Assessing and Comparing the Results of a Meter Analysis and Blower Door Test of Weatherization Programs – Is the Expense of the Blower Door Test Worth It?

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Abstract

This paper will examine the energy impact results of approximately 280 homes that were weatherized through the Department of Energy's Low-Income Weatherization Program. The method of determining the impacts was a billing analysis using the Princeton Scorekeeping Method (PRISM) and these results are compared to pre- and post-weatherization blower door test results.

Missouri and their Community Action Agencies that deliver the Low-Income Weatherization Program perform a blower door test that measures air infiltration rates on participating homes before and after the weatherization services are provided. The blower door tests provide useful data for quantifying and documenting infiltration rate reductions and in helping program implementers identify where infiltration reduction efforts should be focused. The tests also help implementers reduce the level of energy consumption when those tests result in sealing areas of the home that would not have been captured without the tests. The tests also help implementers understand when they should stop sealing, because the home has reached a desired level of "tightness". In this capacity the tests serve as a valued quality control mechanism as well as an energy savings tool.

The results presented in this paper should not be considered definitive. Rather, this paper is published to add to the body of knowledge pertaining to the use of blower door tests and their relationship to energy savings. The results of this paper are based on a small group of homes; too small to serve as a substantial addition to the literature. However, as part of this paper we examined the evaluation literature, searching for other studies that tested the benefits or cost effectiveness of the addition of a blower door test to a typical weatherization service. We also searched for studies that examined the use of blower door results as a predictor for improved savings beyond standard (non-blower door) audits and for studies that compared non-blower door audited and blower door audited populations.

The primary finding in this paper is that there is limited information both in the evaluation literature and from this study to draw a conclusion on the cost effectiveness of adding blower door tests to a weatherization program when the program already conducts a standard audit. The authors are not saying that blower door test should be discontinued in programs with expert air infiltration auditors. Rather there is substantial belief on the parts of the authors that the use of blower door tests is beneficial for a number of reasons. However, the ability of the blower door test to find enough additional energy savings, to cover the added cost of the test is not yet clearly documented.

Introduction

A blower door is a diagnostic tool designed to measure the airtightness of buildings and to help locate air leakage sites. A blower door consists of a calibrated fan for measuring an airflow rate, and a pressure-sensing device to measure the air pressure created by the fan flow. The combination of pressure

and fan-flow measurements are used to determine the building airtightness. According to the DOE's web site:

> Blower door technology has contributed significantly to the evolution of weatherization and building science. Before the advent of this technology and the detailed analysis of patterns of convective energy losses that it allows, most air leakage was thought to occur toward the mid-height of the conditioned building envelope, primarily through doors and windows. Accordingly, DOE and weatherization professionals advocated weatherstripping and caulking in those areas. In fact, blower doors do reveal leaks from doors and windows, although their effects are amplified, since small areas result in high-velocity air currents.
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> However, leakage from doors and windows represents a relatively small percentage of convective losses in most dwellings, and serious leaks tend to occur at the bottom and especially at the top of the conditioned envelope. As a result of the widespread use of blower doors, weatherization crews increasingly seal the air in attics and basements where most air infiltration into the house takes place.

Empire Electric's Low-Income Weatherization Program is designed to provide assistance to customers by managing their energy use and bills through home energy audits and weatherization services. The program is being implemented in southwest Missouri.

The program works directly with local CAP agencies that already provide weatherization services to low income customers through the DOE and other state agencies. Each of the participants' homes were provided with a blower door test as described above.

Empire provides supplemental funds to the CAP agencies to cover the cost of weatherization measures. This program is administered by the CAP agencies and follows the protocol under current federal and state guidelines. Empire funds focus on measures that reduce electricity usage such as electric heat, air conditioning, refrigeration, lighting, etc. Empire is currently in its third contract year of participation in this program. The 2005-2006 contract-year had 103 participants, with 148 participants in the following contract year. The current contract year has benefited 80 customers through May 2008.

The results of the evaluation were based on 100 participants that were customers long enough to have an account history and who have stayed with Empire long enough to look at trends in usage after the program. However, only a fraction of those customers received only infiltration services and were able to be used for the comparison of blower door test results and energy savings estimates using PRISM. With this lack of a strong sample size in Missouri, we examine the results of other studies that included blower door test results throughout the country and present a summary of the findings.

Missouri Case Study

Low-Income Weatherization Program

Seventy-Four of the 100 participants studied used significantly less energy after weatherization than they did before they were weatherized. On average, those that decreased their consumption did so by 3,141 kWhs annually (18.8%) after the savings were adjusted for the comparison group. The 100 participants averaged savings of 2,052 kWhs annually (13.4%) after the savings were adjusted for the comparison group.

Results for the blower door tests conducted before and after weatherization were provided to TecMarket Works for 235 participants. Table 1 below presents the summary of findings of the blower door tests and the PRISM results among the participants. For those 100 participants that had reliable results from the PRISM analysis, the CFM results dropped an average of 30.8% after weatherization, and their energy

consumption dropped an average of 13.4%. If we look at only those PRISM participants that had energy savings, the energy savings is an average of 18.8%, and the change in CFM increases slightly – and insignificantly – from 30.8% to 31.4%. However, there is a conceptual problem with looking at all the participants with energy savings results that fit the reliability criteria. These 100 participants received a myriad of measures that likely had an impact on energy savings. In addition, there is base load electricity usage in each household that would not be affected by the infiltration measures: lighting, refrigeration, etc. In order to make any determination about the relationship between the drop in CFM and the energy savings, we would need to better understand what percentage of the overall electric use would be affected by infiltration reduction.

Table 1. Blower Door Test Results and Change in Annual kWh Consumption

Group	n	% change in CFM	% change in annual kWh consumption
All Participants	235	-33.3%	-
PRISM participants	100	-30.8%	-13.4%
PRISM participants with energy savings	74	-31.4%	-18.8%

Correlations

There is no significant correlation to be found between blower door test results and energy savings in either of the PRISM groups listed in Table 1. For the PRISM participants, the correlation factor of energy savings and CFM the percent change in CFM is 0.19. For PRISM participants with energy savings, the correlation factor of energy savings and the percent change in CFM is 0.20. Correlation factors for CFM reduction to costs of weatherization or number of measures installed are even lower at 0.02 for both. This is not surprising because savings in many homes are more a function of non-air-infiltration measures. This analysis, from this limited population, seems to suggest that there may only be limited benefits in conducting blower door tests in order to achieve weatherization induced energy savings. However, that conclusion is not justified on this comparison alone. This conclusion would have to come from a study specifically designed to test the cost effectiveness of adding the blower door test. That evaluation has not yet been conducted.

Correlation with Participants That Only Received Infiltration and/or Door Measures

There were two participants that received only infiltration measures and that also had reliable PRISM results. This sample was too low for a regression analysis; however, an examination of these two participants indicate that as infiltration is reduced, savings increase. This conclusion supports other studies (referenced later in this paper) conducted on larger populations.

Table 2 presents the results of the infiltration reduction for the two participants.

Table 2. Savings of Participants Receiving Only Infiltration Measures

	Reduction in CFM	Normalized Annual Savings
Participant A	10.4%	426 kWh = 1.9%
Participant B	5.2%	262 kWh = 1.42%

When we expand the analysis to include participants receiving both infiltration and door measures (11 participants), such as sealing existing doors and windows or installing new ones, the correlation between the blower door test results and the electric energy savings increases to .30, indicating a somewhat positive relationship. This low correlation is because 3 of these participants increased their consumption after weatherization while 8 decreased their consumption. Looking at only the 8 participants who decreased their consumption provides a correlation between blower test results and kWh savings of .83, a strong positive relationship. This correlation documents, as have other studies, that if you reduce the air infiltration you will reduce energy use. However, the test does not indicate how much of that reduction would have been captured in a standard audit that already focuses on air infiltration reduction. Thus, for energy savers the relationship between the change in blower door test scores and savings is strong and positive, but not all participants who reduce CFM also save energy.

The mean cost of weatherizing the 235 participants that were studied was $1,212. The measures installed included: insulation, infiltration measures, hot water heater measures (usually insulation, but in a few cases these were replaced), doors and windows, HVAC, and lighting. The most commonly installed measures each addressed air leakage problems and were, in descending order of frequency:

1. Attic insulation
2. Caulking
3. Outlet Gaskets
4. Weatherstripping
5. Foam Sealant

The Case For Blower Door Tests

During the course of the literature review, we were able to find only two studies that suggested that blower door testing improved energy savings from weatherization. The study, "State Level Weatherization Program Evaluations" by Michael Blasnik, found that blower door guided air sealing provided a savings average of 50-100 therms per year, or about 7 therms per year per 100 CFM50, which was found to be 70%-100% of projected savings. However, this report did not compare the savings with what would have been achieved by a standard audit with a focus on sealing air leaks.

Leslie Carlson and Timothy Hennessy found that, according to agency personnel, the blower door tests led to highly effective duct sealing. Thirty-five per cent of the program's energy savings were attributed to duct sealing, and the participant survey revealed that 90% of the respondents indicated that their comfort levels have improved. Again, no information was provided on the incremental effects of the added blower door test.

Other studies that we read in the course of the literature review revealed that blower door tests were an increasing trend that had the expectation of cost effectively improving energy savings from weatherization enough to offset the cost of the added test. However, these expectations are not verified in the evaluation literature and the theory remains untested. While we expect that the use of a blower door has helped train auditors, and auditors have become more capable of identifying leak-sealing opportunities than they were prior to the use of the tests. The cost effectiveness of the tests themselves remains elusive.

The Cases Against Blower Door Tests

The literature review revealed studies indicating blower door tests were not an essential component of weatherization audits and that adding the test did not provide information that enhanced energy savings. A study performed by Quantec in 2000 found that blower door tests are not correlated with energy savings. The paper states, "No strong relationship seems to emerge between air leakage reduction and energy savings". However, this report also advances the need for more study by stating that "this is an issue that needs to be examined more carefully to decide whether the use of the blower door is cost justified or not".

Another study presented in the same paper has similar results as the Missouri case study presented in this paper. From a low-income weatherization program in Ohio (1994), they found that "high saving agencies tend to also have achieved high air leakage reduction, but not necessarily as a function of the use of the blower door test over an experienced auditor. This program achieved an average of 28% air leakage reduction and approximately 10% average savings."

Are Blower Door Tests Cost-Effective?

Weatherization services provide substantial savings to the low-income community. This has been documented in every state and federal weatherization program evaluation conducted since 1980. However, none of these studies address the question of the cost effectiveness of the blower door test itself.

A Wisconsin Residential Characterization Study was performed in 1999, by Suzanne Harmelink and Martha Benewicz. This study reveals some key housing characteristics of single-family owner-occupied homes. As can be seen in Table 3, the low-income housing stock (in Wisconsin, 1999) has higher rates of un-insulated walls and under-insulated ceilings.

Table 3. Single Family Housing Characteristics, Wisconsin 1999

	Statewide Average	Low-Income	Older Homes, Not Low-Income	New Homes
Per Cent of Homes With Un-insulated Walls	14%	20%	15%	0%
Per Cent of Homes With Under Insulated Ceilings	21%	40%	21%	2%

A possible inference that could be drawn from this is that since low-income weatherization programs are servicing homes that are likely to be un-insulated or under-insulated, a blower door test is not needed to make substantial improvements over what can be achieved via a traditional audit that already focuses on air sealing (because of the large savings opportunity from other measures). It may be more cost-effective for weatherization crews to focus on apparent insulation and non-blower door identified sealing needs with their limited time available for each home. However, this possible conclusion is not justified because there is no data to suggest how savings may or may not be improved via the addition of a blower door test.

Another consideration well understood by the evaluation community is that projected savings do not always translate into actual savings. In one study (Malek and Melloch), six houses were carefully studied in order to project savings based on blower door tests. Actual savings were different for all homes, to varying degrees. A summary of savings and predications is provided in the table below. The occupants were interviewed after the energy savings were estimated. The occupants of House 1 had a person that started staying home during the week to care for grandchildren, but the home still achieved therm savings that were higher than projected. Houses 5 and 6 also had an occupant that started staying at home during the day after

the weatherization. House 5 still was able to achieve higher than projected kWh savings, but had a very large (314%) increase in natural gas consumption. House 6 was not able to meet projected savings for either electricity or natural gas.

Table 4. Single Family Housing Characteristics, Wisconsin 1999

	Percent of Projected kWh Savings Realized	Percent of Projected Therm Savings Realized
House 1	76%	120%
House 2	86%	51%
House 3	240%	74%
House 4	85%	123%
House 5	183%	-314%
House 6	55%	67%

Conclusion

There is currently a lack of readily available information that can be used to estimate the cost effectiveness of adding a blower door test to a weatherization program that uses a professionally conducted energy audit that already looks for air sealing opportunities. The blower door tests have helped improve audits so that they now are able to identify additional air sealing opportunities that were not often captured in the early years of the weatherization program. However, expert auditors now understand where to look for non-traditional air sealing opportunities. With the focused energy audits of the current industry, is it cost effective to add a blower door test to a weatherization program? At this time it appears that the evaluation industry does not know the answer to this question.

Epilogue

As a result of the Missouri findings and the lack of our ability to find published research to address the cost effectiveness question, the authors of this paper put out a call for information to key evaluators and weatherization program managers who have substantial experience conducting evaluations and implementing weatherization programs. This call resulted in substantial discussions on the benefits of the use of the blower door test. Discussions covered the ability of the test to document when to stop sealing a home so that homes are not over-sealed; discussions on the ability of the blower door test to serve as an audit training tool; discussions of the use of the blower door test as a quality control tool for program management, and other similar lines of discussion. All of the contributing experts, including the authors of this paper, agreed that the blower door is an effective tool in the weatherization tool box for a host of reasons. However, these discussions resulted in the lack of identified documentation on the cost effectiveness of the addition of a blower door test to a program that already conducts air sealing audits. Our question remains unanswered. For now, the authors of this paper recommend the use of a blower door for the reasons cited above. However, the authors would like to see a well-designed field test evaluation conducted so that program designers would have better information about whether, and to what extent, the use of blower doors in weatherization service delivery improves overall program cost effectiveness. At this point, that information appears to be unavailable.

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