5744

SOUTHEAST

# A Warm Wind Blows South: Virginia's Weatherization Evaluation

by Kathy Greely, John Randolph, and Bill Hill

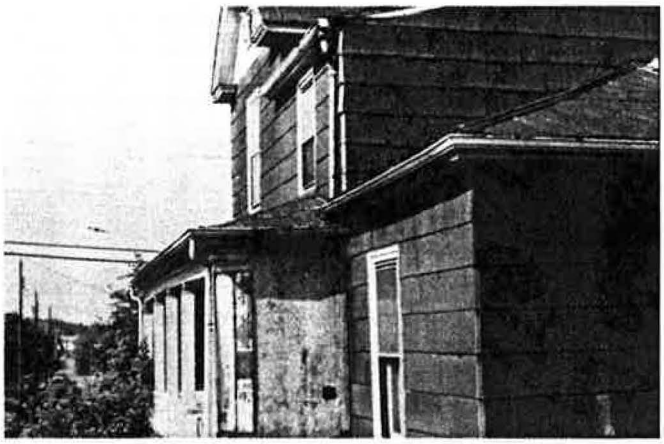
***Low-income homes in the Southeast have just as great a potential for energy savings as many homes in colder climates, according to an evaluation of Virginia's existing weatherization program and pilot program.***

Innovative conservation techniques, previously applied only in Northern and Midwestern states, can save energy just as well in milder climates. Or so it appears from our comprehensive evaluation study, which contrasted energy and dollar savings between existing and new conservation measures used in Virginia's Weatherization Program. The study, part of the program's effort to improve its cost-effectiveness and benefits for low-income consumers, found that by using new measures such as high-density wall insulation and air sealing targeted at basements and attics, space heat savings for single-family homes increased from 10% to 24%, compared to the existing program.

## Why Evaluate?

In its 15 years of operation, the Virginia Weatherization Program installed energy conservation measures in more than 60,000 low-income housing units. However, the state had no hard evidence concerning how much energy the weatherization work saved. State agency staff were also beginning to suspect that Virginia's installation standards, primarily based on DOE's "Project Retro-Tech," were probably not as cost-effective as they could be.

*Kathy Greely is senior research associate and John Randolph is director of the Virginia Center for Coal and Energy Research at Virginia Polytechnic Institute and State University. Bill Hill is senior researcher at the Center for Energy Research/Education/Service at Ball State University.*



John Randolph/VCCER

**Virginia's low-income housing stock is in such bad disrepair that average energy intensity is higher than Minnesota's.**

Exciting news about high-density wall insulation and advanced air sealing techniques used in Northern states was beginning to drift south of the Mason-Dixon line, and Virginia weatherization staff were curious to see if such new conservation techniques could improve their program, too. Although savings from these new techniques had been evaluated in northern states, such measures had not been tested in mild climate states. (Virginia's climate ranges from 3,400–5,000 $HDD_{65}$, 600–1,500 $CDD_{65}$.)

In 1988, the Virginia Association of Community Action Agencies, which administered the state's weatherization program, began changing their standards to reflect some of these advances. However, the agency soon realized that a full assessment of the program would be necessary in order to see which measures would be best suited to Virginia's mix of climate, housing stock, and local agency capabilities, and which would prove most cost-effective to the Commonwealth.

The main objective of the evaluation was to develop a set of recommendations to improve the effectiveness of the program. More specifically, the Virginia Association of Community Action Agencies was interested in finding out how new weatherization techniques, such as high-density wall insulation, would work in a mild climate like Virginia's. To answer these questions, we designed a three-step evaluation:

- high-density, blown cellulose wall insulation;
- advanced air sealing techniques focusing on attics, basements/crawlspaces, bypasses, ducts, and registers (rather than caulking windows, doors, and baseboards);
- heating system safety inspections (because the hazardous effects of inadequately vented combustion gases, cracked heat exchangers, and fuel leaks can all be exacerbated by tightening the building shell); and
- furnace cleaning and tuning.

We retained some measures from the existing Virginia installation standards, such as water heater wraps, attic insulation, and bellyboard insulation (for mobile homes). We specifically de-emphasized conventional caulking and window replacements. Training stressed using the blower door as a diagnostic tool for locating air leakage pathways through the building envelope and in the duct system. The role of estimators was expanded: rather than simply determining a materials list, they were now required to diagnose the weatherization needs of each house (e.g., uncovering leakage sites and bypasses and devising strategies for insulating walls).

Rick Stover

**Blower door training session**

### *Measuring Pilot Savings*

Because the Virginia Association of Community Action Agencies wanted to make improvements to Virginia's weatherization program as quickly as possible, we measured energy savings in pilot houses via a short-term monitoring technique: weatherization crews attached elapsed-time meters to the furnaces and occupants read them weekly. This relatively inexpensive approach yielded pre- and post-retrofit consumption data over the course of one heating season.

Crews recorded the materials cost and labor time required for each installed measure. This information, combined with agency data on wage rates and overhead costs, allowed us to calculate actual on-site and total costs (including program support).

### *Heating System Dangers*

Heating system inspections were done on 44 of the 59 pilot units. Inspections included flue gas and steady-state

## Air Sealing Before and After

How did the Virginia program transform its air sealing practices? The old program used traditional air-sealing techniques—lots of caulking and weatherstripping of "obvious" cracks like those around doors and windows.

Often, the blower door is touted as the solution to the ills of overzealous and inappropriate caulking. But this program proves that the blower door is no panacea. Ineffective use of the tool did not prevent the crews from ignoring bypasses in the walls and using extraordinary amounts of caulk. The priority list method and target air exchange rates did not allow crews to tap the blower door's potential for cost-effectively guiding air sealing.

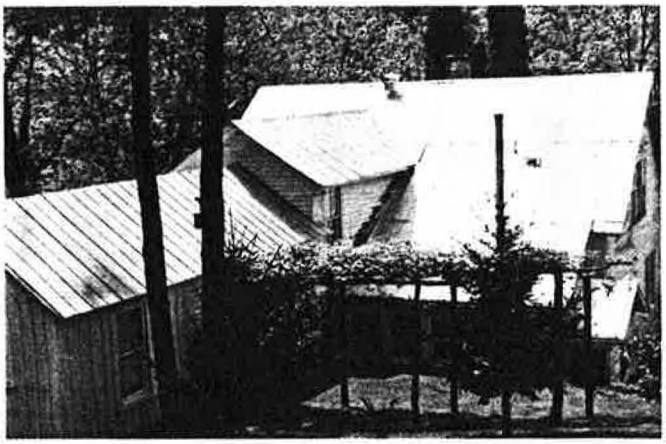
The pilot program trained crews to use the blower door not just to observe minimum ventilation guidelines, but to find the most detrimental air leaks and "bypasses"—constructions in walls that allow air from basements, crawlspaces, and attics outside the building envelope to infiltrate, often at much greater rates than ordinary cracks. Auditors learned to use the blower door as a diagnostic tool, helping to determine how high a priority air sealing should be for any particular home and to guide crews to the most cost-effective changes. Crews, too, learned to use the door's diagnostic potential.

One of the biggest wastes of time in the earlier method was air sealing done on the "neutral pressure plane" of the house. Because of the natural stack effect inside leaky buildings, most houses draw air in through the basement/crawlspace and lower areas of the building, creating a negative pressure (or slight vacuum), while a positive pressure builds up where air is exfiltrating through the upper walls and ceiling. Somewhere in between, there is a plane parallel to the ground where air pressure is the same inside and outside, called the neutral pressure plane. Knowing this, the pilot project trainees didn't bother wasting time and caulk by air-sealing where neutral pressures would minimize infiltration naturally.

Instead, they focused air sealing in basement/crawlspaces and attics, particularly on openings between walls and roofs or ceilings, where many bypasses can be found. Sealing also focused on duct work. One prime candidate for effective air sealing is the "register boot," the portion of the duct fitted (one hopes!) to the register or grille. Often 1-in gaps around the perimeter of the opening and the duct draw outside air in with the conditioned air, exacerbated by the pressure created by the forced air. These are often the easiest duct leaks to reach.

(For more on duct sealing, see *HE*, "Air Handler Fan: A Driving Force for Air Infiltration," Nov/Dec '89, p. 11; "Heat Pump Study: Tricks of the Trade that Can Pump up Efficiency," Mar/Apr '91, p. 29; "An Ounce of Prevention: Residential Cooling Repairs," May/June '91, p. 23. For more on blower door as a diagnostic tool, see "Blower Door Guidelines for Cost-Effective Air Sealing," *HE*, Mar/Apr '90, p. 34. For more on dense-pack cellulose, see "Sidewall Insulation and Air Leakage Control," *HE*, Jan/Feb '90, p. 13.)

— Karina Lutz



John Randolph/VCCER

**Large, leaky, rambling houses with no wall insulation hold potential for great energy savings.**

efficiency measurements, identification of fuel leaks, and inspection of the heat exchanger and venting systems. Safety problems, primarily unsafe flues and fuel leaks, were found in one-third of the inspected units. One agency performed cleaning and tuning on ten furnaces. This typically included cleaning the heat exchanger, adjusting the draft, adjusting the combustion air, and adjusting oil pump pressure. Steady-state efficiencies in these units increased from an average of 75% to 79% as a result of this work.

### *How the Pilot Houses Measured Up*

Median space heat savings for the pilot study were 24% in single-family houses and 17% in mobile homes. Savings ranged from 26% to 71% for one agency's single-family homes, all six of which received wall insulation. Median on-site labor and materials costs were $653 for single-family homes and $679 for mobile homes. Median total costs, including program support, were $1,119 for single-family homes and $1,145 for mobile homes.

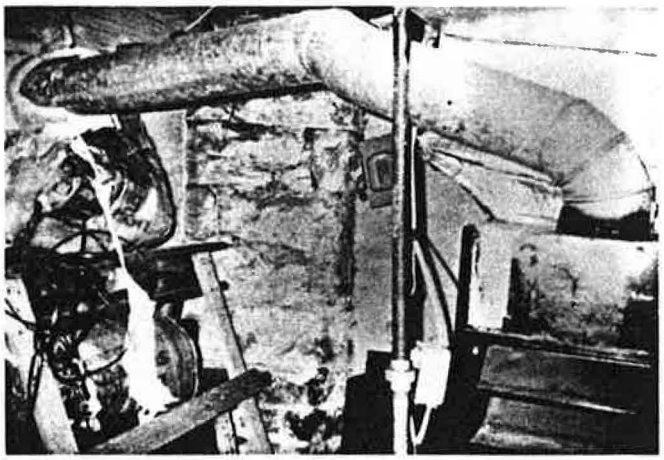
It is difficult to compare precisely the savings from the existing program with savings from the pilot study, because we had to measure the savings in different ways (PRISM analysis of utility bills versus weekly submetered space heating data). Ideally, the same measurement method should have been used for both parts of the evaluation; however, time constraints ruled out this course of action. (We plan to do a PRISM analysis on the pilot homes as sufficient utility billing data become available.)

Despite these differences in measurement techniques, however, it is clear that the pilot study savings were substantially greater than savings from the existing program. Table 1 shows savings for both groups of houses, by building and heating fuel type. The savings for single-family homes in the pilot study were over two times greater than the space heat savings for gas-heated single-family homes in the existing program (Figure 1).

Weatherization cost-effectiveness was also much better. For fuel-heated single-family homes, paybacks improved from 30 years for the existing program to 10 years for the pilot study. The cost of conserved energy for the single-family homes in the pilot fell below prevailing residential gas and oil prices. Mobile home weatherization in the pilot, while much more cost-effective than the work done as part of the existing program, was still not quite cost-effective (payback time of 17 years and cost of conserved energy greater than fuel prices).

Not only does the pilot study represent a substantial improvement over the existing Virginia program, it also compares favorably with other weatherization demonstration programs throughout the country (Figure 2). Cost-effectiveness was greater than in all but one of the other demonstration programs documented in the BECA-B database, a 1986 Michigan weatherization pilot program.

While the paybacks based on actual costs are somewhat lengthy, we expect the cost-effectiveness of the pilot measures to improve, for several reasons. First, the new standards were not fully implemented in all the pilot houses (for example, less than half of single-family homes received wall insulation, four-fifths of mobile homes still received new windows). Second, the crews had only a short training period to learn installation techniques for the new



Billy Weltzenfeld/New River Community Action Agency

**AUDITOR QUIZ**
**Question: What is wrong with this picture?**
**Answer: 1) Sagging insulation**
**2) "Safety" switch hanging loose**
**3) Possible asbestos around flue egress**
**4) Loose wiring**
**5) But most important, ineffective flue is a safety hazard. Backdrafting is indicated by the black soot visible where the flue meets the furnace.**

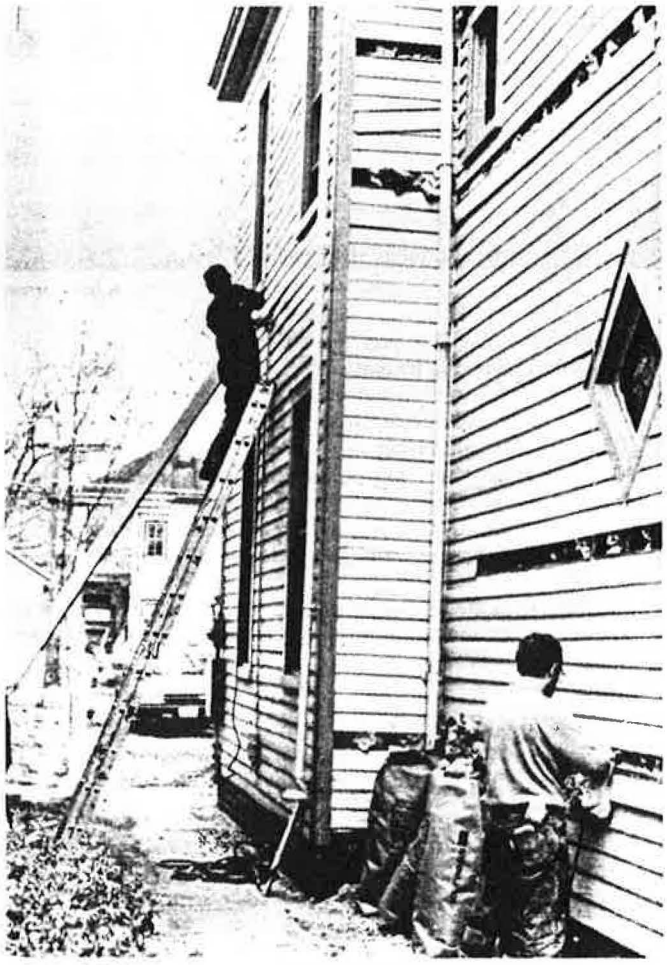
measures, and were basically "learning by doing." With more experience, labor time and costs will likely drop, and, with continued training, installation quality and savings will likely improve. Third, the pilot study required additional crew time to record measure-specific labor-time data and perform frequent blower door tests (to document changes in infiltration caused by specific measures). These tasks would not be required under non-research conditions. (On the other hand, without researchers looking over the shoulders of crew members—and utility bills of residents—they may behave differently.)

### *Lessons from the Pilot Study*

The most important lesson from the pilot study was that the new weatherization measures were substantially more

cost-effective than the work being done under the existing weatherization program. Although the sample size for the pilot was small, and differences in techniques used to measure consumption made the precise comparison of savings difficult, the large magnitude of the difference in savings allowed us to recommend with confidence that the new measures be widely implemented. The heating system work carried out in the pilot uncovered many serious safety problems; therefore, we also recommended safety inspections as a component of future weatherization work. These benefits, like comfort benefits, are difficult to quantify and were not incorporated into our evaluation.

Crews demonstrated that they were capable of learning and applying the new measures; however, post-weatherization inspections revealed that the quality of the work was mixed. For example, agencies did a good job of achieving a high-density pack with wall insulation, but missed some key bypasses. Similarly, heating system inspectors had no trouble carrying out inspections, but were unsure of how to deal with the problems they found. Since the training sessions for the pilot study were rather short (one day of classroom study and three days of field work for a wall insulation/advanced air sealing training; two days in the classroom and two days in the field for the heating system training), this need for further training was not unexpected. Rather than extending the initial training session, however, we recommended follow-up training in the field as the best approach for improving the skills of agency personnel. This would allow crews the opportunity to try out their new skills, and discover which installation techniques are particularly troublesome.



Billy Weitzenfeld/New River Community Action Agency

**Virginia's weatherization evaluation demonstrated that high-density blown cellulose sidewall insulation can be an effective measure in mild-climate states.**

### Mild Climate, High Heating Bills? Lessons for the South

Measures like high-density wall insulation and advanced air sealing, previously limited to northern states, have just as great a potential for savings in milder climates, this study suggests. Pre- and post-weatherization space-heating intensity (Btu/ft²-$DD_{65}$) for the homes we examined in Virginia were higher than both the national average and the low-income stock average, and higher than the space-heating intensity for homes in many cold-climate weatherization programs. We find a number of explanations for this: more Southern houses have no wall insulation, and the housing stock is leakier, with more opportunities for savings from infiltration-reduction work. This is certainly what we found in the houses we examined in Virginia, and while we are aware of no research supporting or contradicting these claims for other mild climate states, we suspect that such conditions may exist in housing throughout the South.

These weatherization techniques would also be expected to reduce cooling loads, which are much more significant in the South than in the North. For these reasons, we believe that southern weatherization programs have just as great a need for these and other new weatherization advances as do their northern counterparts. There are still some unresolved questions concerning these techniques, in particular whether the higher humidity prevalent in the South might lead to moisture problems in houses retrofitted with high-density wall insulation. We urge southern researchers to investigate these issues in customizing new weatherization techniques for the region.

The Virginia findings also indicate the need for other southern states to undertake weatherization evaluations. To the best of our knowledge, there have been no other completed evaluations of low-income weatherization programs in the South since the '70s. Recognizing this void, U.S. DOE's National Weatherization Evaluation has been designed to provide robust performance measures for the South, along with separate results for a northern and middle tier of states. Given the poor performance of the existing Virginia program, and the fact that it relied on typical weatherization measures like window replacements, storms, and caulking and weatherstripping, there may be much room for improvement in other mild-climate weatherization programs, as well.

## What's Next? Making Changes to Virginia's Weatherization Program

Based on the evaluation of the existing program, the engineering-economic analyses, and the pilot study, we formulated new installation standards for site-built single-family and mobile homes (Table 2). The new standards are basically the same as those used for homes in the pilot study,

## Table 2. Recommended Installation Standards

**Site-Built, Single-Family Homes**

1. Heating System Inspection
   a. Inspect heating system for safety problems
   b. Perform simple repairs, improvements
2. Heating System Ducts and Registers
   a. Seal leaks in forced-air plenum, ducts, and register boots
   b. Insulate ducts/pipes if in unheated area, as needed
3. Large Leak & Bypass Sealing
   a. Blower door test (record pre-weatherization reading; use as diagnostic tool to find major leaks in attic, basement/crawlspace, and ducts; guard against dropping below the minimum ventilation rate
   b. Major air sealing (if above minimum ventilation rate)
      1) seal large openings
      2) seal attic and basement/crawl space bypasses
      3) seal other major bypasses; use blown cellulose insulation as needed
4. Sidewall Insulation; use high-density, blown cellulose
5. Attic Insulation
   a. If existing insulation is < R-19, add insulation to R-30; if existing insulation is </= R-19, do not add additional insulation.
   c. Install venting (only if insulation added)
   d. Insulate hatch
6. Water Heater Insulation (electric and gas water heaters)
   a. Lower thermostat setting, as needed
   b. Insulate first 3 feet of hot and cold water lines
   c. Install insulation jacket
7. Caulking & Weatherstripping (install only if needed for client comfort and still above minimum ventilation rate)
8. Weatherization Repairs
   a. Replace windows or door if inoperable or deteriorated beyond repair.
   b. Perform any other repairs necessary to protect weatherization work.

**Mobile Homes**

1. Heating System Inspection
   a. Inspect heating system for safety problems
   b. Perform simple repairs for safety problems
2. Heating System Ducts and Registers
   a. Seal leaks in forced-air plenum, ducts, and register boots
   b. Insulate ducts/pipes if in unheated area, as needed
3. Large Leak Sealing
   a. Blower door test (as aboe under site-built homes)
   b. Major air sealing (if above minimum ventilation rate): seal large openings
4. Floor Insulation (blown between floor and bellyboard, or batts if no bellyboard)
5. Water Heater Insulation (electric and gas water heaters)
   a. Lower thermostat setting, as needed
   b. Insulate first 3 feet of hot and cold water lines
   c. Insulate insulation jacket
6. Caulking & Weatherstripping (install only if needed for client comfort and still above minimum ventilation rate)
7. Weatherization Repairs
   a. Replace windows or doors if inoperable or deteriorated beyond repair
   b. Perform any other repairs necessary to protect weatherization work.

except they do not include furnace cleaning and tuning. The new standards are not intended as a traditional step-by-step priority list, but rather as a package of measures to be installed in all houses where applicable. Their applicability to specific houses is determined by diagnostics, primarily during estimation but also during installation. These standards, with minor changes, have been approved for inclusion in the program for the 1991–92 contract year. To prepare for the state-wide implementation of the new standards, the Virginia Association of Community Action Agencies began training local agencies in high-density wall insulation, advanced air sealing, and heating system safety inspections during the spring of 1991. The Virginia Department of Housing and Community Development, which took over management of the program from the Virginia Association of Community Action Agencies in mid-1991, has continued to implement recommendations from the evaluation. As of late summer 1991, seven of the 27 Virginia local agencies had been trained in the new techniques.

## Conclusion

The new measures tested in the pilot study substantially improved the cost-effectiveness of Virginia weatherization. In site-built single-family homes, median space heat savings of 24% were achieved; the median cost of conserved energy of $5.20/MBtu represented a vast improvement over the existing program, and is expected to decrease as crews become more adept at implementing the new measures. This research suggests that measures like high-density wall insulation and advanced air sealing, previously limited to northern states, have just as great a potential for savings in milder climates. We hope that other Southern states will investigate the use of these techniques to improve the quality of their weatherization programs. ■

### Reference

More details on methodology and results may be found in the project's final report: John Randolph, Kathleen M. Greely, and William W. Hill, "Evaluation of the Virginia Weatherization Program: Final Report," Blacksburg, VA: Virginia Center for Coal and Energy Research, 1991.

### Acknowledgements

This study could not have been completed successfully without the contributions of many people. The Virginia Association of Community Action Agencies not only provided the funding for this research, but also played an integral role in the design and execution of the evaluation. Larry Kinney, Tom Wilson, Rana Belshe, Jim Fitzgerald, and the Corporation for Ohio Appalachian Development (including R.W. Davis, Rudy Leatherman, Jack Laverty, and Mike Keyes) conducted trainings for the pilot study and prepared training manuals. The effective participation of the four local weatherization agencies was crucial to the success of the pilot study. Several electric and natural gas utilities graciously provided the billing data essential for the study of the existing weatherization program.

We also wish to thank Michael Blasnik (GRASP), Samuel Cohen (Lawrence Berkeley Laboratory), Scott Pigg (Wisconsin Energy Conservation Corp.), and Lester Shen (University of Minnesota Underground Space Center) for their thoughtful reviews of earlier reports on this research.