases in energy savings were achieved through better training, audit tools, and management practices with little increase in costs.** The trend toward increased savings was demonstrated in three ways:

- regression modeling results obtained from a metaevaluation of 17 state-level evaluations;
- comparisons of a 1990 and a 1996 literature review of state-level evaluations; and
- comparisons of within state savings over time.

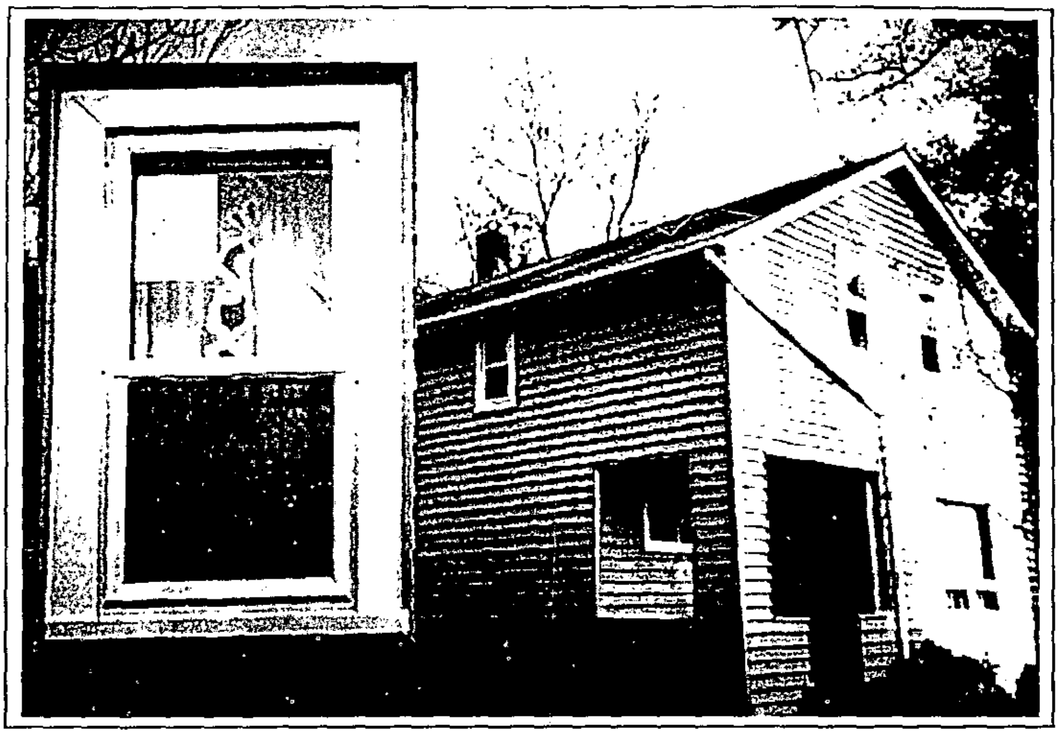
Each of these approaches pointed to significant increases in Program energy savings. As a result, Program benefit/cost ratios are even higher today than they were in 1989, with a 1996 societal benefit/cost ratio of 2.40.

The DOE will continue to monitor on-going state-level evaluation efforts and will conduct several cooperative state-level evaluations in the next few years. Results of additional state-level evaluations will be incorporated into the metaevaluation framework as they become available. Periodically updated metaevaluation results will be used to track Program performance.

State Evaluation Activities Are Continuing



Housing Rehabilitation



This rehabilitated home had new windows installed with HUD funds, and insulation installed with DOE funds.

Before Weatherization

This dilapidated home which received an impressive retrofit is one example of the substandard housing local agencies often serve. Holes in roofs, walls, and ceilings, and broken windows are common problems. Leveraged funds from non-DOE sources are often used to meet housing rehabilitation needs.

After Weatherization

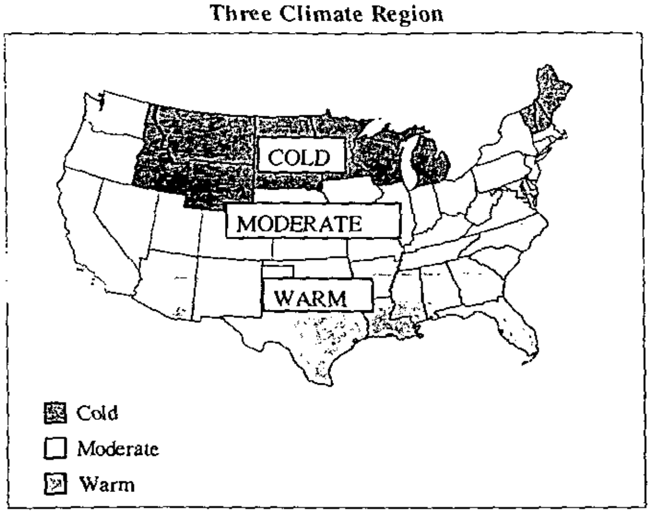
V. NATIONAL EVALUATION METHODS AND RESULTS FOR 1989

A. National Evaluation Process and Publications

The National Weatherization Evaluation was a comprehensive evaluation of the Weatherization Assistance Program, which was designed to accomplish the following goals:

- estimate energy savings and cost effectiveness;
- assess nonenergy impacts;
- describe the weatherization network;
- characterize the eligible population and resources; and
- identify factors influencing outcomes and opportunities for the future.

The National Weatherization Evaluation's Three Climate Region



Working groups with more than 30 nationally known evaluation specialists and conservation program professionals were formed to help define these goals. They gave guidance to the ORNL evaluation team in planning five major studies and in reviewing draft reports. The five studies were as follows:

Single-Family Study--this study estimated the national savings and cost effectiveness of weatherizing single-family and small multifamily dwellings that use natural gas or electricity for space heating.

Fuel-Oil Study--this study estimated the savings and cost effectiveness of weatherizing single-family homes in nine northeastern states that use fuel oil for space heating.

Multifamily Study--this study described the measures used, resources employed, and challenges faced in weatherizing large multifamily buildings.

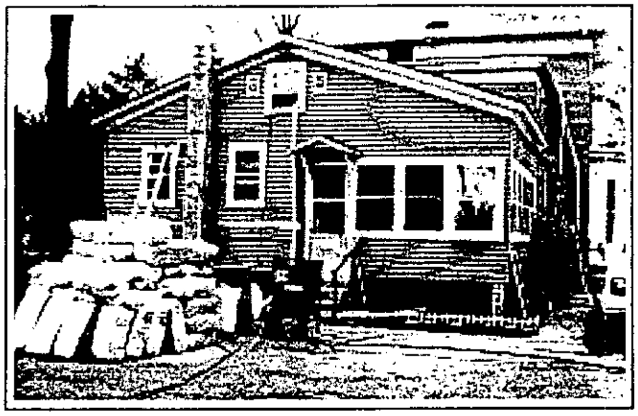
Network Study--this study characterized the weatherization network's leveraging, capabilities, procedures, staff, technologies, and innovations.

Resources and Population Study--this study profiled low-income weatherization resources, the weatherized population, and the population remaining to be served.

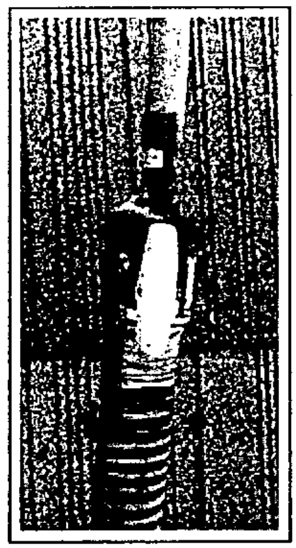
DENSE-PACK CELLULOSE

Installing cellulose at high density has been found to be a powerful technique for installing insulation and achieving air sealing at the same time. Many crews find that the infiltration rates of some houses can be cut in half without using a tube of caulk. The secret is careful installation of high-density cellulose in wall cavities (and other places where it really counts) with a tube inserted directly where the insulation needs to go--and using power blowing machines to pack it in tightly.

Powerful blowing machines make the job of installing cellulose insulation more efficient.



Installing insulation as the snow flies.

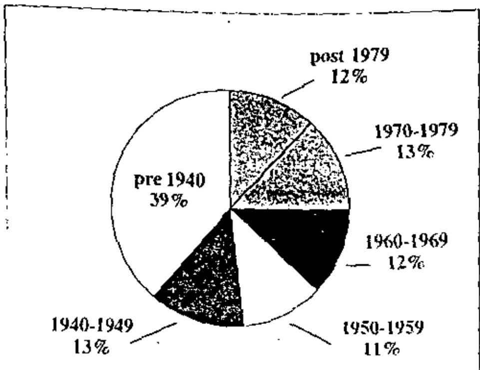


The small tube at the top is snaked into wall cavities, then slowly withdrawn as insulation fills them up. The result is a very tight fill.

Preparation, insulation, and cleanup keeps two weatherization team members working for most of a day.

Wall preparation. Shingles are positioned for fast reattachment after insulation blowing.

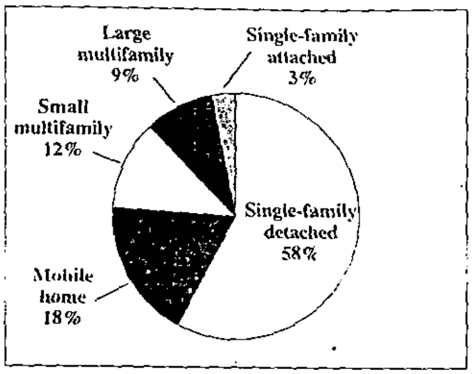
The findings from each of these studies were documented in a series of eleven reports published between 1990 and 1994. References to these reports are at the end of this document.



Year of Construction of Dwellings Weatherized in 1989

B. Diversity of Dwellings and Agencies

Perhaps the most striking finding of the comprehensive National Evaluation was the diversity among local weatherization agencies across the country. Some agencies weatherized 15 homes in a year; others weatherized thousands. Some agencies achieved savings of 30 to 40 percent of pre-weatherization consumption. Others produced no measurable savings. Some agencies employed state-of-the-art procedures, used a variety of funding and technical resources, and performed sophisticated self-evaluations. Others followed the same procedures year after year, did not evaluate their impacts, and relied entirely on DOE for funding. With the downsizing of the Program in the last few years, many areas previously served by the smaller agencies have been incorporated into larger agency service areas.



Types of Dwellings Weatherized in 1989

The housing stock addressed by the Program also is diverse. Most low-income people live in homes built when energy was not an expensive commodity. Poor insulation and leaky construction have wasted energy from the start, and, inevitably, aging makes structures more energy inefficient, more expensive to heat, and often cold, unsafe, and unhealthy. Among the dwellings weatherized in 1989, 39 percent were more than 50 years old. On the other hand, only 12 percent were less than 10 years old.

Dwellings can be classified into five types. Each type has unique weatherization needs.

Single-family detached homes were the dominant type of structure weatherized by the Program in 1989 (representing 58 percent of the total). Half of these single-family detached units heated primarily with natural gas, and only 10 percent heated with electricity. Elderly occupants resided in 40 percent of these houses, a higher concentration than for any other dwelling type. The vast majority of these houses (73 percent) were owner-occupied.

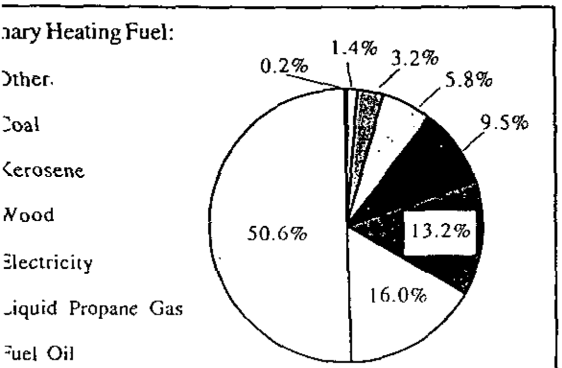
Single-family attached dwellings (often called row houses) comprised the smallest housing-type category (3 percent of the weatherized population). Almost all were centrally heated (93 percent). As a class, these were the oldest buildings, with a mean age of 56 years. They also tended to have higher-income occupants and were located almost entirely in the moderate region.

Mobile homes comprised 18 percent of the weatherized population. They were by far the "newest" units, with an average age of only 17 years. These homes were more likely than any other housing to be heated with a nonmetered fuel (mainly propane) and were 78 percent owner-occupied. Mobile homes were occupied by individuals with the lowest incomes.

Net average annual energy savings (by fuel type) per dwelling for dwellings weatherized in 1989 (based on a billing analysis of a representative national sample of homes) ***Estimated average annual savings per dwelling heated with natural gas in 1996 (based on a regression model developed from 17 state-level evaluations of natural gas savings conducted between 1990 and 1995)***			
Primary heating fuel	Percent of space heating consumption	Percent of total fuel consumption	Net savings (Mbtu/year)
Natural gas 1989 National Evaluation ***1996 Metaevaluation (estimated from regression model)***	18.3% ***33.5%***	13.0% ***23.4%***	17.3 Mbtu/year ***31.2 Mbtu/year***
Electricity	35.9%	12.2%	18.9 Mbtu/year
Fuel Oil (Northeast)	17.7%	17.7%	22.4 Mbtu/year
All fuels*	18.2%	13.5%	17.6 Mbtu/year

*includes estimates for propane, wood, kerosene, and other fuels

Small multifamily dwellings (those located in buildings with 2 to 4 units) comprised 12 percent of the weatherized population. They were heated primarily with natural gas (73 percent) and were typically renter-occupied (82 percent). Compared to single-family detached homes, they were only half as likely to have an elderly or handicapped occupant.



Distribution of Weatherized Dwellings by Primary Heating Fuel

Large multifamily dwellings comprised 9 percent of the weatherized population and represented a distinct building type. They were located almost entirely in the moderate and cold regions (approximately half are located in New York City), and they tended to be older than the single-family dwellings weatherized by the Program (52 percent vs. 38 percent were built before 1940). This type of dwelling is, for the most part, centrally heated by gas, electricity, or fuel oil.

C. Program Benefits

National Energy Savings in 1989

Equivalent 1989 Savings in Barrels of Oil

per day	1,650
per year	601,000
20-year lifetime	12 million

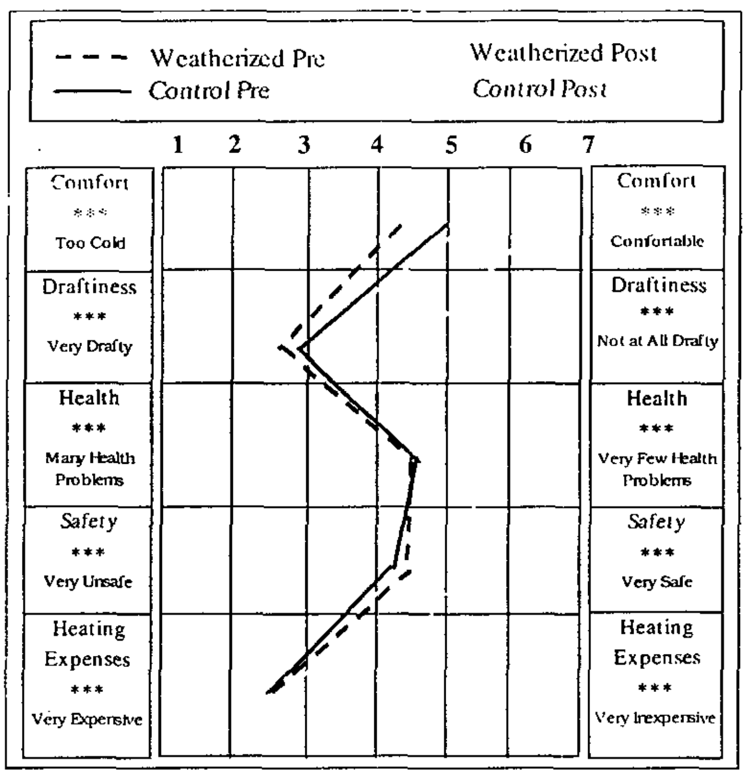
During Program Year (PY) 1989, the Program weatherized 198,000 single-family or small multifamily homes, resulting in net energy savings during the following year equivalent to 601,000 barrels of oil, or almost 1,650 barrels of oil per day.[2] Over the estimated 20-year lifetime of the weatherization measures, net savings from Program expenditures in 1989 are projected to be **69.7 trillion Btus, the energy equivalent of 12 million barrels of oil.** These estimates are based on measured reductions in the use of primary heating fuels after weatherization. Savings of supplemental heating fuels were not measured.

Gas-heated dwellings accounted for 50 percent of the dwellings weatherized by the Program in 1989. It is estimated that the Program, which addresses only space heating and sometimes water heating energy efficiency, saved 18.3 percent of the gas used for space heating. This represented 13.0 percent of total gas use, including water heating, cooking, and other gas-appliance uses. Variations in savings by dwelling type were significant. For example, single-family detached dwellings (the dominant dwelling type served by the Program) saved over 50 percent more natural gas per dwelling than did mobile homes.

Electrically heated homes represented only 10 percent of the dwellings weatherized under the Program during 1989. Weatherization of these dwellings saved 35.9 percent of the electricity used for space heating. This represented 12.2 percent of total electricity use. As with gas-heated homes, both single-family detached and small multifamily dwellings saved more electricity than did mobile homes.

[2]A barrel of oil is equal to 42 U.S. gallons and represented approximately two weeks of petroleum consumption per ican in 1990. The equivalent number of barrel(s) of oil is, of course, a concrete way of expressing the 3,370 billion British al units (Btus) saved during 1990 due to weatherization work on single-family dwellings during Program Year 1989. In , of course, the savings occurred not only in gallons of oil, but also in hundreds of cubic feet (ccf) of natural gas, kilowatt-(kWh) of electricity, and other units of fuel. Where electricity is concerned, savings reported include the energy required erate electricity at its source.

Type of nonenergy impact	Value of the impact per dwelling
Increased property value	$126
Reduced incidence of fire	$3
Reduced arrearages	$32
Federal taxes generated from direct employment	$55
Income generated from indirect employment	$506
Avoided costs of unemployment benefits	$82
Environmental externalities	$172
Total	$976



Occupant Perceptions of Nonenergy Benefits of Weatherization in Weatherized and Control Dwellings

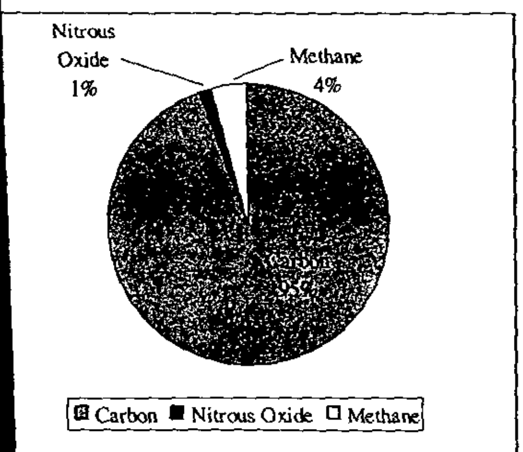
The Fuel-Oil Study showed that an average single-family dwelling located in the Northeast and heated primarily by fuel oil saved 160 gallons of fuel oil in the first year following weatherization. This is equivalent to 22.4 million Btus, or 17.7 percent of total fuel-oil use. (Fuel oil is generally used only for space heating.)

Measured savings for gas, electricity, and fuel oil were combined with estimates of energy savings for dwellings that heated primarily with other fuels such as propane, wood, kerosene, and coal. The average savings for all single-family and small multifamily dwellings weatherized in 1989 was estimated to be 17.6 million Btus per year, 18.2 percent of the energy used for space heating and 13.5 percent of total energy use.

Nonenergy Benefits

The Program's weatherization activities have numerous benefits beyond reductions in energy consumption. Improvements to dwellings often raise the health, safety and comfort levels of occupants as well as increase the value of their homes. Reducing energy demand decreases the environmental impacts of energy production. In addition, lowering energy consumption produces a variety of economic benefits such as reduced energy burdens, more funds for other expenditures, and increased employment. In this section, information on selected nonenergy benefits is discussed.

Occupants' perceptions of the health, safety and comfort of their homes were much improved after weatherization. Occupants of weatherized and control homes were asked to rate the comfort, draftiness, safety, and heating expenses for their homes. They also were asked to rate their own health (in terms of the incidence of illnesses, such as colds, flu, allergies, headaches, nausea, arthritis, which may be affected by the temperature, CO levels, or draftiness of the dwelling).



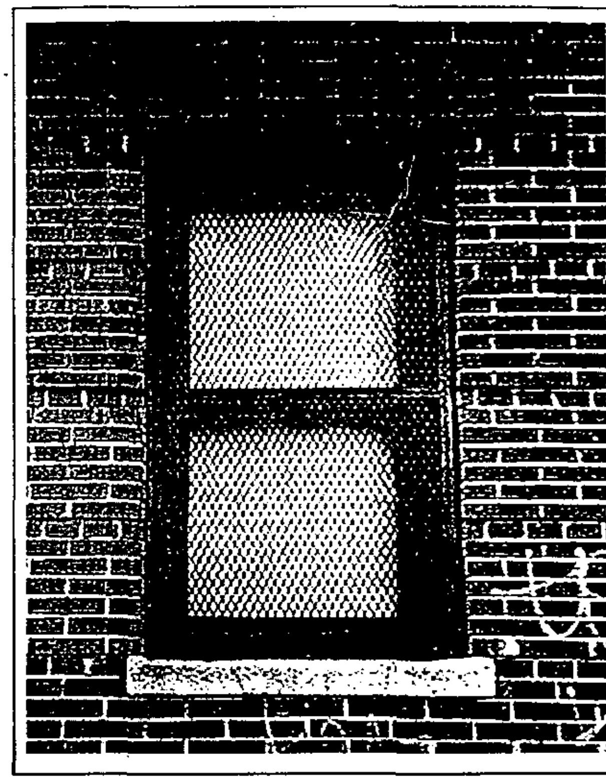
ate change equivalent emission reductions of Program, by type of greenhouse gas.

On every rating scale the weatherized group reported a highly significant and positive change after weatherization was completed. The control group, on the other hand, reported no change in any of the ratings. Thus, the weatherization clients experienced improvements in the comfort and safety of their homes, while the control group did not. The weatherized group also believed their homes became less drafty and their heating bills more affordable after weatherization. The control reported no changes. Finally, the weatherized group believed that there had been an improvement in their own health, while the control group did not. Although it is difficult to place a monetary value on these health, safety, and comfort benefits, occupants of weatherized dwellings recognize and appreciate them.

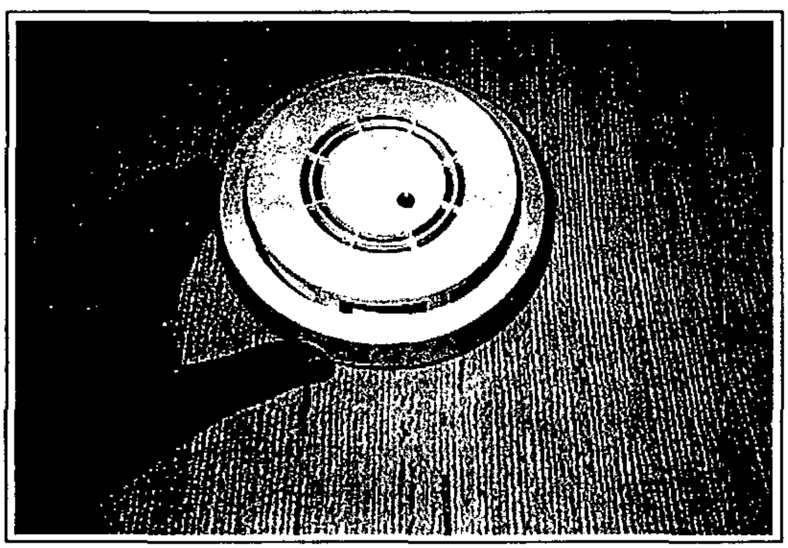
Environmental benefits from weatherization include the reduction of greenhouse gas emissions. The principal gases of concern from the perspective of global warming are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The following calculations are based on dwellings weatherized in 1989 that heated primarily with electricity, natural gas, fuel oil, LPG, or kerosene.

HEALTH AND SAFETY

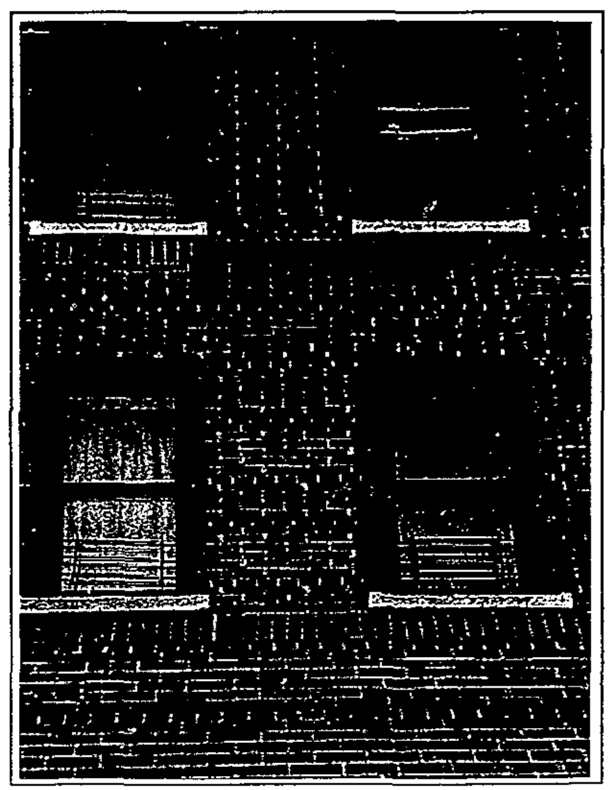
Testing for carbon monoxide ensures both furnace efficiency and safety.



Some weatherization crews install security measures on first-story windows.



Smoke alarm installations improve safety.

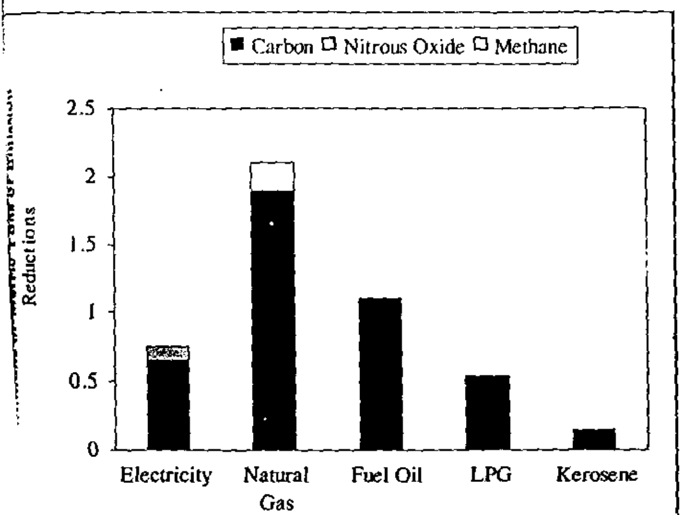


Higher-level windows receive grates to promote child safety.

Weatherizing a dwelling that heats primarily with natural gas reduces **carbon** emissions by 0.2489 metric tons per year. Weatherizing a dwelling heating with electricity reduces carbon emissions by 0.475 metric tons per year, assuming that emissions from electricity generation are equivalent to those from bituminous coal combustion. The carbon emission reductions per dwelling unit for fuel oil, LPG, and kerosene are 0.445, 0.263, and 0.306 metric tons of carbon, respectively. These estimates translate into CO_2 emissions 3.67 times higher because of the additional weight of the two oxygen atoms.

Methane has 35 times the warming potential of CO_2. If the entire cycle of production, transmission, distribution, and household end-use is included, a typical weatherized dwelling heated primarily with natural gas will reduce methane emissions (in CO_2 equivalents) by 0.090 metric tons per year. The emission reductions from the other types of heating fuels are much smaller.

Electricity generation is the only source of **nitrous oxide** emissions that is relevant to home heating. Weatherization yields an annual reduction in N_2O emissions of 0.173 metric tons per electrically heated dwelling, in CO_2 equivalents.



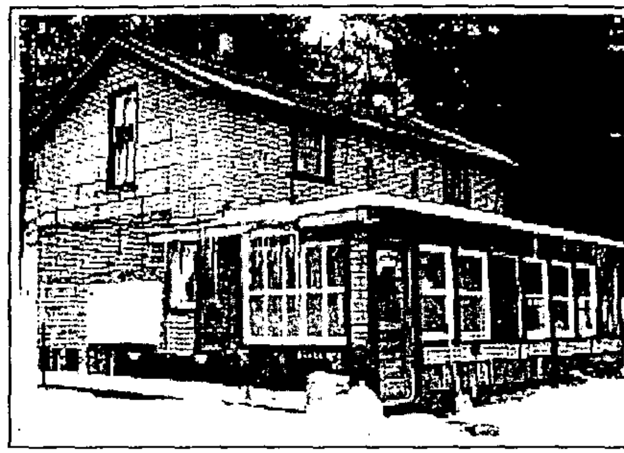
ate change equivalent emission reductions of all houses herized by the program in 1989 over the 20-year lifetime e measures, by type of heating fuel

The 1989 Program as a whole reduced the equivalent of more than 4 million metric tons of CO_2 over the 20 year lifetime of the measures in the 198,000 weatherized homes. The amount of CO_2-equivalent emission reductions due to various types of heating fuels and greenhouses gases are shown in the figure on this page. Since most of the dwellings weatherized by the 1989 Program were heated primarily with natural gas, these dwellings are responsible for the biggest share of the CO_2-equivalent reductions. They are also the only dwellings with a measurable methane impact. Carbon reductions account for the vast majority of the Weatherization Program's reductions of CO_2-equivalent greenhouse gas emissions. The next largest greenhouse gas impacted by the Program is methane.

The value of nonenergy benefits is often difficult to quantify. For the purposes of the evaluation, selected nonenergy benefits were assigned a dollar value, but the methods used to estimate their value varied.

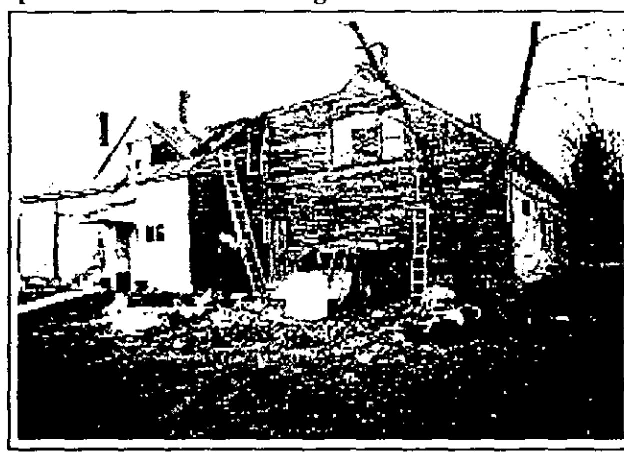
SINGLE-FAMILY DETACHED HOMES ARE FIFTY-EIGHT PERCENT OF TOTAL DWELLINGS WEATHERIZED

This farmhouse saved over 50 percent by air sealing, wall insulation, and furnace replacement.



An uninsulated attic and air leakage between the porch and main structure are the main energy problems with this dwelling.

Joining the new to the old often causes trouble.



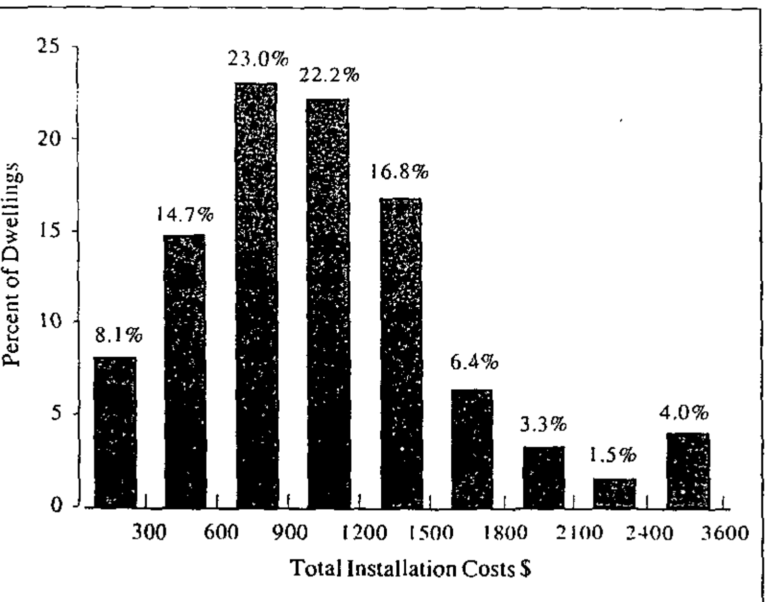
Movement of deteriorated foundation walls has opened large paths for air leakage.

Retrofit siding hides major holes that cause air leakage.

Built in sections over many years, this dwelling has major leaks between the main house and newer additions.

Estimates of environmental benefits relied on a literature review and on information about the proportions of weatherized dwellings using various fuel types and the average savings of different fuels. Estimates of employment benefits combined a literature review with data on Program employment, the skill levels of workers, and managers' judgments concerning the job market for weatherization workers. Data on Program expenditures for home repair were used to quantify the benefits associated with maintaining or enhancing property values and extending the lifetimes of dwellings. The monetary benefits of reducing the incidence of fires were quantified using insurance industry data. Estimates of reductions in arrearages were based on a literature review and data on payment histories collected on the dwellings included in the National Evaluation. For each benefit included in the estimate, we developed an average value per weatherized dwelling.

Ultimately, the dollar value of nonenergy benefits resulting from the weatherization of single-family and small multifamily dwellings was estimated to be $976 per dwelling. The table on page 38 provides a summary of these nonenergy benefit estimates.



tallation Costs for Single-Family and Small Multifamily Dwellings
atherized in 1989

D. Cost Effectiveness

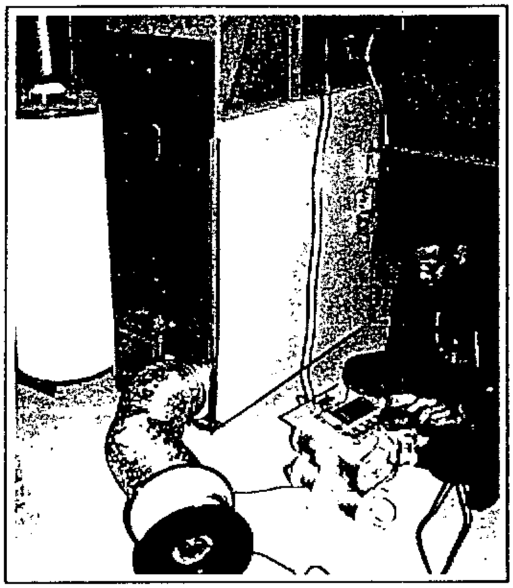
Cost effectiveness is a measure of how well a program works. To assess the cost effectiveness of the Weatherization Assistance Program, the market value of energy savings (and in some cases other benefits) was compared to the cost of installing the measures that produced them. Benefits and costs were discounted over the estimated life of the measures. Cost effectiveness was assessed only for single-family and small multifamily dwellings because estimates of program impacts were not available for large multifamily buildings, which comprised only 9 percent of the dwellings weatherized in 1989.

Program Costs

DOE regulations in 1989 required (subject to certain exceptions) that the average of all costs not exceed $1,600 per house. When the weatherization work is supplemented by non-DOE funds, average costs may exceed $1,600.

To provide a picture of costs that is reasonably consistent regardless of the sources of funds used, costs were grouped under two broad categories: (1) installation costs (i.e., labor and materials assignable to particular houses) and (2) overhead and management costs. Overhead and management costs include costs directly related to installation but not readily assignable to particular houses (e.g., vehicles, travel time, and field supervision), and program management (e.g., intake, inspections, training and general administration).

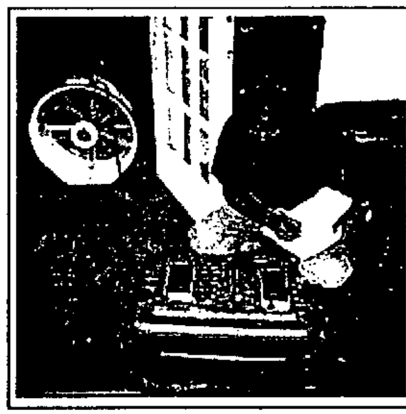
DISTRIBUTION SYSTEMS



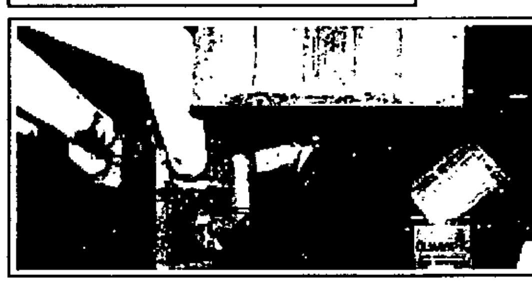
The blower door and pressure-measuring gauges are useful both in quantifying duct leakage associated with duct work and in revealing the locus of significant leaks. Protocols for using both blower doors and the distribution system's own fan to quantify leaks are currently being developed, and several companies have recently developed small calibrated blowers useful in leak detection and quality control in duct sealing.

Recent research has revealed that the distribution systems associated with central heating and air conditioning units are themselves frequently leaky. The combination of loose houses and large holes in return air systems results in inefficiency, uncomfortable drafts, and high energy bills. The combination of **tight** houses and large holes in return air systems can cause backdrafting of the products of combustion from furnaces and hot water heaters, can dramatically increase the rate at which radon enters the dwelling--and can propel of these undesirable gases through the furnace's heat exchanger directly into the main part of the dwelling.

Duct problems can also negate the benefits of other weatherization work. On the other hand, sealing and balancing duct systems can raise furnace system efficiency, lower overall air infiltration, solve moisture problems, enhance indoor air quality--and save energy.

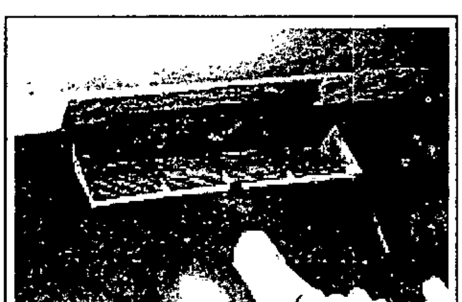


Permanent air sealing of the return air system is accomplished with a fiberglass mesh and special mastic.



A wooden return system on a gravity furnace is not only leaky but also immediately adjacent to sundry volatile organic compounds. When the furnace is fired, fumes from these compounds can be whisked from the basement into the living area.

This return air duct is the only one in the dwelling for a 100,000 Btu/hour furnace in a Philadelphia row house. Undersized by a factor of 20 when initially installed, it is now full of dirt. A $50 retrofit would save well over $100 each heating season.



Holes like these in supply ducts can be quite wasteful--yet they can be repaired quickly and cost effectively.

Installation costs for single-family and small multifamily dwellings weatherized in 1989 averaged $1,050. For not quite half (45 percent) of the dwellings, these costs fell within the $600 to $1,200 range. The chart on page 43 shows the range of costs.

Because of variations in record keeping, it proved difficult to specify overhead and management costs with the same degree of precision as installation costs. After approaching the problem from several perspectives, the evaluators settled on an average cost of $500 per single-family and small multifamily dwelling nationwide.

'ERSPECTIVE	BENEFITS INCLUDED	COSTS INCLUDED
PROGRAM	Energy Savings Only	All Costs
	Benefit/Cost Ratio = 1.09	
INSTALLATION	Energy Savings Only	On-Site Installation Costs
	Benefit/Cost Ratio = 1.61	
SOCIETAL	Both Energy and Nonenergy Benefits	All Costs
	Benefit/Cost Ratio = 1.72	

nal Benefit/Cost Ratios for
uel Types for the 1989 Program

The evaluation examined cost effectiveness in detail from three perspectives:

• The **program perspective:** the only benefit valued was net energy savings, and costs included installation, management, and overhead costs.

• The **installation perspective:** the only benefit valued was net energy savings and the only costs included were installation expenditures; and

• The **societal perspective:** benefits included both net energy and nonenergy benefits, and costs included installation, management and overhead.

National Cost Effectiveness

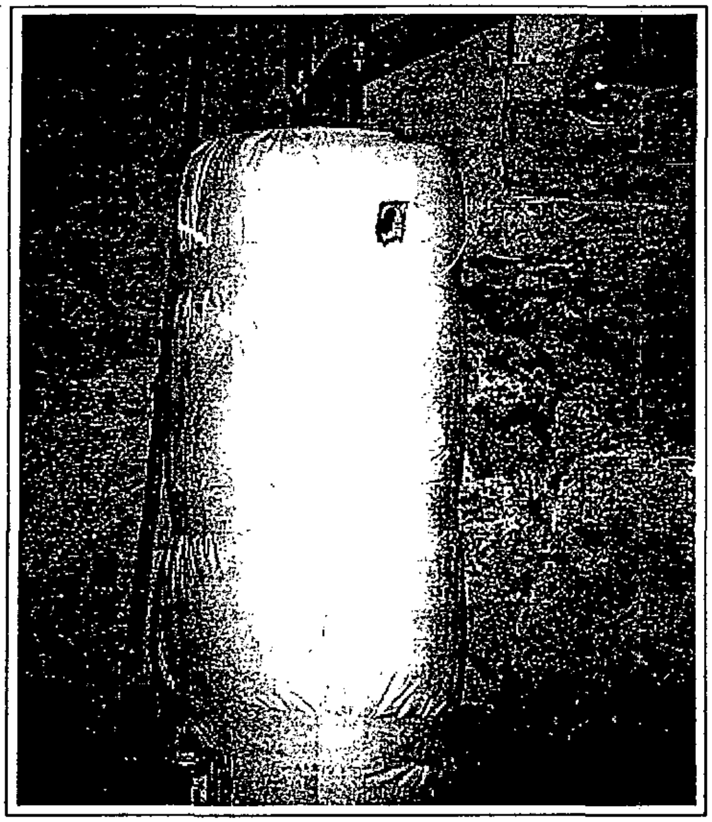
The results of each of the three perspectives used to measure cost effectiveness are described below.

The **program perspective** is the most conservative analysis because it includes all classes of costs (i.e., both installation costs and program overhead and management) but only the value of energy savings as a benefit. From this perspective, the national program is still cost effective. For gas-heated homes, the benefit/cost ratio is 1.06. For electrically heated homes, the ratio is 1.13, and for dwellings located in the Northeast heated primarily with fuel oil, the benefit/cost ratio is 1.48.

For the Program as a whole, including all fuel types, the program benefit/cost ratio is 1.09.

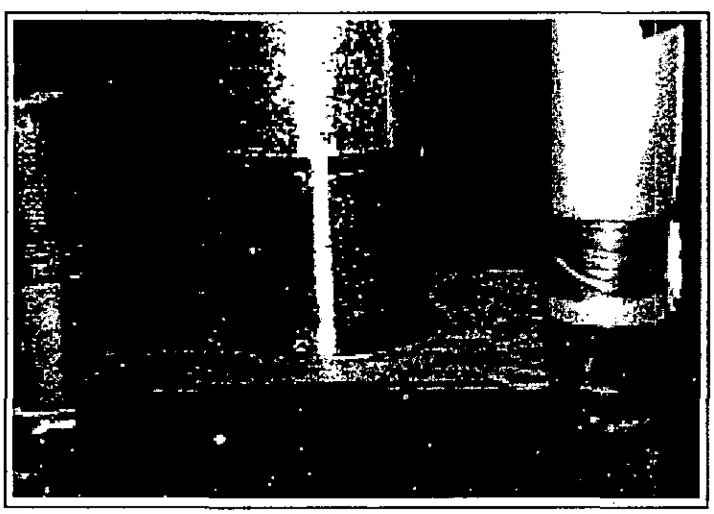
The **installation perspective** is the traditional approach used to evaluate weatherization programs. Nationally, for gas-heated dwellings, weatherization costs averaged $1,015 in 1989 dollars. Average energy

DOMESTIC HOT WATER



Well-insulated water heaters use less fuel.

Conserving energy used to heat water is usually a cost-effective undertaking. Stopping leaks with minor plumbing repairs can result in substantial savings, as can installing low-flow devices like shower heads and faucet aerators. Most weatherization agencies report that the best results come from combining client education with good-quality shower heads. Similarily, the installation of tank insulation by weatherization agencies is frequently accompanied by turning down the thermostat on the water heater, an action that is often taken in conjunction with client education to promote sustained energy savings. Many agencies also install pipe insulation a few feet on the cold water inlet side (to prevent thermosiphoning during the standby cycle) and 10 feet or more on the hot water side.



A flue damper installed on this domestic hot water heater limits heat loss to the chimney during the off cycle.

The weatherization crew that insulated the tank and pipes entering and exiting from this hot water heater did an excellent job.

savings benefits were calculated to be worth $1,605. The resulting benefit/cost ratio, therefore, is 1.58. For electrically heated dwellings, average expenditures of $1,025 yield energy savings benefits of $1,728, producing a benefit/cost ratio of 1.69. For dwellings located in the Northeast heated primarily with fuel oil, average installation costs of $1,192 yielded energy saving benefits of $2,694, producing a benefit/cost ratio of 2.26.

For the 1989 Program as a whole, including all fuel types, the installation benefit/cost ratio is 1.61.

Benefit/Cost Ratios
for Gas-Heated Homes

Perspective	1989	1996
Program	1.06	1.79
Installation	1.58	2.39
Societal	1.61	2.40

The **societal perspective** produces the highest benefit/cost ratios because it includes an estimated value of the nonenergy benefits of weatherization ($976), which exceeds the overhead and management costs of weatherization ($500). For gas-heated dwellings, the benefit/cost ratio is 1.61. For electrically heated dwellings, the benefit/cost ratio is 2.33. For fuel-oil-heated dwellings located in the Northeast, the benefit/cost ratio is 2.01.

For the Program as a whole, including all fuel types, the societal benefit/cost ratio is 1.72.

The bottom line is that the Program is a cost-effective government investment. Total costs (including materials, labor, overhead, and management) for all fuel types averaged $1,550 per single-family and small multifamily dwelling weatherized in Program Year 1989. The net current value of the energy saved per dwelling is $1,690 (in 1989 dollars). This results in a benefit/cost ratio of 1.09. When conservative values are included for some of the Program's various nonenergy benefits, the benefit/cost ratio increases to 1.72.

Because of the higher average national savings estimated for the Program in the 1996 Metaevaluation, cost-effectiveness estimates also increased. In 1989, the National Evaluation estimated the Program benefit/cost ratio for gas-heated homes from the program perspective as 1.06. Applying the same procedures and assumptions used in the National Evaluation to the 1996 savings estimate yields a benefit/cost ratio of 1.79. With the installation perspective, the 1989 result is 1.58, and for 1996 is 2.39. Societal ratios, which include the value of nonenergy benefits, were 1.61 in 1989, and 2.40 in 1996.

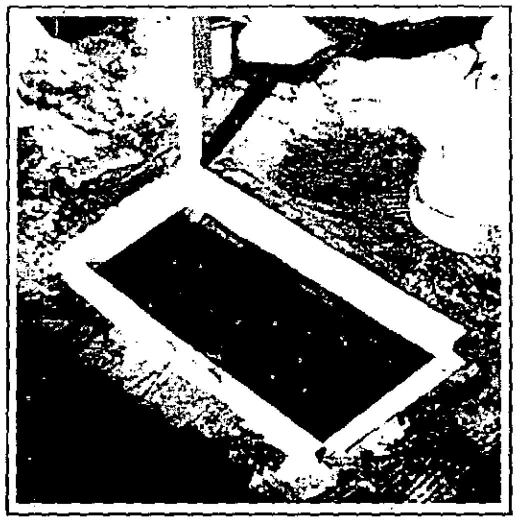
E. Performance by Climate Region in 1989

Performance indicators for the national Program mask a great deal of diversity. This diversity springs from regional differences and associated housing types and needs and from varying practices of weatherization agencies. The following sections discuss differences by region. Characteristics of the housing stock and local agencies account for much of the regional variation in weatherization practices and measures installed. These, in turn, provide important background for understanding regional variations in weatherization costs, energy savings, and cost effectiveness.

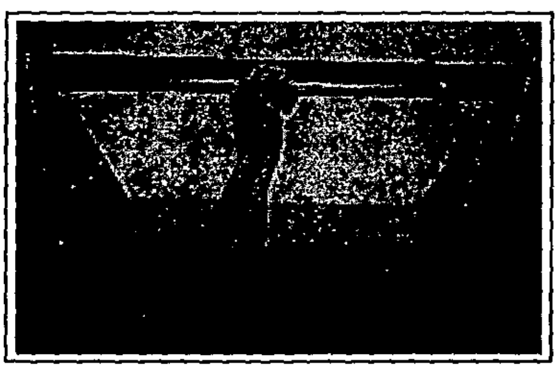
As a whole, the 1989 Program was most cost effective in the cold and moderate climate regions of the country, where program activity was

MOBILE HOME MEASURES

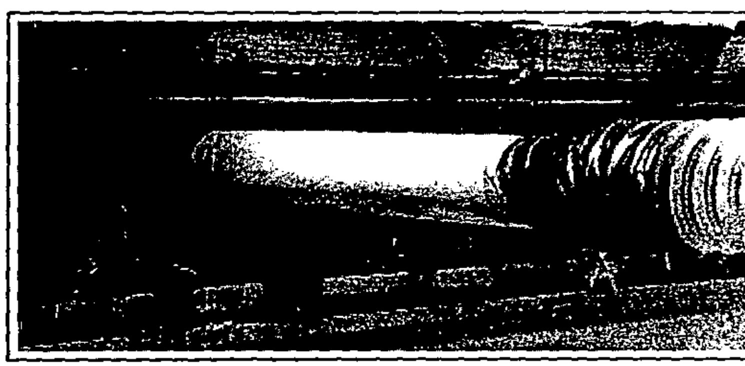
Many mobile homes have inconspicuous air leakage paths that can be clearly identified with blower doors. Successful weatherization work focuses on closing leaks at the bottom of the conditioned envelope, especially around the duct system. A recent Indiana study showed that 32 percent savings in mobile homes resulted from blower-door guided infiltration reduction and from blowing cellulose insulation in the belly board. A recent evaluation of the Vermont Weatherization Assistance Program provided evidence of substantial electricity savings from air sealing the water heater compartment of mobile homes, even when the electric water heater had already been jacketed.



The interface between the riser in a supply duct and the floor of a mobile home is frequently found to be a source of air leaks, both when the furnace fan is on and when it is not. Here a technician in Indiana uses a technique his agency developed to achieve a tight, lifelong seal.

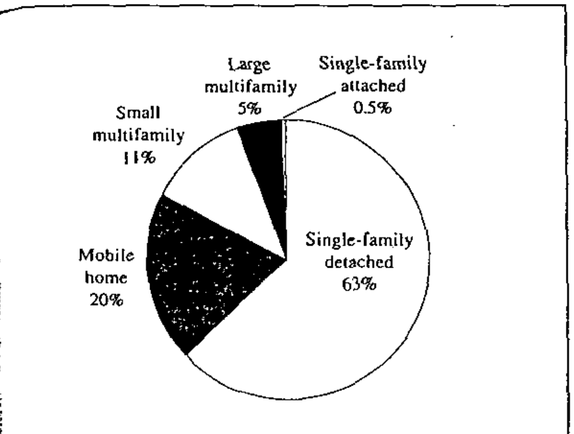


Sealing the opening to the evaporative cooler during winter months is routinely accomplished by weatherization technicians in Arizona, who find this a very cost-effective weatherization tactic with both mobile homes and site-built structures. Solar screens also result in significant savings in this semidesert climate.



A 30-foot-long plastic pipe is used to blow insulation between the belly board and the floor of a mobile home.

concentrated. In the warm climate region, where agencies were smallest and the low-income housing was most dilapidated, the Program saved less energy per dollar expended.

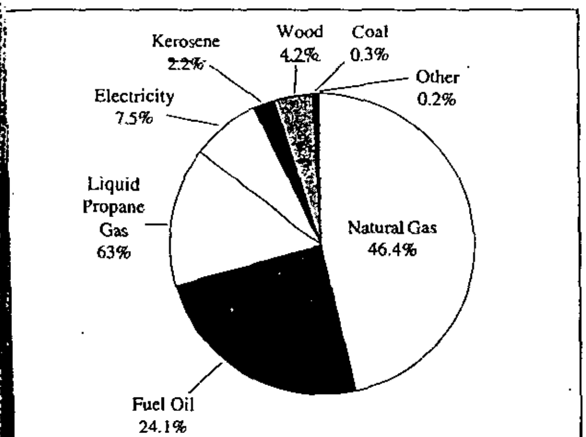


Types of Dwellings Weatherized in 1989 in the Cold Region

The Cold Climate Region

The cold climate region contains 11 states with an average of 7,444 heating degree days. In 1989, approximately 150 local agencies in this region weatherized more than 40,000 dwellings (18 percent of the total weatherized population).

Benefit/cost ratios were greater in this region than in any other region, ranging from 1.3 to 2.9 depending upon the perspective. This region also achieved the highest savings of any region, based on the Single-Family Study. For natural gas consumption, the first-year net savings of 235 ccf represented a 25 percent reduction in the gas used for space heating and an 18 percent reduction in total gas usage. Net electricity savings totaled 2,686 kWh for the first year, which was a 42 percent reduction in electricity use for heating and a 14 percent reduction in total electricity usage. Total costs averaged $1,576 per household, higher than the national average.



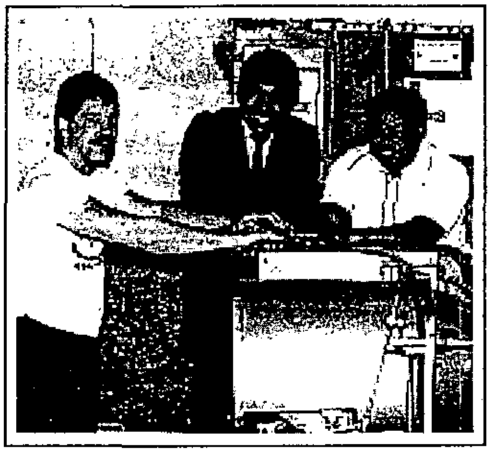
Types of Heating Fuels in Single Family and Small Multifamily Dwellings Weatherized in 1989 in the Cold Region

The majority of weatherized homes in the cold region are single-family detached (63 percent). Findings from the Single-Family Study show that this region has the oldest housing stock (averaging 45 years) and weatherizes dwellings that are on average larger than the other two regions (1,181 square feet). The primary heating fuel, as with all regions, is natural gas. This region, however, has a significantly higher portion of the population using fuel oil. A central heating system was found in 83 percent of the dwellings, the largest proportion of any region, and supplemental heating fuels were less common (24 percent of the weatherized single-family population). Two-thirds of these dwellings were owner-occupied, and they had the largest average number of occupants of any region.

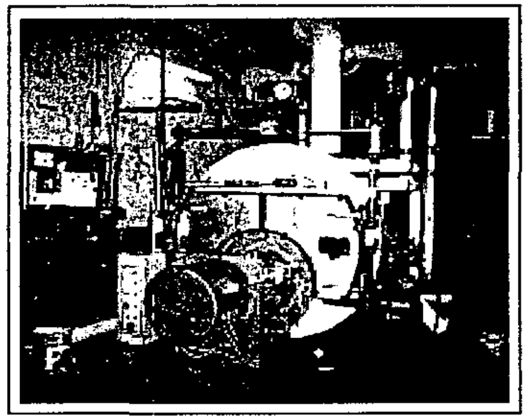
The cold region used the most rigorous methods for both client and weatherization measures selection. Integrated audits for measure selection were used over three times more frequently than the national average. The use of advanced diagnostic techniques was higher than in any other region. The Single-Family Study showed that blower door tests were performed almost twice as frequently as the national average. The cold climate zone had high installation rates for insulation, water heating, and space heating measures. In contrast, the cold region had relatively low installation rates for structural measures and windows and doors.

HEATING SYSTEMS

Furnace testing for safety and efficiency has recently become a routine part of many weatherization operations, yet there are still states which pay little attention to heating system work. Others do major work--when needed--ranging from switching to efficient oil burners to boiler replacement.

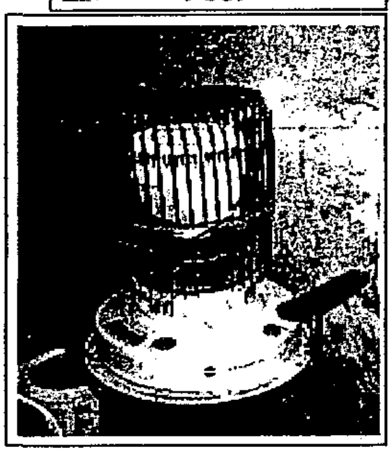


From left to right: A boiler technician, a local weatherization official, and an owner celebrate the recent installation of an energy-efficient boiler in a large multifamily building in Brooklyn. Owners in New York and some other states provide 25 percent or more of the cost of the work, thus leveraging scarce weatherization funds.

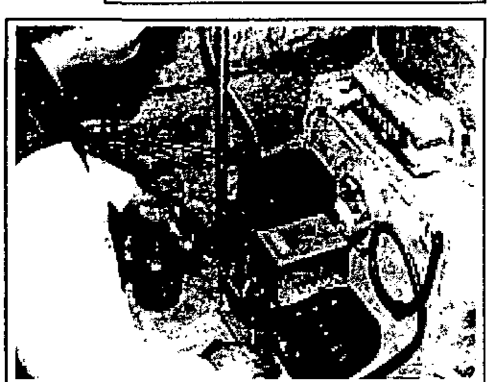


Modern multi-setback thermostats are cost-effective measures in many weatherization jobs.

Many weatherization agencies use furnace testing equipment to measure the efficiency and safety of heating equipment.



Kerosene heaters, like this one stored in the basement, contribute to poor indoor air quality. Education work with weatherization clients includes stern warnings about the hazards of these heaters--and the importance of getting rid of them entirely.



An old boiler in a single-family dwelling in Philadelphia has plenty of life left in it, but its burner was inefficient and unsafe. This new burner assembly will save about 14 percent of the annual fuel oil bill.

Filthy return air filters, found frequently in the weatherization program, are both unhealthful and inefficient. Cleaning and tuning of furnaces, setting controls for efficiency, replacing filters--and empowering clients to do the job in the future--are routinely accomplished in most weatherization operations.

• **Installing attic insulation.** The 1989 evaluation clearly showed that the installation of insulation in attics never before insulated is particularly cost effective. Today advanced audits consistently recommend more attic insulation than was recommended by the priority list selection procedures used by most agencies in 1989.

• **Installing wall insulation.** During the time of the 1989 evaluation, only a few agencies had begun using the high-density installation technique (which accomplishes air sealing and insulation with a single operation). However, weatherization jobs that included high-density wall insulation showed even greater savings than those that used the older technique. More agencies are using high-density wall insulation techniques today.

• **Blower-door-assisted air sealing.** The payoff expected from blower-door-assisted air sealing was not discernible in the Single-Family Study in 1989. Because the effectiveness of blower-door-assisted air sealing has been demonstrated in small scale studies, this unexpected finding was attributed to the fact that blower doors were just being introduced into local agency procedures in 1989, when only 18 percent of completed dwellings received blower-door-assisted sealing. Today, many agencies offer training in blower door use, and many homes receive blower-door-assisted sealing. In fact, low-income weatherization agencies have become leaders in the application of blower doors and are generally convinced they save energy.

Recommended Practices

- Client education
- Resource leveraging
- Utility partnerships
- Housing rehabilitation funds

B. Promising Management Practices

A handful of other practices employed by many weatherization agencies clearly make sense, but their impact could not be quantified in the 1989 evaluation. These include client education and resource leveraging. Some agencies are very active in providing client education and report good success in forming partnerships in which recipients of weatherization services participate in a number of concrete conservation activities in their homes.

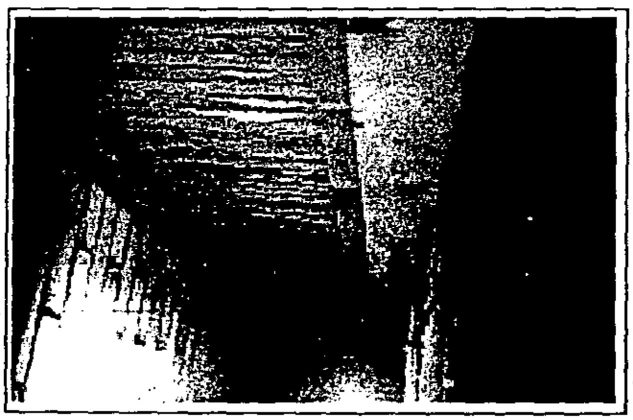
Leveraging from utilities to accomplish the ends of demand-side management on the one hand and cost-saving conservation services for low-income families on the other has been an important opportunity for enhancing weatherization. Some agencies, for instance, provide electricity conservation services in conjunction with weatherization. These routinely involve removing inefficient incandescent lighting fixtures and replacing them with compact fluorescent lighting, and sometimes replacing inefficient refrigerators with efficient ones. Other utility partnerships have enabled capital-intensive investments such as energy-efficient replacement furnaces that otherwise might not be possible.

Still problematic for many local agencies is the extremely poor condition of many dwellings. The Program will be stronger when

ATTICS

This is a 12-inch fiberglass batt that has been on top of a small crack in the ceiling below for only one winter. The dirt is from the passing of massive amounts of air driven by stack-effect exfiltration.

Single-component foams in conjunction with rigid board stock cut to fit attic openings achieve tight, long-lasting attic sealing.



This space between the chimney interior framing is completely open to the attic. Sealing this at the level of the attic insulation is likely to save more energy than replacing every window in the dwelling. An experienced weatherization crew technician can thoroughly (and safely) seal this opening in 15 minutes with a material cost of $4.

Interior walls open to attics are commonplace—and must be sealed to prevent thermal siphoning. If this hole is not sealed during weatherization, the interior wall below is likely to be much colder in the winter than exterior insulated walls.

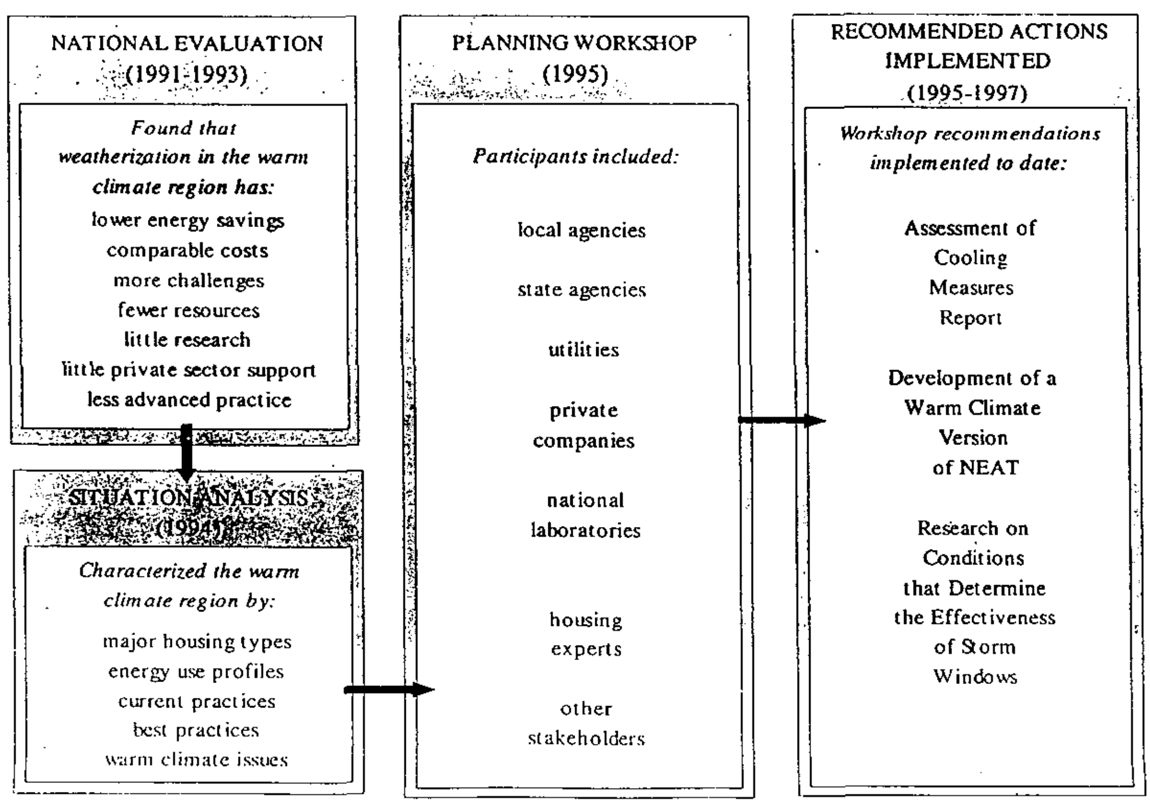
adequate housing rehabilitation funding allows local agencies to provide needed repairs and to devote a larger share of their DOE funds to energy-efficiency improvements.

C. The Warm Climate Weatherization Initiative

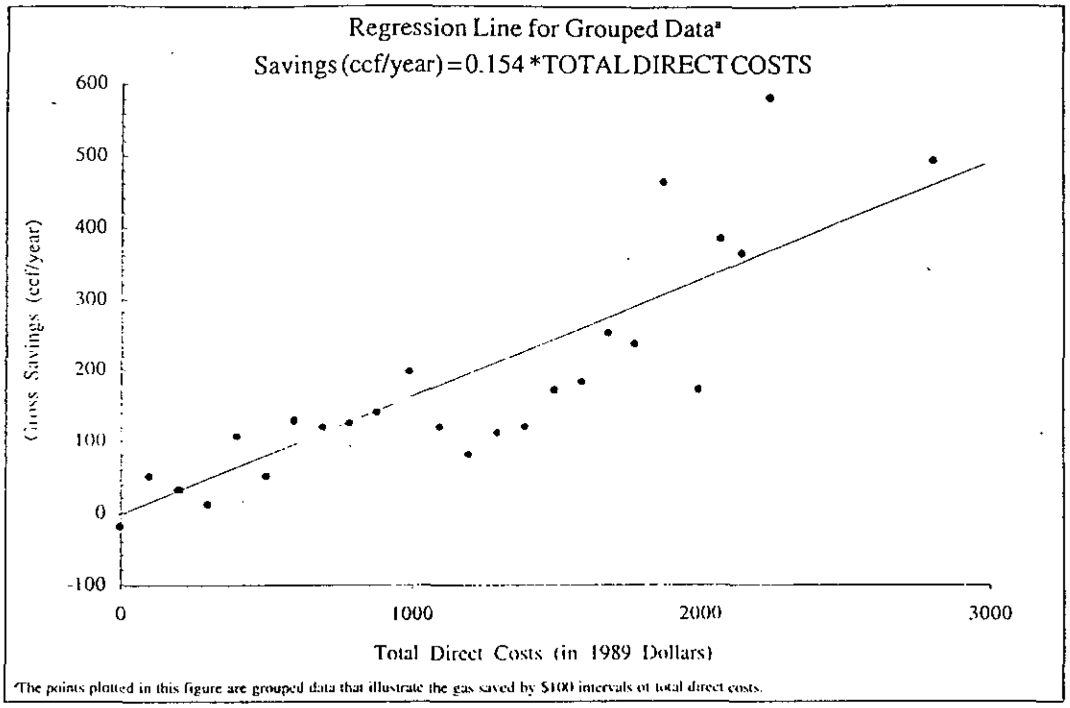
The lower-than-average savings in the warm climate region suggested the need for efforts designed to identify and implement ways of increasing energy savings from weatherization in warm climates. In addition, studies had decisively shown that improved procedures in warm climates could produce dramatic improvements in savings. The results of a 1993 ORNL study, for example, showed that the use of an advanced audit procedure more than doubled the amount of energy savings in North Carolina homes. A similar study in Virginia found that savings more than doubled with the implementation of improved procedures.

Although some improvements were already being adopted, DOE believed that it was important to accelerate the pace of change. Therefore, DOE decided to sponsor the Warm Climate Weatherization Initiative. This Initiative was designed to identify, develop, test, and transfer into widespread use a set of technological and programmatic approaches that can further increase the energy saved by weatherizing low-income homes in warm climates.

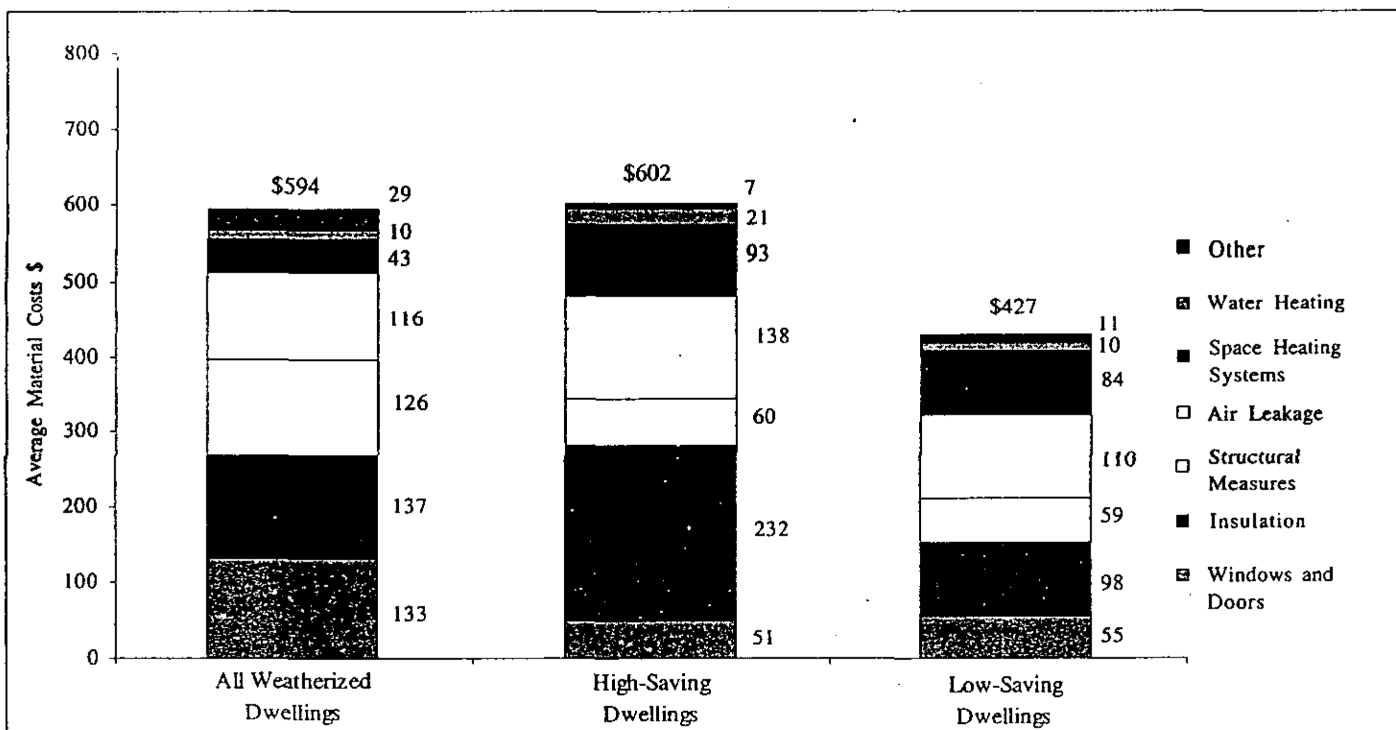
Overview of the Warm Climate Weatherization Initiative



RELATIONSHIP OF COSTS TO SAVINGS



Relationship of Amount Invested in Weatherization Measures to Energy Savings



Average Material Costs (in 1989 dollars): All Weatherized Dwellings vs. High- and Low-Saving Dwellings

The Warm Climate Initiative began with a Situation Analysis, in 1994, and a Planning Workshop, in 1995. The Situation Analysis, which was distributed prior to the Workshop, described current weatherization practices, housing conditions, energy end-use profiles, warm climate issues, and promising new technologies. The Workshop (which brought together Program representatives from all of the warm climate states, several local agencies, and DOE Headquarters, along with technical experts, and utility representatives) was asked to review the background information, identify the most important issues, and set an agenda for future research and improvements. Many of the Workshop recommendations have now been implemented. An ORNL report assessing cooling measures was completed in 1996, and research on the conditions that determine the effectiveness of storm windows produced preliminary results in the same year. Modifications to the National Energy Audit (NEAT) designed to improve its usefulness in warm climates are currently nearing completion. Furthermore, cooperative state-level evaluations in three warm climate states began in 1997.

VII. REMAINING OPPORTUNITIES

A. Additional Investments per Home

Many Opportunities for Additional Cost-Effective Investments

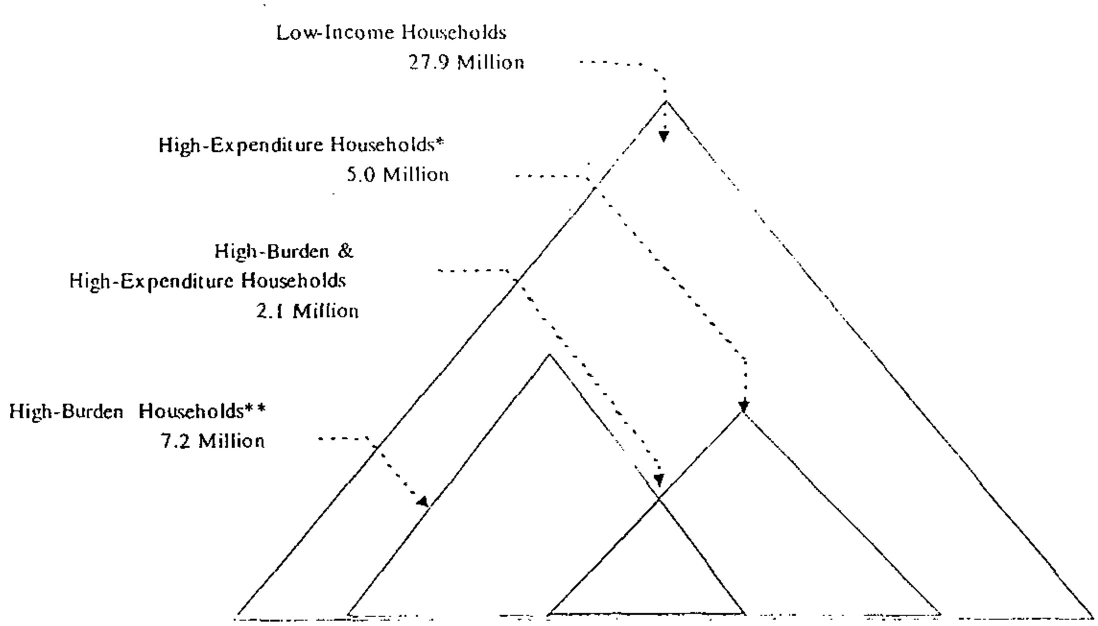
- Further reduce air leakage
- Increase levels of insulation
- Give more attention to heating systems and ducts
- Use more leveraged funds for housing rehabilitation

In general, the amount invested in weatherizing a home is directly related to the magnitude of energy savings. A regression analysis of over 1,800 gas-heated homes showed that gas energy savings increased by 15 ccf/year with each additional $100 invested in labor and materials. The average rate of increase in energy savings did not diminish as investments increased from $1,000 to $3,000. In PY 1989, the average investment per house was about $1,000 for labor and materials. Houses that received larger investments, however, clearly saved more energy. For example, high-saving dwellings benefited from total expenditures for labor and materials of $1,192, which was 14% more than the national average of $1,050. Low-saving dwellings, however, received an investment of only $714 (or 68%) of the average national investment. Similarly, higher-saving agencies were more likely to obtain funds from non-DOE sources so that a higher average investment per dwelling was possible. These results suggest that there is a cost-effective potential for substantially increasing energy savings by increasing the average investment per dwelling.

The proportion of the funds invested in various types of weatherization measures also is an important determinant of energy savings. In high-saving dwellings, 38% of the total spent on materials was invested in insulation and 16% in heating systems. In low-saving dwellings, in contrast, 27% of the total spent on materials was invested in insulation and 3% in heating systems. In low-saving dwellings far larger proportions were spent on structural repairs (25% versus 7%) than in high-saving dwellings, and more was invested in windows and doors (15% versus 4%). Similarly, higher-saving agencies invested more in insulation and heating systems and less in windows and doors.

TARGETING NEEDY HOUSEHOLDS

LOW-INCOME HOUSEHOLDS AND SUBPOPULATIONS IN 1990



*averaging $1,233 in annual energy expenditures

**averaging 30.1% of their income

Targeting high-burden and high-expenditure households offers the opportunity to reduce utility bills of the neediest households and achieve sizable energy savings. The above diagram identifies 2.1 million program-eligible households that have both high energy expenditures (averaging $1,339 per year) and high energy burdens (averaging 30.4 percent of their income).

Many measures installed by the Program show significant opportunities for additional energy-efficiency improvements. Although the weatherized homes were clearly tighter than the control homes, approximately 80% of them still had air leakage rates that exceeded 1,500 cfm_{50} (a threshold above which more air-infiltration reduction is generally recommended). The R-values in weatherized homes were significantly higher than those in control homes. However, the R-values of the attic insulation in weatherized homes were still often below DOE-recommended levels. For example, about 26% of weatherized homes had attic R-values of less than R-19 and 63% had R-values of less than R-30. R-19 or less is below recommended levels in all climate regions in the U.S. and R-30 is below the recommended level for all except the hottest regions. The need for more frequent installations of attic and wall insulation was especially important in the warm climate region. The poor condition of heating systems and ducts in many homes also pointed to opportunities for additional savings (Berry and Brown, 1994).

Although many important and cost-effective energy-efficiency improvements are being implemented by the Program, more funding would make it possible to do much more. Because of the overhead costs involved in setting up work in each home, it would be most cost efficient to capture as many opportunities as possible during the DOE-sponsored installation. In addition, because a home will rarely be revisited at a later date, cost-effective measures that are not installed are likely to be long-term "lost opportunities." Leveraged funds from utilities and other sources are an important vehicle for providing more complete and comprehensive weatherization and for minimizing lost opportunities.

Many low-income homes need extensive structural repairs, which must be paid for with leveraged funds. For these homes, leveraging of housing rehabilitation funds to supplement DOE funds is an essential step in achieving structural integrity and energy efficiency.

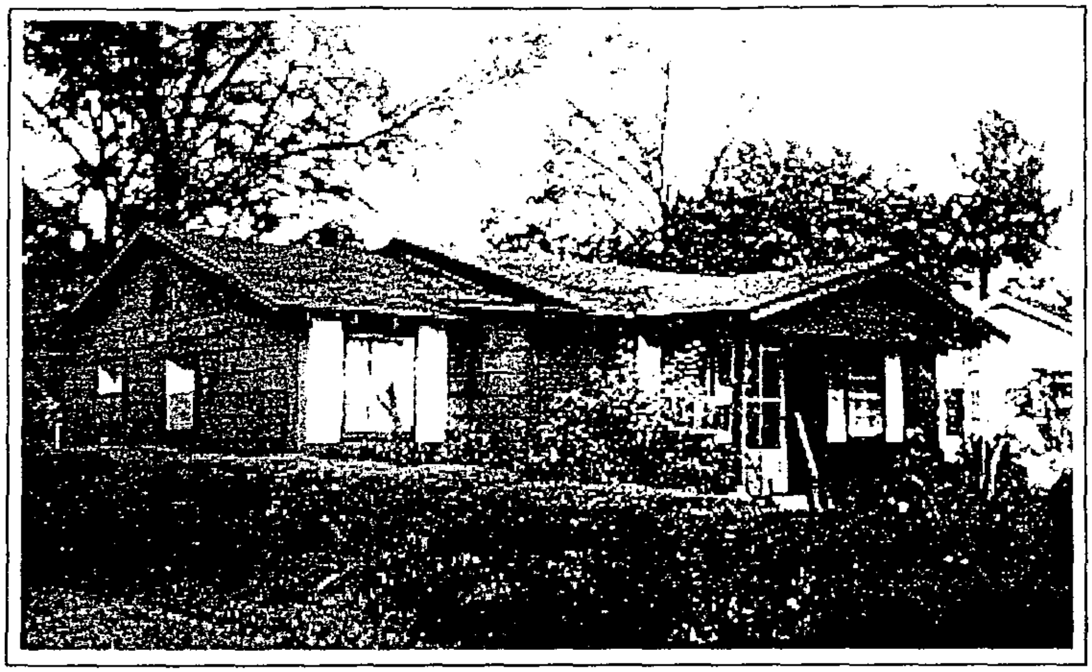
B. Targeting the Neediest Households

The Department of Health and Human Services has reported that, based on Energy Information Administration data, there were 29.1 million households with incomes near or below the federal poverty guidelines for weatherization eligibility in 1994. Given the large population remaining to be served by the Weatherization Program, it is critical for local agencies to focus resources on households with the greatest need for weatherization and with the largest potential for benefits.

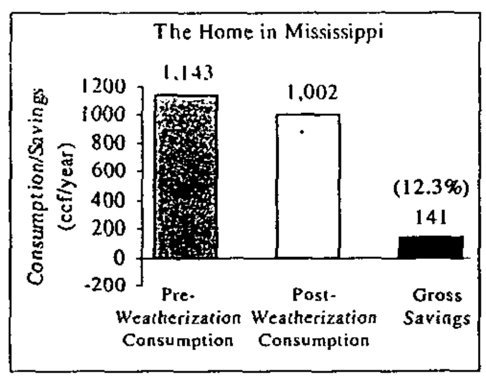
One strategy for targeting weatherization assistance funds is to identify households with both high energy expenditures and high energy burdens. High-expenditure households are good targets because high expenditures are correlated with high energy savings potential. High-burden households are good targets because they can least afford the costs of the energy they consume and they are the least likely to be able to make energy-saving investments in their homes.

The 1990 Residential Energy Consumption Survey (RECS) was used to estimate statistically the size and characteristics of the target groups

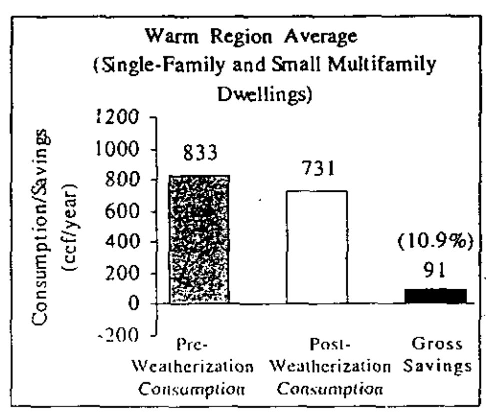
HIGH SAVINGS FROM ATTIC INSULATION



The core of this wood-framed home was built around 1955; since then, two small additions have been constructed, resulting in 1,277 square feet of living space and in a complicated roof-line prone to water and air leakage. Prior to weatherization, the home had no insulation in its attic, walls, or foundation, and its 14 wooden window frames and two wooden doors were rotten and leaky. The home was heated by two gas space heaters—one in the living room and the other in one of the four bedrooms. The 30-gallon water heater and the stove also used natural gas.



The weatherization agency spent $900 in materials and $400 in labor to weatherize this house. A state-wide priority list of measures was used to select the weatherization measures. The job involved blowing approximately 3" of loose-fill fiberglass insulation across the attic floor, adding two gravity vents for each of the bathrooms, repairing and replacing several windows, replacing one of the doors, and generally caulking and weatherstripping.



During the year after weatherization, the client used 1,002 ccf of natural gas, representing a decrease of 141 ccf (12.3%). The occupants judged their home to be noticeably less drafty after weatherization and much less expensive to heat.

that appear to have the greatest potential to benefit from weatherization assistance. The evaluation defined the groups as follows:

• **High-Expenditure Households**--those with the highest space heating costs per heating degree day and square foot relative to others in their climate zone and region. This group included 5.0 million low-income households which had average energy expenditures of $1,233 and an average energy burden of 19.2% of income.

• **High-Burden Households**--those with the highest energy burden (expenditures in proportion to income) relative to others in their climate zone and region. This group included 7.2 million low-income households which had average energy expenditures of $1,175 and an average energy burden of 30.1% of income.

• **High-Burden/High-Expenditure Households**--those that qualified in both categories above. This group included the 2.1 million households which had average energy expenditures of $1,339 and an average energy burden of 30.4% of income.

Several key characteristics help to define the High-Burden/High-Expenditure households. These households have very low incomes--they have an average income of $6,114 compared to $10,048 for all low-income households. A substantial share of these households represent vulnerable population groups--about 40% are elderly households and another 24% are single-parent households. In other ways, however, they are much like other low-income households--they occupy the same types of dwellings and they use the same types of fuels. Thus, in order to target these households, local agencies need to be particularly attuned to their client's expenditure and burden levels.

VIII. THE FUTURE OF WEATHERIZATION: THE NEXT STEPS

The various reports produced by the National Weatherization Evaluation presented a comprehensive profile of the weatherization procedures and measures that characterized high-performing agencies and high-saving dwellings. The following recommendations, which resulted from these findings, describe a series of next steps to enhance the Weatherization Program beyond its already strong foundation.

The Metaevaluation results, which showed an 80% increase in energy savings during the past seven years, suggest that substantial progress has already been made in implementing many of the National Evaluation's recommendations.

A. Service Delivery Procedures

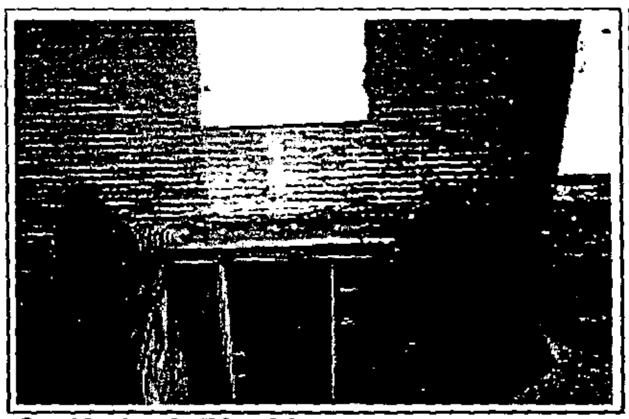
• **Enhance the existing high quality of the weatherization work force through increased training and professional development.** High-performing agencies were characterized by experienced and well-trained employees. Improving the ability of the weatherization work force to employ diagnostic reasoning and principles from building science will result in even more cost-effective weatherization.

BASEMENTS

These photos illustrate a weatherization tactic used to block massive infiltration at the bottom of the heated envelope. Sometimes doors or even insulating walls have to be constructed to form an effective air barrier. Skilled weatherization crews can accomplish this job in two hours or less at a materials cost of only $60 or so.

A new bulkhead door and insulated sheathing isolate the area under a porch, thus solving a major infiltration problem.

Sealing a new basement partition wall.



Outside view, bulkhead doors open.

Inside view, new partition wall with weatherstripped access door.

Air sealing at sill plate with foam. This infiltration-stopping measure is necessary with most weatherization jobs.

• **Encourage agencies to direct their resources towards clients that have higher-than-average levels of energy burden.** This can be done either through the selection of clients that have a higher-than-average energy burden or the determination of investment levels based on the pre-weatherization energy burden. Both the Single-Family and the Fuel-Oil Studies found that energy savings are greatest in dwellings that consume large amounts of energy prior to weatherization. These same households also tend to spend a high proportion of their income on energy. By matching levels of investment with potential for savings, overall program cost effectiveness will improve.

> **Technology Transfer Efforts in the 1990's**
>
> - Development and promotion of advanced audits
> - Warm Climate Initiative
> - Development of mobile home audit
> - Refined assessment methods for storm windows

• **Encourage the efforts of states to mobilize other resources to address the rehabilitation needs of low-income housing.** This will enable DOE resources to be focused more on energy-efficiency improvements. Most high-performing agencies have access to non-DOE funds to help pay for housing repairs. The Program will be stronger as more local agencies have access to non-DOE funds for housing rehabilitation while using DOE funds to improve energy efficiency.

• **Establish technology transfer mechanisms to promote replication of the success of high-performing agencies.** One striking finding of the Single-Family Study is the tremendous diversity among local agencies. A challenge to DOE's Weatherization Program is to help bring the less innovative and less advanced agencies up to the level of the high-performing agencies in their region. The promotion of advanced audits and the Warm Climate Initiative are two examples of successful recent technology transfer efforts. Additional research efforts that are nearing completion include the development of an audit designed specifically for mobile homes and the development of refined assessment methods for decisions about the installation of storm windows. When these improved tools are adopted by the Weatherization network, additional improvements in performance will result.

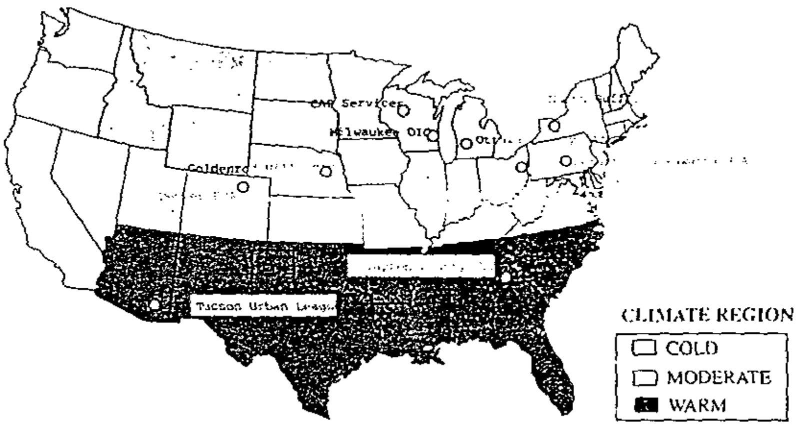
B. Weatherization Measures

• **Continue the Program's strong emphasis on attic, wall, and floor insulation.** High savings in both the Single-Family and Fuel-Oil Studies are associated with greater-than-average levels of investment in insulation. High-density wall insulation techniques that can achieve air sealing and insulation in the same operation appear to be especially effective. Advanced audits tend to increase the level of investment in both wall and attic insulation.

• **Further analyze the role of replacement windows and storm windows.** The Single-Family and Fuel-Oil Studies showed that large investments in windows are especially characteristic of dwellings and agencies that achieve lower-than-average energy savings. Yet at least one high-performing agency specialized in storm windows. Further, owner investments in the weatherization of large multifamily buildings tend to target storm windows. Preliminary research, conducted in 1996, has refined assessment methods for determining the conditions under which storm and replacement windows are a cost-effective Program expenditure. The findings from this research will be incorporated into future versions of the National Energy Audit.

KEYS TO SUCCESS

Case studies of ten high-performing local agencies demonstrate that there are many different formulas for the successful operation of a weatherization program. Each of the ten agencies employs a unique combination of useful and innovative approaches. At the same time, common features do exist. The following table summarizes the most notable characteristics that distinguish the ten high-performing agencies from other agencies. These noteworthy features range from agency and staff characteristics to client recruitment and selection practices; weatherization measures; resource leveraging; and cost controls.



Category	Characteristics of a Majority of the High Performers
Agency Characteristics	Large, multi-program community action agencies
Characteristics of Weatherized Housing	High levels of pre-weatherization energy use; older dwellings; more elderly occupants; fewer mobile homes; more central heating; fewer supplemental heating fuels
Weatherization Staff	Limited turnover and substantial weatherization experience
Delivery System	In-house crews supplemented by contractors for furnace work
Client Recruitment	Reliance on LIHEAP rosters for recruiting applicants
Selection of Clients and Investment Levels	Strong and increasing focus on high energy users
Blower Door Use	Limited use in 1989, extensive use in 1996, during the audit, while air sealing, and as part of the final inspection
Weatherization Measures	More first-time attic insulation and wall insulation; furnace retrofits and replacements; and water-heater measures
Leveraging Home Repairs	Access to housing rehabilitation funds from non-DOE sources
Cost Controls	Effective cost controls such as bulk purchasing & in-house fabrication of measures

• **Increase the emphasis on replacing inefficient space-heating systems.** High-performing agencies identified in the Single-Family Study replaced more space-heating systems than other agencies. In addition, they made greater use of instrumented analyses of furnaces and boilers to select measures that promote health, safety, and energy efficiency. System replacements and instrumented analyses were characteristic of high-saving homes in both the Single-Family and Fuel-Oil Studies.

• **Increase attention to heating system distribution systems.** Dwellings that received duct leakage control measures and distribution system diagnostics achieved above-average savings in the Single-Family Study.

• **Increase attention to water-heating measures.** Water-heating conservation measures are characteristic of high-saving homes in the Single-Family and Fuel-Oil Studies. Measures to consider should include domestic warm water tank and pipe insulation, water temperature reduction, low-flow showerheads, and aerators.

• **Select measures based on savings-to-investment ratios produced by audits.** The Program has successfully moved away from the use of prescriptive methods such as statewide priority lists for the selection of measures. Advanced audits that rank measures by savings-to-investment ratios, calculated for each individual house, were used in 37 states in 1996.

IX. CONCLUSIONS

Weatherization is a sound public program that has advanced technically during the past seven years. In spite of some impediments, such as reduced funding, **the Program is saving 80% more energy per dwelling and is more cost effective than in 1989.** Procedures and measures associated with higher energy savings and new technologies are the major sources of this progress.

Societal benefits resulting from the Program include:

- the creation of about 8,000 jobs (in 1996);
- cleaner air through reduced CO_2 and power plant emissions;
- reduced consumption of imported fuels through reduced residential consumption; and
- reduced demand on other social programs such as fuel assistance, housing and health care.

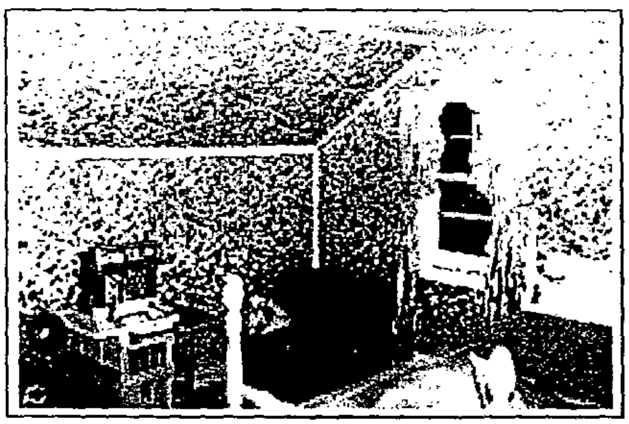
Other benefits include improvement of neighborhood housing conditions, and promoting the use of newly developed conservation tools, materials and techniques. Most importantly, alleviation of the high energy burden faced by low-income Americans enables them to gain increased financial independence and greater flexibility in spending for other essential items.

The table on page 73 compares the findings of the National Evaluation of the Weatherization Assistance Program, based on 1989 data, to the Metaevaluation of 17 state-level evaluations completed in 1996.

To sum up, the Weatherization Assistance Program Works!

PUTTING IT ALL TOGETHER

This home in rural New England had a weatherization job that reduced energy costs by more than 50 percent. After the knee wall on the second floor was accessed with a saw from the outside, extensive air sealing and insulation work were performed. (The access hole is now covered with a rectangular vent.) This weatherization job also included extensive repair of a leaky distribution system and other infiltration-stopping measures, including a new basement door. Although exterior aesthetics were not altered, the clients were overjoyed with a much more comfortable house--and a $600 per year saving on their oil bill.



Significant Findings of the 1989 National Weatherization Evaluation and the 1996 Metaevaluation for Gas-Heated Dwellings

Finding	1989 Value for Gas-Heated homes	1996 Value for Gas-Heated homes
Annual energy savings per dwelling (in Mbtus)	17.3	31.2
Energy savings as a percentage of energy used for space heating	18.3%	33.5%
Energy savings as a percentage of total gas consumption	13.0%	23.4%
Value of annual energy savings per dwelling in 1996 dollars	$107	$193
"Program" benefit/cost ratio*	1.06	1.79
"Installation" benefit/cost ratio**	1.58	2.39
"Societal" benefit/cost ratio***	1.61	2.40

*Based on energy-savings benefits and total weatherization costs.
**Based on energy-savings benefits and labor and materials costs.
***Based on energy-savings, employment, and other non-energy benefits and total weatherization costs.

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ACKNOWLEDGMENTS

For additional help in preparing this report, special thanks to Terry Baxter, Mike Bonn, Connie Cudd, Joel Eisenberg, Philip Hayes, Jeanne Van Vlandren, and Heather Walden. Members of the National Weatherization Evaluation's working groups helped design the National Evaluation, guide its implementation, and interpret its findings. The authors are grateful for their contributions and would like to acknowledge them individually:

Jeff Ackermann
Colorado Department of
Local Affairs

Don Barnett
Missouri Department of
Natural Resources

Mary Ann Bernald
Edison Electric Institute

Jeff Brown
Energy Division,
North Carolina Department of
Commerce

Dale Canning
Salt Lake Community Action
Agency

David Carroll
Response Analysis
Corporation

Merl Dahl
State of Arizona
Department of Commerce
Energy Office

Margaret Fels
Princeton University Center
for Energy and
Environmental Studies

Michael Foley
National Association of
Regulatory Utility
Commissioners

Michael Ganley
National Rural Electric
Cooperative Association

Richard Gerardi
New York State Dept. of State
Division of Economic
Opportunity

Sharon Gill
U.S. Department of Energy,
Chicago Support Office

Larry Goldberg
Sequoia Technical Services

Miriam Goldberg
U.S. Department of Energy,
Energy Information
Administration

Judy Gregory
Center for Neighborhood
Development

Al Guyant
Public Services Commission
of Wisconsin

Martha Hewett
Center for Energy and the
Urban Environment

Bion Howard
Alliance to Save Energy

Larry Kinney
Synertech Systems
Corporation

Judith Laukaitis
Orange and Rockland
Utilities

Leon Litow
U.S. Department of Health
and Human Services

Ron Marabate
Michigan Department of
Labor
Bureau of Community
Services

Jane Marden
American Gas Association

Phil Mihlmester
Aspen Systems Corporation

John Mitchell
Consolidated Edison
Company, Inc.

Barry Moline
American Public Power
Association

John Nelson
Wisconsin Gas Company

Karl Pnazek
Director, Community Action
Program Services

Meg Power
National Community Action
Foundation

Bill Prindle
Alliance to Save Energy

Ken Rauseo
The Commonwealth of
Massachusetts

Jeffrey Schlegel
Wisconsin Energy
Conservation Corporation

Ken Tohinaka
Vermont Energy Investment
Corp

Wendel Thompson
U.S. Department of Energy

Marjorie J. Witherspoon
National Association of State
Community Services
Programs

ORNL/CON-467

OAK RIDGE
NATIONAL
LABORATORY

LOCKHEED MARTIN

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

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MANAGED AND OPERATED BY
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ORNL-27 (3-96)

ORNL/CON-467

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Martin Schweitzer
Linda Berry

May 1999

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract number DE-AC05-96OR22464

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ACKNOWLEDGMENTS

We wish to thank those staff members at the state weatherization offices who provided the information that we used in our study of the Weatherization Assistance Program. Without their kind assistance, this report would have not been possible. Similarly, we were assisted by several evaluation contractors, whom we also would like to thank.

Joel Eisenberg and Bruce Tonn, colleagues at Oak Ridge National Laboratory, reviewed a draft of this report and provided valuable comments which led to an improved document.

Finally, we would like to thank Mariann Huskey for the final preparation of this report.

EXECUTIVE SUMMARY

INTRODUCTION

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

Table ES-1. Studies used in metaevaluation

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

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

METHODS

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

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

KEY FINDINGS

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

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

According to the descriptive equation produced by the simple regression analysis mentioned above, natural gas savings equal −29.06 plus the product of pre-weatherization consumption times 0.415. By inserting the national average of pre-weatherization household natural gas consumption into the equation, we can estimate average national savings. According to the latest national weatherization program evaluation (Brown, Berry, Balzer, and Faby 1993), average pre-weatherization natural gas consumption for all end uses is 133 million BTUs per house, so our estimate of national household savings is 26.1 million BTUs annually. This amounts to 19.6% of average pre-weatherization consumption for all end uses.

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

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

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

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

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

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

1. INTRODUCTION

1.1 BACKGROUND

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

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

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

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

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

1.2 SCOPE OF REPORT

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

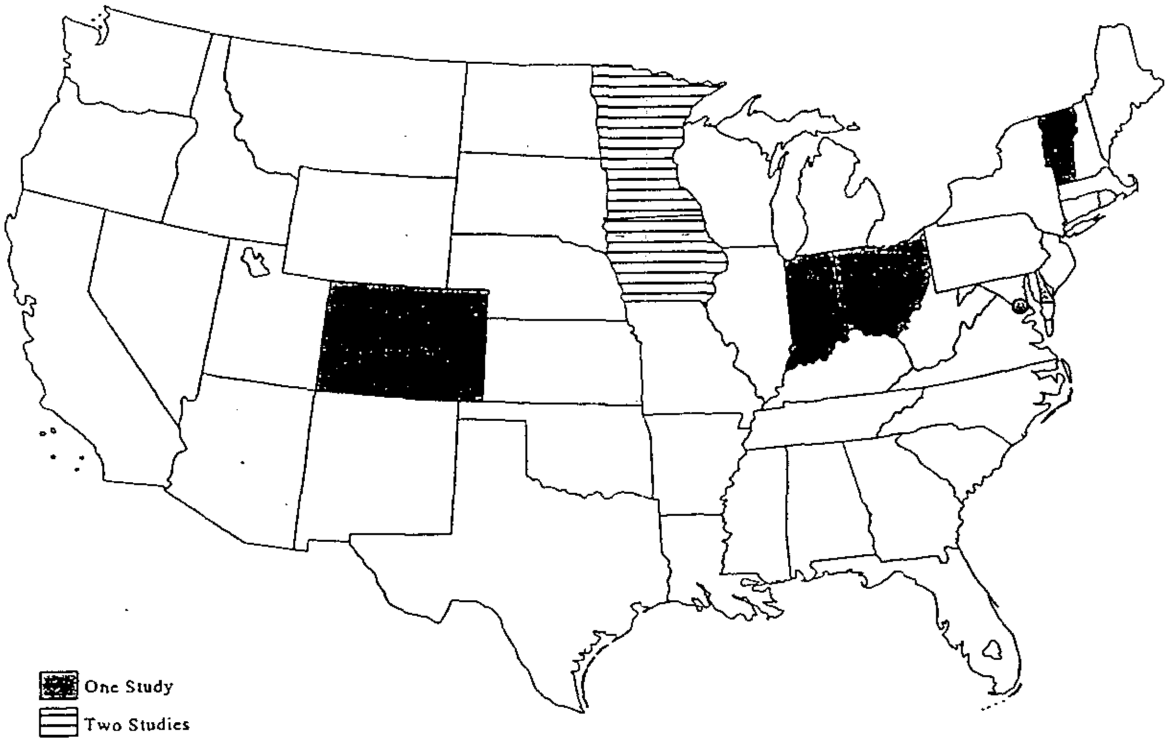

Figure 1. States with weatherization program studies used in metaevaluation.

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

2. METHODS

2.1 SELECTING STATE EVALUATIONS

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

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

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

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

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

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

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

Table 1. Key features of state evaluations

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

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

studies examined houses that used natural gas and seven looked at houses that used electricity (Table 1). Three of the studies of electricity use focused on houses with electric heat and four looked only at the use of electricity for nonheating purposes. The number of houses examined varied widely from study to study. For studies of natural gas consumption, four were based on data for less than 100 houses while another four looked at over 1,000 houses. On the electricity side, three of the studies examined less than 100 houses and two evaluated savings for over 1,000 structures.

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

2.2 WORKING WITH THE DATA

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

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

The major *outcome* of interest in this metaevaluation is the magnitude of energy savings experienced by weatherized households. Our data points for this variable are the average annual energy savings identified in each of the state studies described in Section 2.1. Most of the state studies did not employ a control group, so the energy savings they identified are gross (or unadjusted) savings. However, a few states reported net savings that had been adjusted based on the performance of a control group, and we used these adjusted savings whenever they were available. Average savings for the entire set of state studies was calculated by taking the arithmetic mean of the average savings reported in the individual studies, and the 90% confidence interval also was computed.[4] Separate calculations were made for different fuel sources and applications: one using data from the nine state studies of gas-fueled houses; another using data from the three state studies of electrically-heated dwellings; and a third using the four evaluations of structures that used electricity for nonheating purposes. The findings for the gas-fueled homes are presented in Chapter 3, while electricity savings (which are based on a smaller number of observations) are discussed in Appendix B.

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

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

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

3. FINDINGS

3.1 NATURAL GAS SAVINGS FROM STATE STUDIES

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

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

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

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

3.2 EXPLAINING NATURAL GAS SAVINGS

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

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

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

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

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

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

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

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

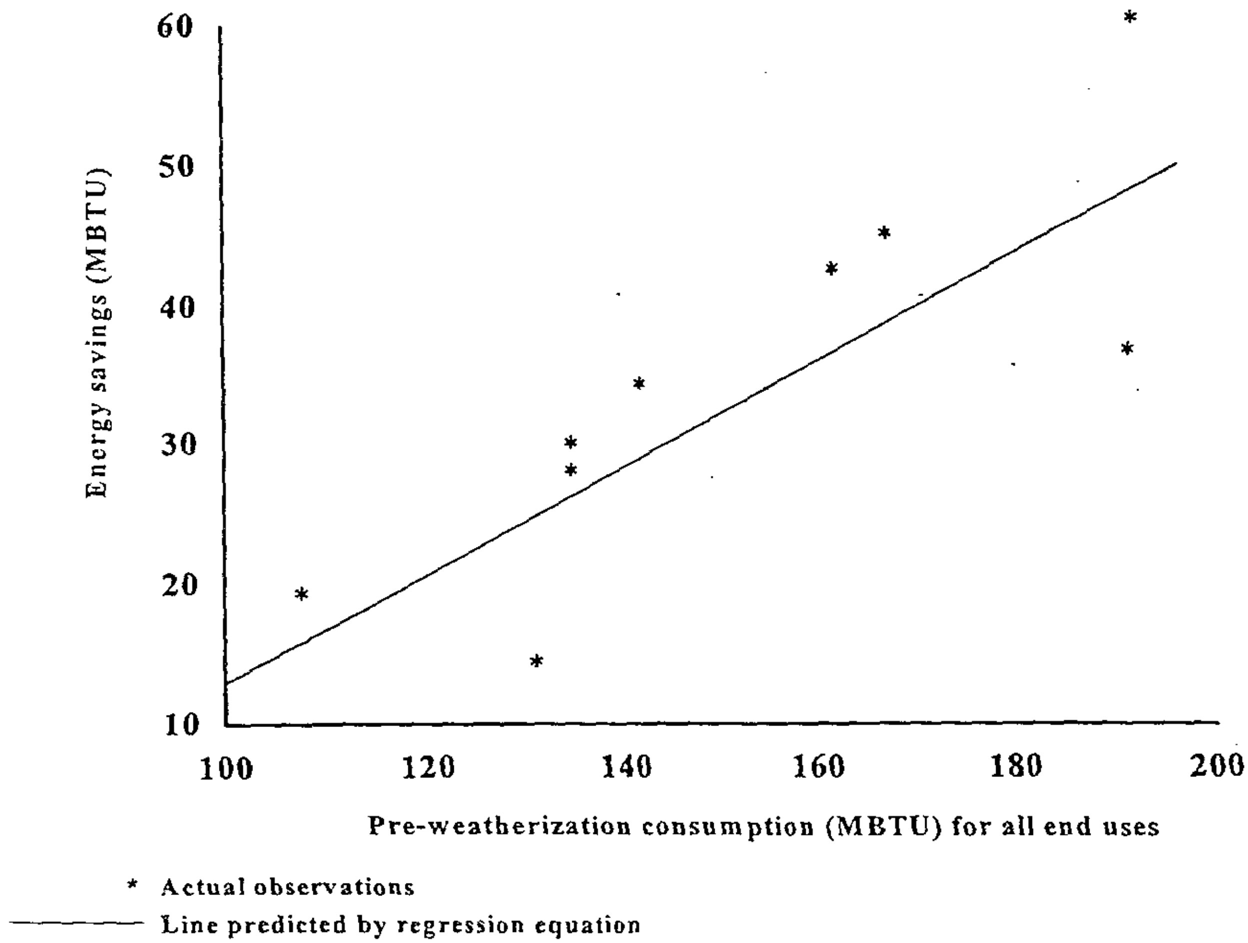

Figure 2. Plot of energy savings by pre-weatherization consumption for gas-heated structures.

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

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

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

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

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

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

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

133 MBTU*

Predicted average household natural gas savings, nationwide:

−29.06 MBTU + (0.415 × 133 MBTU) = 26.1 MBTU

90% confidence interval: 19.4–32.8 MBTU (26.1 ± 6.7)

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

26.1 MBTU / 133MBTU = 19.6%

90% confidence interval: 14.6–24.6% (19.6% ± 5.0)

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

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

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

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

3.4 COST EFFECTIVENESS RESULTS FOR BUILDINGS HEATED WITH NATURAL GAS

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

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

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

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

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

4. CONCLUSIONS

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

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

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

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

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

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

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

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

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

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

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

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

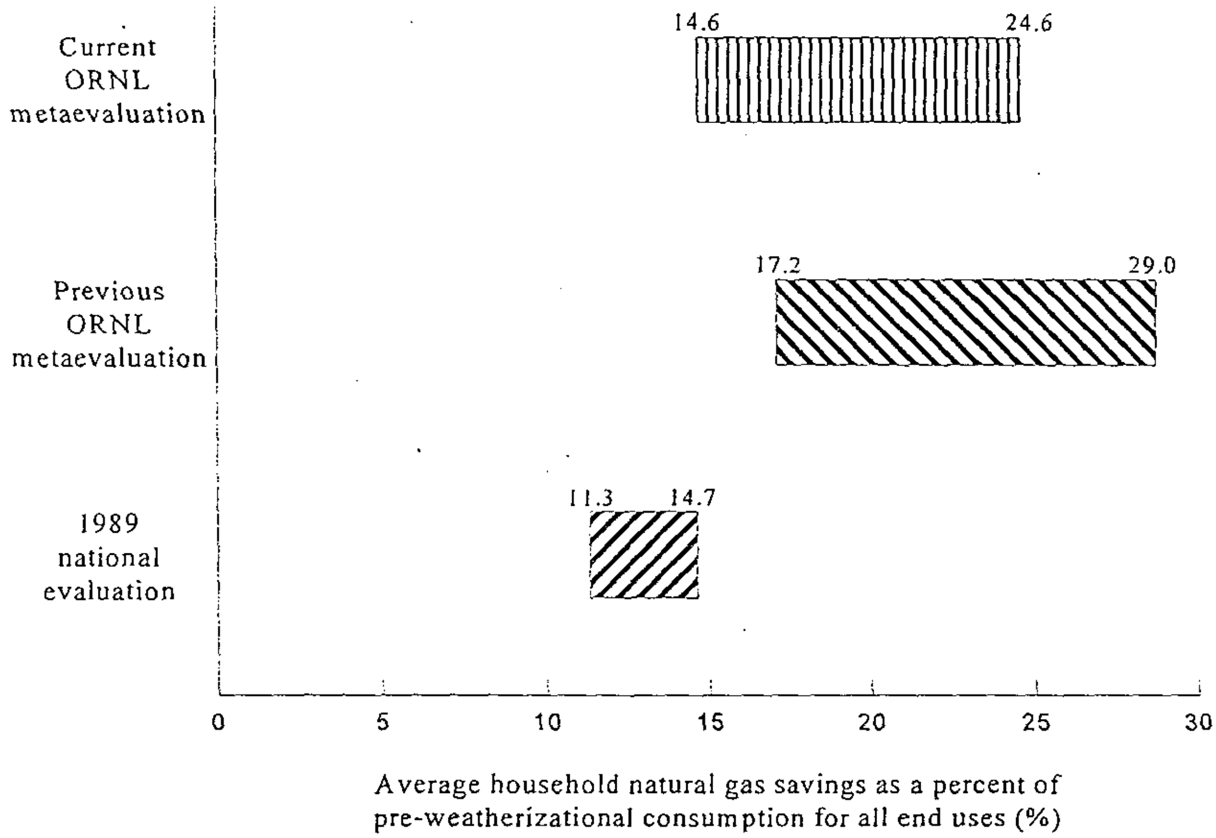

Figure 3. Average national whole-house savings: 90% confidence intervals from three evaluations.

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

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

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

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

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APPENDIX A

STATE WEATHERIZATION OFFICE SURVEY RESULTS

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

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

Table A.1. Continued

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

APPENDIX B

ELECTRICITY SAVINGS

B.1 SAVINGS BY ELECTRICALLY-HEATED HOUSES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX C

INDEPENDENT VARIABLES USED IN REGRESSION ANALYSIS

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

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

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

Table C.2 shows the findings of a correlation analysis run on the set of four independent variables used in this evaluation. As this table illustrates, the strongest correlations were between (1) square footage of structures and weatherization expenditures ($r=0.675$, $p=.14$); and (2) square footage of structures and pre-weatherization energy consumption ($r=0.591$, $p=.09$). When we excluded one study focusing on households with abnormally high values for pre-weatherization consumption from the data set, we found that the relationship between pre-weatherization energy consumption and heating degree days was strengthened (r=0.516, p=.19). However, none of these relationships was significant at the .05 level.

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

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

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