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National Weatherization Assistance Program Impact Evaluation: A Field Investigation of Apparent Low and High Savers

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NATIONAL WEATHERIZATION ASSISTANCE PROGRAM IMPACT EVALUATION: A FIELD INVESTIGATION OF APPARENT LOW AND HIGH SAVERS

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ACRONYMS

AFUE	Annual Fuel Utilization Efficiency
CFM50	Cubic Feet per Minute @ 50 pascals
CFR	Code of Federal Regulations
DOE	Department of Energy
HVAC	Heating Ventilating and Air Conditioning
ORNL	Oak Ridge National Laboratory
PY	Program Year
WAP	Weatherization Assistance Program

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EXECUTIVE SUMMARY

The study described here was an investigation of apparent low and high savers among single-family households treated by the U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) in Program Year (PY) 2008. The study sought to better understand the factors leading to unusually low and high savings estimates that derived from analysis of pre- and post-weatherization utility consumption histories for homes heated with natural gas or electricity.

To implement the study, a geographically diverse sample of 19 locations in 17 states was selected from among geographies represented in a much larger sample of homes included in the impact evaluation of the PY 2008 program. Individual homes within each sampled location were then randomly selected from among those determined to have unusually low or high apparent savings relative to the major heating-related measures installed in the home.[1] A total of 105 homes were included in the final sample, of which 71 had lower-than-expected apparent savings and 34 had higher-than-expected savings.

For each home, a trained field technician reviewed the local weatherization agency job file to better understand the site and the work that was performed, then conducted a roughly two- to three-hour site visit that included a visual inspection, air leakage and duct leakage tests, an infrared scan and an interview with the client about household changes over the period of interest. The data were then compiled and the sites were coded for the presence or absence of various explanatory factors for low or high savings.

The analysis revealed a set of 10 explanatory factors for apparent low or high savings among the study sites, some of which were household-driven factors unrelated to the program, and some of which were program related.

Household factors

<u>Household change</u> – About one in four study participants experienced a change in household composition or schedule that could be considered a primary or contributing factor to apparent low or high energy savings. These occurred with about equal incidence among apparent low- and high-savers.

<u>Change in use of supplemental heating</u> – About one in three participants changed how they used supplemental heating sources (mainly electric space heaters). On balance, these households were somewhat less likely to use supplemental sources following weatherization. Since supplemental heating offsets the need for primary heat to some degree, decreased use of sources like space heaters reduces savings for the primary heating fuel relative to what would be seen if no supplementary fuels were used.

<u>Change in thermostat settings</u> – About one in ten households reported a change in thermostat-setting practices following weatherization. These were more likely to involve lower settings during the heating season than higher settings. There is thus little evidence for "take-back" of heating energy savings following weatherization.

<u>Remodeling or other changes to home</u> – Remodeling activity that would affect energy consumption was rare in the sample: only two cases were identified, both involving changes that likely led to low apparent energy savings.

<u>Idiosyncratic consumption</u> – Some households (particularly in warmer climates) used their heating system irregularly, such that estimated annual consumption—and savings—was particularly uncertain. This was

[1] Major heating-related measures are generally considered to be: attic insulation, wall insulation, heating system replacement and substantial reduction in air leakage, as measured by pre- and post-weatherization blower-door tests.

identified as an important factor for about one in ten cases with low apparent savings, but was rarer among apparent high savers.

Program factors

Atypical measure application – About one in three or four apparent low savers had wall or ceiling insulation treatments that were in fact minor applications involving a limited area. Since the program typically treats most or all of the wall or ceiling area when these areas are addressed, this would explain lower-than-expected savings relative to more typical jobs where the treatments were more extensive. Conversely, about one in seven apparent high savers received ceiling insulation in spaces with little or no existing insulation: this would explain higher-than-average savings in these cases, because most homes that receive additional ceiling insulation have some existing insulation in place.

Issue with existing heating system – A small number of apparent low savers had a heating system that was non-functional or malfunctioning prior to weatherization. Repair or replacement of this system as part of the weatherization package meant that usage of the primary heating fuel increased following weatherization, leading to negative apparent savings. In other cases, functional heating systems were replaced for health-and-safety reasons with new units that had about the same efficiency level as the existing unit: savings from these would be expected to be less than for energy-efficiency replacements, which generally involved high-efficiency, condensing equipment.

Measure persistence – A small number of apparent low savers experienced premature failure of an installed measure. For example, in one case, animals largely destroyed a belly insulation work under a mobile home.

Work quality – Issues with the quality of the weatherization work were deemed to be a primary or contributing factor to apparent low savings in about one in five cases. These mostly had to do with the quality of insulation work in ceiling spaces and missed cavities for wall insulation.

Additional measures – About half of the apparent high savers received measures such as duct sealing or foundation insulation that would help explain higher-than-average savings relative to the more limited set of measures used to establish expected savings for each site. A small number of apparent low savers had health and safety related measures installed that might plausibly increase heating energy consumption: in one case, for example, a home with forced-air heat had a supply register added to a crawlspace, presumably to help deal with moisture issues.

Missed Opportunities

The study identified missed energy-saving opportunities in addition to explanatory factors for apparent low or high energy savings. Missed opportunities for wall or ceiling insulation, duct sealing or air leakage reduction were identified for about half of the apparent low savers and about a quarter of apparent high savers, suggesting that there is potential for additional savings from the program.

1. INTRODUCTION

1.1 NATIONAL WEATHERIZATION ASSISTANCE PROGRAM EVALUATION OVERVIEW

The U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) was created by Congress in 1976 under Title IV of the Energy Conservation and Production Act. The purpose and scope of the Program as currently stated in the Code of Federal Regulations (CFR) 10 CFR 440.1 is "to increase the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, persons with disabilities, families with children, high residential energy users, and households with high energy burden." (*Code of Federal Regulations, 2011*)

At the request of DOE, Oak Ridge National Laboratory (ORNL) developed a comprehensive plan for a national evaluation of WAP that was published in 2007. DOE furnished funding to ORNL in 2009 for a national evaluation for Program Years (PY) 2007 and 2008, with a particular emphasis on PY 2008. ORNL subcontracted evaluation research to APPRISE Incorporated and its partners (the Energy Center of Wisconsin, Michael Blasnik and Associates, and Dalhoff Associates LLC). The Scope of Work (SOW) for the evaluation includes the following components.

<u>Impact Assessment</u> – Characterization of the weatherization network and the households that are income-eligible for WAP, measurement and monetization of the energy and nonenergy impacts of the program, and assessment of the factors associated with higher levels of energy savings, cost savings, and cost-effectiveness.

<u>Process Assessment</u> – Direct observation of how the weatherization network delivers services and assessment of how service delivery compares to national standards and documentation of how weatherization staff and clients perceive service delivery.

<u>Special Technical Studies</u> – Examination of the performance of the program with respect to technical issues such as air sealing, duct sealing, furnace efficiency, and refrigerators.

<u>Synthesis Study</u> – Synthesis of the findings from this evaluation into a comprehensive assessment of the success of the program in meeting its goals and identification of key areas for program enhancement.

The field study described here falls under the Special Technical Studies component of the larger evaluation effort.

1.2 BACKGROUND AND OBJECTIVES

A key objective of the national evaluation is to measure the energy savings achieved by the program, and the primary approach used in the evaluation is to compare pre- and post-weatherization energy consumption for a large sample of participating households, including a comparison group of households that did not receive weatherization services during the period of interest. The average impact for the program is estimated as the average savings observed for participants less the average observed for the comparison group.

While perfectly appropriate and necessary for estimating the aggregate national impact of the program on energy use, the reported averages mask considerable variation in observed savings from home to home. For example, Fig. 1 shows the distribution of weather-normalized (but otherwise unadjusted) gas savings for a national sample of homes treated by the program in PY2008. While most homes show a reduction in gas consumption associated with weatherization, the observed change in usage for individual homes ranges from a 40 percent increase to a 75 percent decrease.

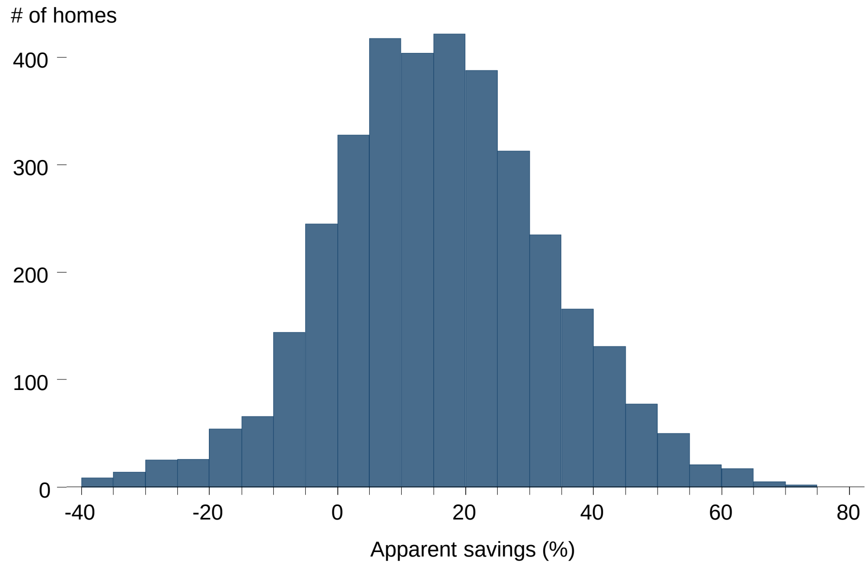

Fig. 1. Distribution of apparent savings for national impact-evaluation sample

Some of the variation in savings like that seen in Fig. 1 owes to differences in the measures that were installed in homes; some (e.g., thermostat-setting behavior) may owe to differences in how households respond to the weatherization work; and some is no doubt due to household factors that are completely unrelated to the program.

The purpose of the study described here was to go beyond the averages, so to speak, and investigate in more detail both the program and non-program factors affecting changes in energy consumption—in essence to better understand the factors that drive homes into the tails of the savings distribution.

In this regard, the study had a special interest in homes with low or negative savings, because the apparent savings for these are contrary to the intent of the program. In particular, the study sought to assess the extent to which low apparent savings arise due to factors that are under the program's control and, thus, potentially correctable.

2. METHODOLOGY

2.1 SAMPLING

The study was scoped for field investigation of 100 to 120 single-family homes. In keeping with the study focus on apparent low savers, a sampling goal of two-thirds low savers and one-third high savers was established. The sample frame for the study was a pool of approximately 4,700 PY2008 single-family homes with natural gas or electric heat for which pre- and post-weatherization utility data had been collected for the primary heating fuel. Detailed information about the home, occupants and weatherization work had also been gathered under a separate task of the overall evaluation effort. The sample frame included both site-built and manufactured homes.

To keep field costs reasonable, it was necessary to geographically cluster the homes selected for the study. This imposed some constraints on sample selection, because the pool of available jobs was itself geographically clustered. To deal with this, homes in the sample frame were geocoded and assigned to geographic areas bounded by a grid of 2 degrees latitude and longitude. This procedure yielded 38 geographic locations with sufficient apparent low and high savers to merit consideration for the study. Eighteen of these locations were then selected using a procedure intended to mimic the distribution of the WAP population by climate region and provide geographic diversity within climate region.

Cases with apparent low and high energy savings for the primary heating fuel (as described in more detail below) were then randomly selected for recruitment within each geographic area, with a goal of about six recruited sites per location. Sampled households were recruited by telephone, and offered a cash incentive for participating. The final study sampled comprised 105 homes in 17 states (Fig. 2).

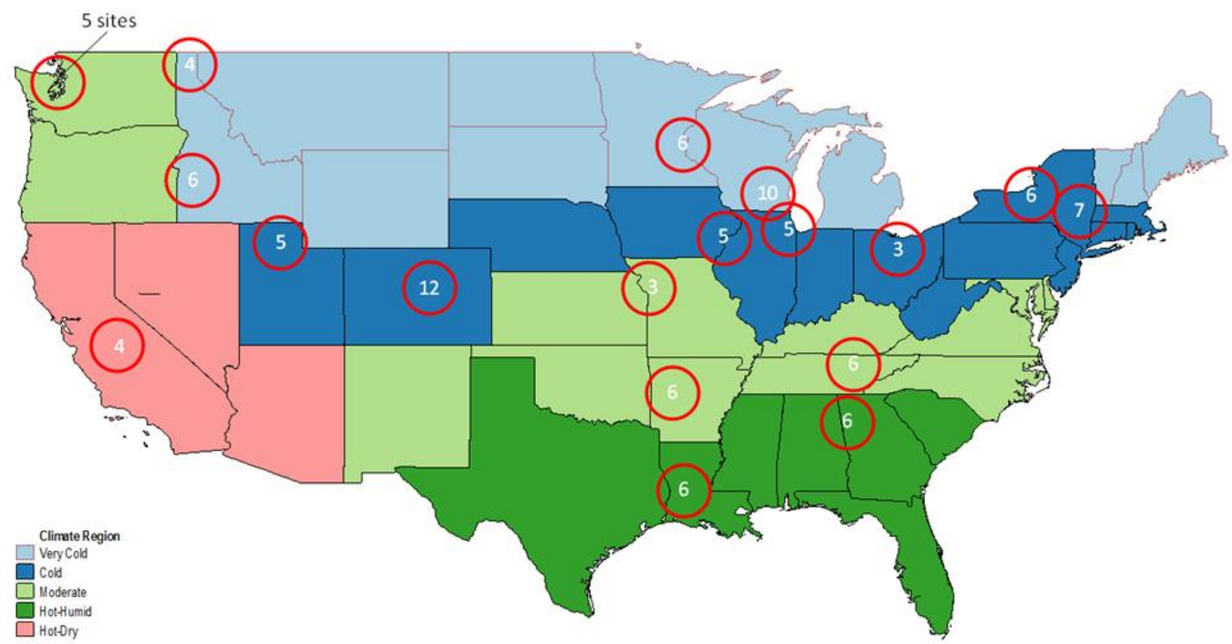

Fig. 2. Sampled locations, with number of sites

2.2 CLASSIFICATION OF LOW AND HIGH SAVERS

The original plan for the study called for targeting homes with apparent savings that differed significantly from computer audit predictions. However, this plan was deemed infeasible for two reasons. First, only about half of local weatherization agencies use a computer-audit that provides savings estimates for each measure and participating home—and these agencies tend to be concentrated in the Cold and Very Cold climate regions. Confining the study to this portion of the population would have thus made the geographic breadth of the study uneven. Second, the available sample frame for the study was Program Year 2008 participants that had been randomly sampled for the program-characterization and impact-assessment components of the larger national evaluation effort. While detailed household and measure data were collected for these sites as part of the larger data-collection effort, collection of computer-audit files was not designed into this earlier effort, and was thus not generally available for identifying a sample of low- and high- savers for this study. Some computer-audit data was gathered incidentally in the course of executing the earlier effort, but relying on these ad hoc situations would have made the current study very housing-stock and geographically limited.

Instead, as an alternative approach, a regression model was used to identify apparent low and high savers. The model used information about pre-weatherization heating energy intensity, measured air leakage reduction and whether certain major measures were installed to establish an expected range of savings for each job in the sample frame: homes with apparent savings below the expected range were classified as apparent low savers, and sites with apparent savings above the range were deemed apparent high savers. The modeling procedure is described in more detail in Appendix A.

Note that while this approach provided for some tailoring to the individual circumstances for each site, it was limited by the fact that the data for individual homes consisted only of binary indicators for whether a measure was installed. The procedure thus could not take into account factors such as how many square feet of ceiling insulation was installed or what the existing insulation level was. Overall, while the approach taken provided a more representative national sample of apparent high- and low-savers, this came somewhat at the expense of knowing less about the measures and expected savings for the sites selected for the study.

2.3 FIELD PROTOCOL

The field protocol for the study comprised three parts:

- Review of agency job files
- On-site inspection and client interview
- Post-visit review and with evaluation team member debrief

At the outset of the field deployment for each location, study technicians visited local weatherization agencies to review job files prior to the site visits. The purpose of the review was to check the accuracy of evaluation data about the household, home and measures that had been previously provided, as well as to obtain more detailed information from the files about the installed measures. The field form for these reviews is included in Appendix B.

The site visits lasted between 1.5 and three hours, and included:

- a review of mechanical systems and appliances
- inspection of insulation levels
- a blower-door test for air leakage
- infrared scans prior to and during the blower-door test
- an interview with the client, covering
    - household composition and schedule changes over the period of interest
    - remodeling activity
    - use of supplementary heating fuels

- early removal of measures
- recall of energy education provided under the program

The field form is included in Appendix B.

Following each deployment, photos and form data provided by the field technician were reviewed by a member of the Evaluation Team, who also debriefed the technician on key findings for each site, and reviewed the available natural gas and electricity consumption histories for the home. This information formed the basis for a written summary for each site.

2.4 ANALYSIS

Analysis for the study consisted of developing a set of potential explanatory factors for apparent low or high energy savings, then coding each site for the presence or absence of the factor along with a short description of the factor, if present. As described later, there were often multiple potential explanatory factors present: the analysis distinguished between primary and contributing factors, allowing for more than one of each to be present for a given site.

3. RESULTS

Results of the study are presented as follows:

- Characteristics of the study sample
- Results of the analysis of explanatory factors for apparent low and high savings
- Summary of missed opportunities

3.1 CHARACTERISTICS OF THE STUDY SAMPLE

It is not a given that apparent low or high savers should reflect the average characteristics of all homes treated by the program, but in most respects the study sample is comparable to the larger sub-population of single-family homes with natural gas or electric heat (Table 1). The strongest differences have to do with air leakage, where apparent low savers are leakier and high savers are tighter, and with measures, where apparent high savers are more likely to receive major insulation work.

Table 1. Selected characteristics of the study sample and all PY2008 single-family homes with natural gas or electric heat.

	Study Sample		All PY2008 homes*
	Apparent Low Savers	Apparent High Savers	
	n=71	n=34	n=8,836
Heating fuel			
Natural gas	80%	82%	74%
Electricity	20%	18%	26%
Type of home			
Site-built	85%	79%	77%
Mobile home	18%	21%	23%
Heated area (mean ft^2)	1,490	1,390	1,340
Air leakage (mean cfm50)			
Pre-weatherization	3,860	2,910	3,350
Post-weatherization	2,480	2,030	2,260
Major measures (% incidence)			
Ceiling insulation	53%	79%	58%
Wall insulation	22%	35%	24%
New heating system	31%	35%	24%

*Sample of single-family, site-built homes and mobile homes with natural gas or electric heat for which detailed home and program data were collected as part of the overall evaluation effort.

Fig. 3 provides a visual depiction of the apparent savings for the sites in the sample in relation to the range of expected savings from the regression model used to identify high and lower savers. Sites are arranged from lowest to highest apparent savings, with each point representing one home in the sample. The shaded bars in the figure represent the expected range (20th to 80th percentile) of savings for each site from the regression models used to classify sites as apparent low or high savers (see Appendix A). Apparent savings range from -32 percent to +16 percent for the low savers, and from +12 percent to +60 percent for the high savers, and the two groups can more or less be separated at about 15 percent savings. Notably, this is not far from the estimated national average savings for single-family, gas-heated homes in the program (17.8%). However, the two groups should not be considered to be random samples of below-average and above-average savers, as they tend to be more extreme in terms of savings.

For the most part, apparent savings lies outside the expected range for each site. However, the fieldwork did uncover some errors in the original evaluation data that was the basis for the expected savings: correcting these shifted the expected savings range significantly in some cases. In addition, a small number of "moderate" savers were included in the original sample to fill out sample quotas in certain locations. Nonetheless, it is fair to say that apparent savings for the low savers are generally lower than expected, and, conversely apparent savings for high savers are higher than expected.

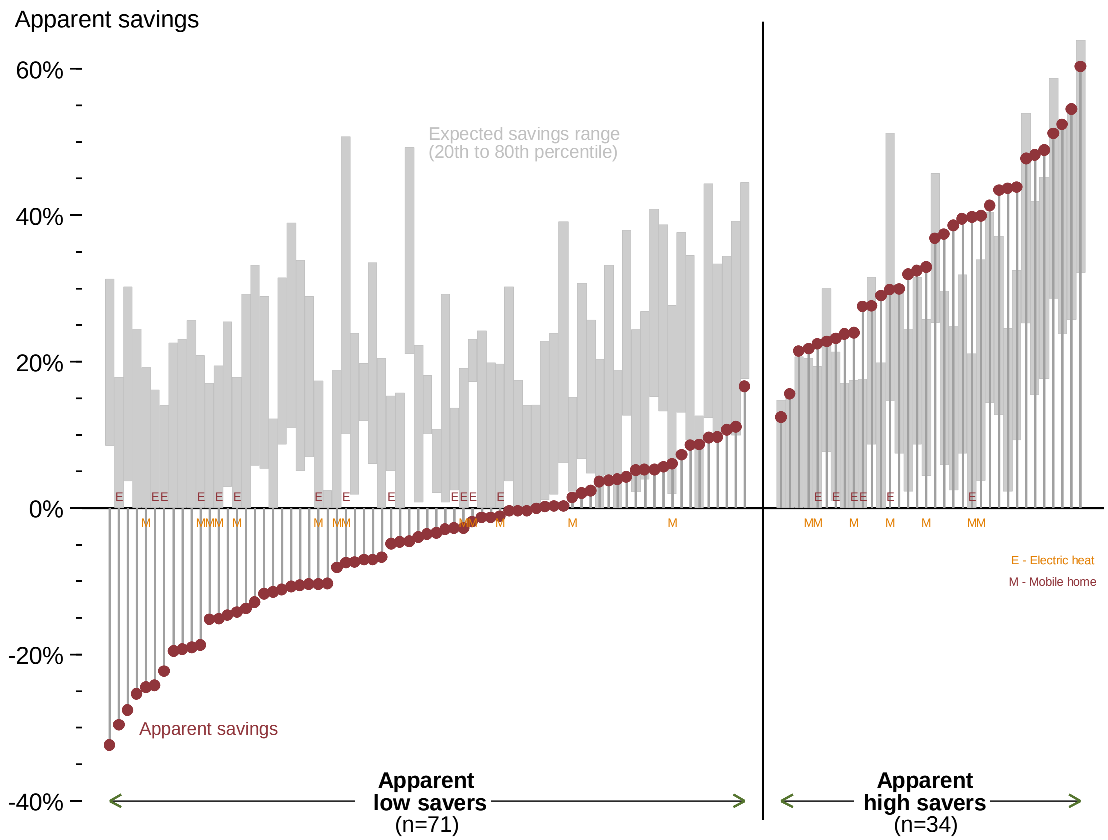

Fig. 3. Observed apparent savings and predicted savings range for study sample

3.2 FACTORS ASSOCIATED WITH APPARENT LOW AND HIGH SAVINGS

Before discussing explanatory factors identified in the field study in detail, it is worthwhile to first explore in more detail what is implied in the notions of *low* and *high* savings. First, it is important to acknowledge that *low* and *high* attain their meaning only in relation to some notion of *expected* savings. For this study, the *a priori* expected savings range for each home takes into account whether certain major measures were installed or not.

However, there are at least three possibilities for how the expected savings range might shift upon closer examination of a given home:

1. As already noted, the information about whether a major measure was installed may simply be erroneous.
2. A measure may have differed markedly from a typical installation. For example, a home listed as having received ceiling insulation might have had only a small portion of the ceiling area insulated.
3. There may have been other important measures implemented that were not accounted for in the original estimates. For example, duct sealing can sometimes have a large impact on heating energy consumption.

To the extent that these factors are present for a given home, they shift the range of expected savings, and thus the notion of whether the observed savings are in fact low or high. The expected savings ranges were adjusted to account for the first factor above: in a few cases, this led to an apparent low- or high-saver no longer appearing to be so. The second and third factors above were treated as explanatory factors for the analysis here.

Second, it is clear that weatherization is only one of potentially many influences on household energy consumption. Changes in household composition or schedule—or changes in the use of supplemental heating sources—for example, can affect usage.[2] Savings estimates that are based on the difference between pre- and post-weatherization energy consumption necessarily incorporate both the impact of the program and any non-program factors that influenced consumption during the analysis period. It is in acknowledgement of this fact that "apparent" is used throughout this report when referring to savings estimates that may include non-program factors in addition to the actual impact of the program measures.

The factors leading to lower- or higher-than-expected savings can thus be divided into household factors that are (for the most part) unrelated to the program and factors related to the program itself. This section provides a brief overview of the key identified factors leading to apparent low or high savings, which are then discussed in more detail in subsequent subsections.

First, though, it is useful to provide some additional detail about how the various factors were identified and coded. The analysis for the study involved reviewing each site in terms of the various identified explanatory factors, and determining whether each was a *primary* or *contributing* factor. *Primary* factors were those that were deemed to largely explain the full discrepancy between expected savings and observed changes in usage. *Contributing* factors were those that would help explain these savings discrepancies but were unlikely to fully explain them.[3]

[2] Weather is another obvious non-program influence on energy consumption, but savings estimates are typically normalized for weather using statistical techniques, as is the case here.
[3] Note that in a few cases, *offsetting* factors were also identified, such as when a reduction in thermostat setpoint—which would tend to increase apparent savings—was noted for a site with apparently low savings. These situations were infrequent enough that they are omitted here.

The situation is complicated by the fact that multiple explanatory factors were identified for many sites. The analysis protocol provided for multiple primary and/or contributing factors to be identified for a single site. Two (and in one case, three) primary factors were identified for about a quarter of the sites where any primary factor was identified. Conversely, 17 cases lacked any identified primary factors but had one or more contributing factors. The former situation is one where the full discrepancy between expected savings and the observed change in energy consumption could reasonably be explained by the combination of identified primary factors. The latter situation represents cases where none of the identified factors were deemed to be sufficient to explain the discrepancy, either singly or in combination. There were only three cases where no primary or contributing factors could be identified.

As noted above, in some cases, the detailed review suggested that the savings calculated for a site were in fact reasonably in line with the measures that were installed. Most of these were cases where the field investigation revealed an error in the original data regarding the measures installed, and where correcting the error led to a revised expectation of savings that was consistent with the observed savings.

Given this background, Table 2 summarizes the various household and program-related explanatory factors. Five household factors were identified, four of which involve identified household-initiated changes, such as a change in household composition that affect energy consumption. The fifth factor (idiosyncratic consumption) does not involve a specific change *per se*, but rather flags cases where the estimated savings are particularly uncertain because the household uses their heating system in an unpredictable fashion. As noted in the table, all of the household factors have the potential to make estimated savings appear either higher or lower than they actually are. Several program-related factors, on the other hand, work in one direction or the other. For example, if there is an issue with measure persistence, it is safe to say that it will reduce the savings from the measure.

The remainder of this section is devoted to discussing each of the factors in Table 2 in more detail.

Table 2. Overview of explanatory factors for apparently low or high savings.

	Impact on apparent savings	Apparent Low Savers (n=71)		Apparent High Savers (n=34)	
		Primary factor	Contributing factor	Primary factor	Contributing factor
Identified household factors					
Household change	↑↓	10%	14%	12%	15%
Change in use of supplemental heating	↑↓	14%	15%	6%	12%
Change in thermostat settings	↑↓	1%	3%	12%	6%
Remodeling or other changes to home	↑↓	1%	0%	0%	0%
Idiosyncratic consumption	↑↓	11%	17%	3%	3%
Identified program factors					
Atypical measure application	↑↓	18%	10%	15%	0%
Issue with existing heating system	↓	7%	0%	0%	0%
Measure persistence	↓	4%	6%	0%	0%
Work quality	↓	14%	6%	0%	3%
Additional measures	↑↓	1%	6%	47%	6%
Contributing, but no Primary factor identified		23%		3%	
No Primary or contributing factor identified		4%		0%	
Savings within expected range		11%		18%	

Household Changes

The client interview asked about changes in household members or household schedule that might have affected space heating energy consumption over the period of interest. About half of the households reported some type of change, but many of these were deemed to be unlikely to have an appreciable impact on energy consumption, such as cases where the change affected only a few months of the period of interest, or where the household reported a change in household schedule, but stated that their thermostat settings were not altered.

Other cases included changes that likely did affect energy consumption to some degree, including a small fraction (11 households) where the change could be considered a primary explanatory factor for apparent low or high energy savings (Fig. 4, Table 3). These include occupancy changes that were either explicitly noted as having affected energy consumption in the home, or for which a non-heating change in consumption was relatively clear in the billing history.

Household changes were about equally prevalent as an explanatory factor among apparent low- and high-savers. This suggests that while these changes add variability to analyses of energy savings they do not particularly skew the average savings in one direction or the other.

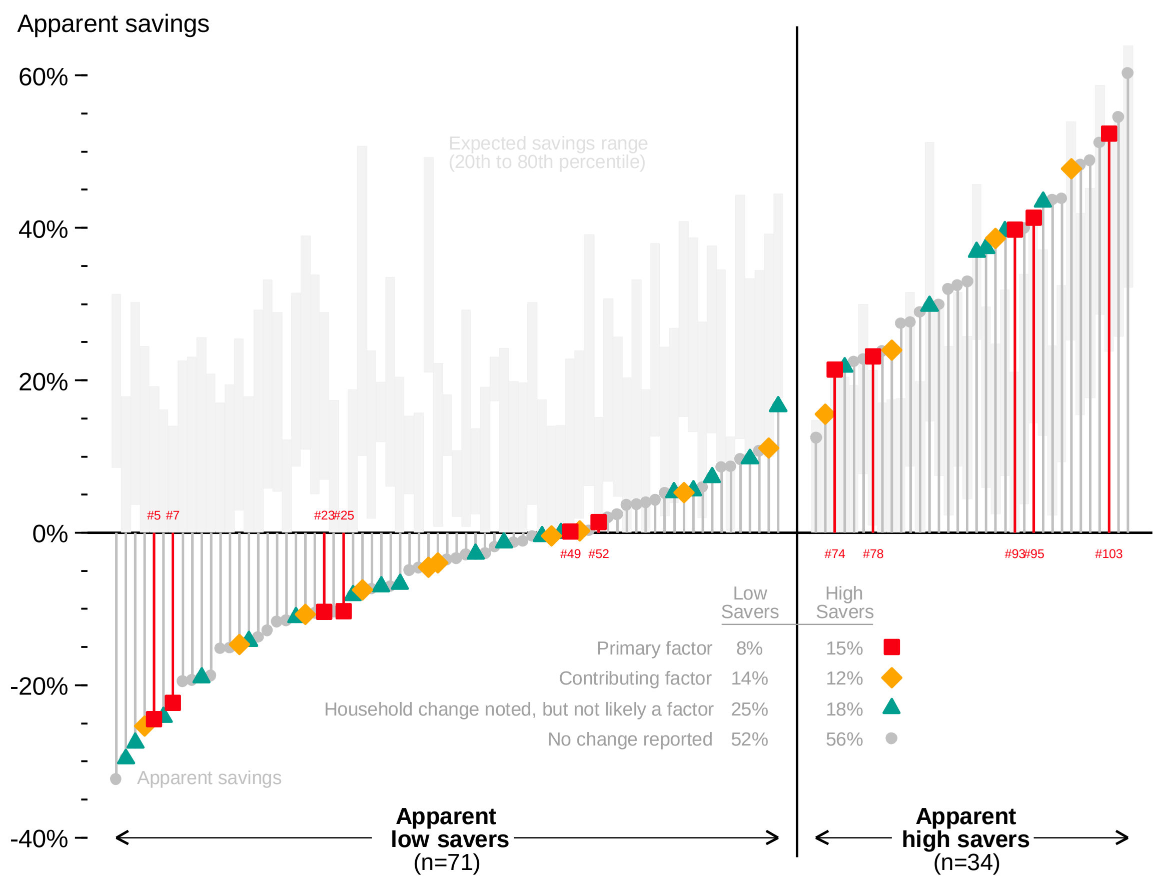

Fig. 4. Changes in household composition or schedule as an explanatory factor for apparent low or high savings.

Table 3. Cases where a household change was deemed a primary factor for apparent low or high savings

Site	Description
#5	Client hospitalized during period of interest; others moved in and out
#7	Client retired around time of Wx; other occupancy changes noted
#23	Numerous household and schedule changes over period of interest
#25	New baby in post-weatherization period
#49	Additional household member and change in schedule in post-weatherization period
#52	Significant changes in non-heating electricity consumption suggests behavioral factors for this electrically-heated mobile home
#74	Household member passed away partway through pre-weatherization analysis year.
#78	Home was occupied by someone else while owner was away for much of post-Weatherization period
#93	Two occupants moved out around the time of weatherization; this coincided with large reduction in non-heating electricity use for electrically-heated mobile home
#95	Daycare in home prior to Weatherization; new baby post-Weatherization
#103	Upstairs previously occupied by son; now unused and unheated. Household size has declined from 8 to 3

Supplementary Fuels

The client interview asked about current use of supplementary heating fuels, and whether there had been changes in the use of these over the period of interest. A little more than half of the study participants reported some use of a supplementary heating fuel, with electric space heaters being the dominant type (Table 4).

Table 4. Reported current use of supplementary heating sources

	Never	Rarely	Occasionally	Frequently
Electric space heater(s)[a]	58%	10%	13%	19%
Wood fireplace	91%	6%	2%	1%
Wood/pellet stove	94%	0%	2%	4%
Gas fireplace[b]	100%	0%	0%	0%
Oil/kerosene heater	99%	0%	1%	0%
Other	98%	0%	0%	2%
Any of above		15%	17%	26%
No reported use of any supplementary fuels	45%			

[a] Excludes reported use of electric space heaters in homes with electric resistance heat.
[b] Excludes reported use of gas fireplaces in gas-heated homes.

Some cases of supplemental fuel use were judged to be inconsequential in terms of the impact on the primary heating fuel, as when no evidence of reported electric space heater consumption was seen in the electric billing history. On the other hand, evidence of substantial, degree-day correlated electricity usage was seen for a few sites where no electric space heater use was reported. The regular increases in electricity consumption during winter months (in addition to summertime increases due to air conditioning) in Fig. 5 illustrate one such case. These were also coded as sites with supplemental fuel use.

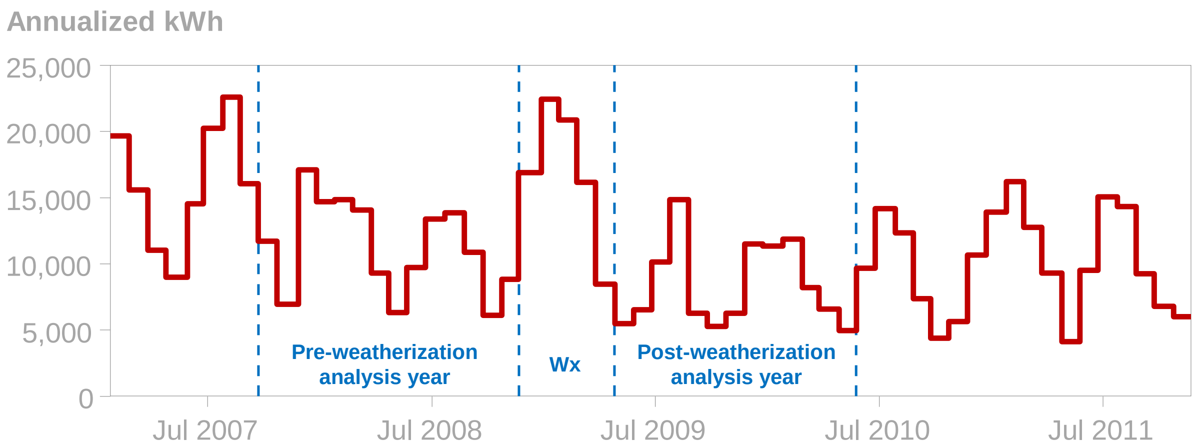

Fig. 5. Electric consumption for a gas-heated home with evidence of electric space heater use before and after weatherization (#26).

Review of the 105 sites indicated that changes in the use of supplementary fuels was likely a primary explanatory factor in 12 cases, and was a contributing factor for an additional 15 sites (Fig. 6, Table 5).

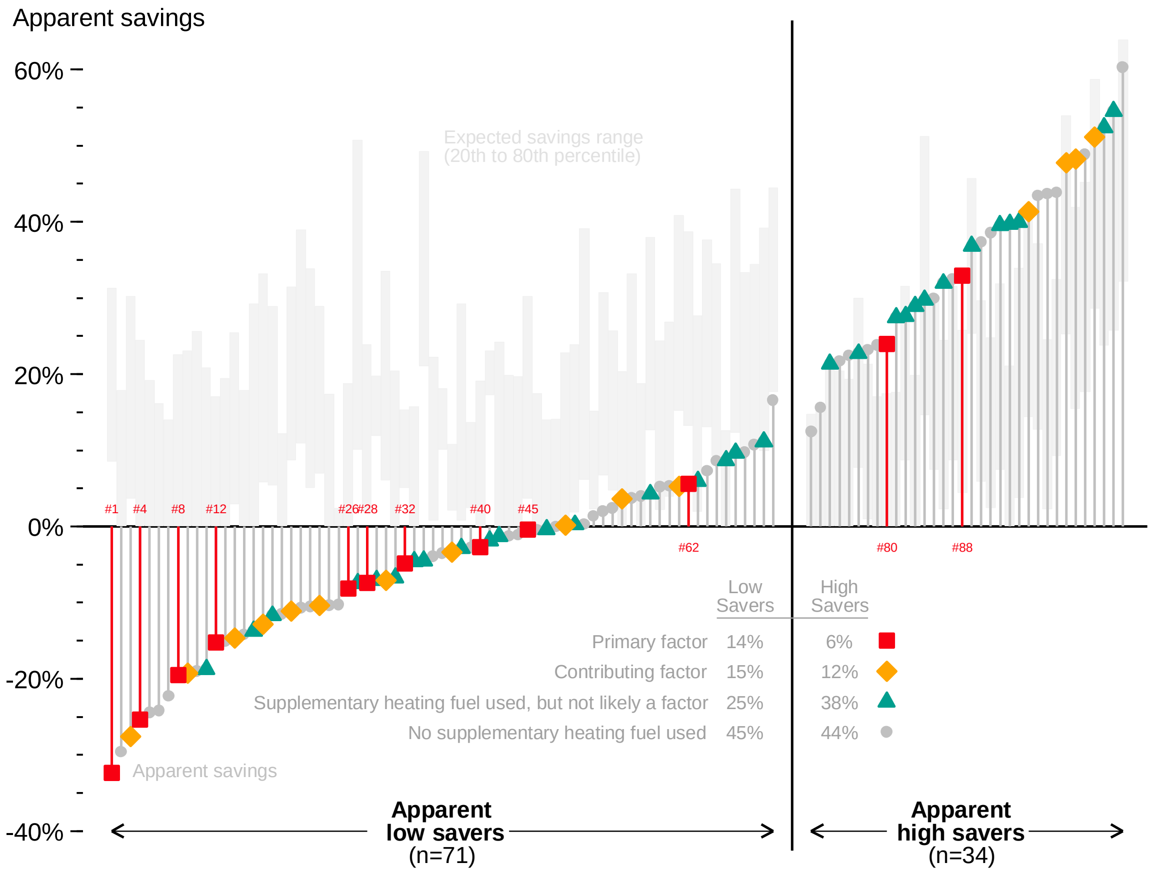

Fig. 6. Changes in supplementary fuel use as an explanatory factor for apparent low or high savings

Table 5. Cases where a change in supplementary fuel use was deemed a primary factor for apparent low or high savings

Site	Description
#1	Substantial drop in electric use evident, and client reports using electric space heaters.
#4	Substantial reported electric space heater use prior to Wx (confirmed by electric usage history); discontinued after weatherization
#8	Electric space heater use evident in electric history, though none reported by client
#12	Frequent use of electric space heaters reported by client and evident in electric billing history.
#26	Evidence of substantial electric space heater use in electric billing history, though no indication of this in interview (see Fig. 5).
#28	Reported occasional use of wood stove and fireplace appears to confound analysis of gas savings.
#32	Savings analysis confounded by substantial use of wood heater in this electrically heated home.
#40	Use of pellet stove likely confounded analysis of savings for this electrically-heated mobile home.
#45	Electric space heater use evident in billing history, and confirmed by interview
#62	Electric space heater use evident in electric history and noted in interview; use was higher prior to Wx.
#80	Change in wood stove use in this electrically heated mobile home.
#88	Significant increase in degree-day correlated electricity use following Wx suggests use of electric space heaters in this mobile home.

Unlike other household changes, changes in supplemental fuel use were more likely to be identified as a factor for apparent low savings than high savings. The majority (80%) of these were cases where a client discontinued or reduced the use of electric space heaters in a gas-heated home following weatherization. Such behavior is plausible, given that electric space heaters are typically used in rooms that are cold and drafty, which weatherization often remedies.

Note that the use of electric space heaters prior to weatherization reduces gas consumption in that period, and this in turn could be expected to lead to lower apparent gas savings from weatherization for impact analyses that focus solely on that fuel. At the same time, electricity savings for these homes will appear to be larger than otherwise would be the case, and impact analyses that account for both fuels will correctly capture the full impact of the program.

Such is not necessarily the case for homes with other supplementary heating sources, such as wood stoves, because actual consumption data on bulk fuels is difficult to obtain. Here, reduced wood-stove use following weatherization will cause estimated gas savings to be artificially low, but there may be no compensating data showing significant wood savings from weatherization—leading to an overall estimated impact that is low. However, the limited data from this study suggests that changes in bulk-fuel supplementary sources are relatively uncommon.

Thermostat Settings

Clients were asked about their current thermostat-setting practices and about any changes over the period of interest. Those who reported changing how they set their thermostat were asked about the reasons for these changes, with probes for whether weatherization played a role in these.

Such changes were identified for 14 sites, with about a 60/40 split between clients who reported reducing settings, either permanently or by practicing regular setbacks, and those reporting increases (Table 6).

Table 6. Incidence of reported changes in thermostat settings (number of sites)

	Apparent low savers	Apparent high savers	Total
Reduced settings	3	6	9
Increased settings	3	2	5
Total	6	8	14

Fig. 7 highlights the nine cases where changes in thermostat setting were deemed to be a primary or contributing explanatory factor, along with Table 7 that presents five cases where the reported change was opposite to what would be needed to explain apparent low or high savings (other factors likely offset the reported thermostat changes for these). Because reductions in settings were more likely to be reported than increases, these changes were more likely to be identified as a contributing factor to apparent high savings than low savings. In any event, these self-reported data provide little evidence for widespread "take-back" of weatherization savings through increased thermostat settings as an explanatory factor for apparent low savers.

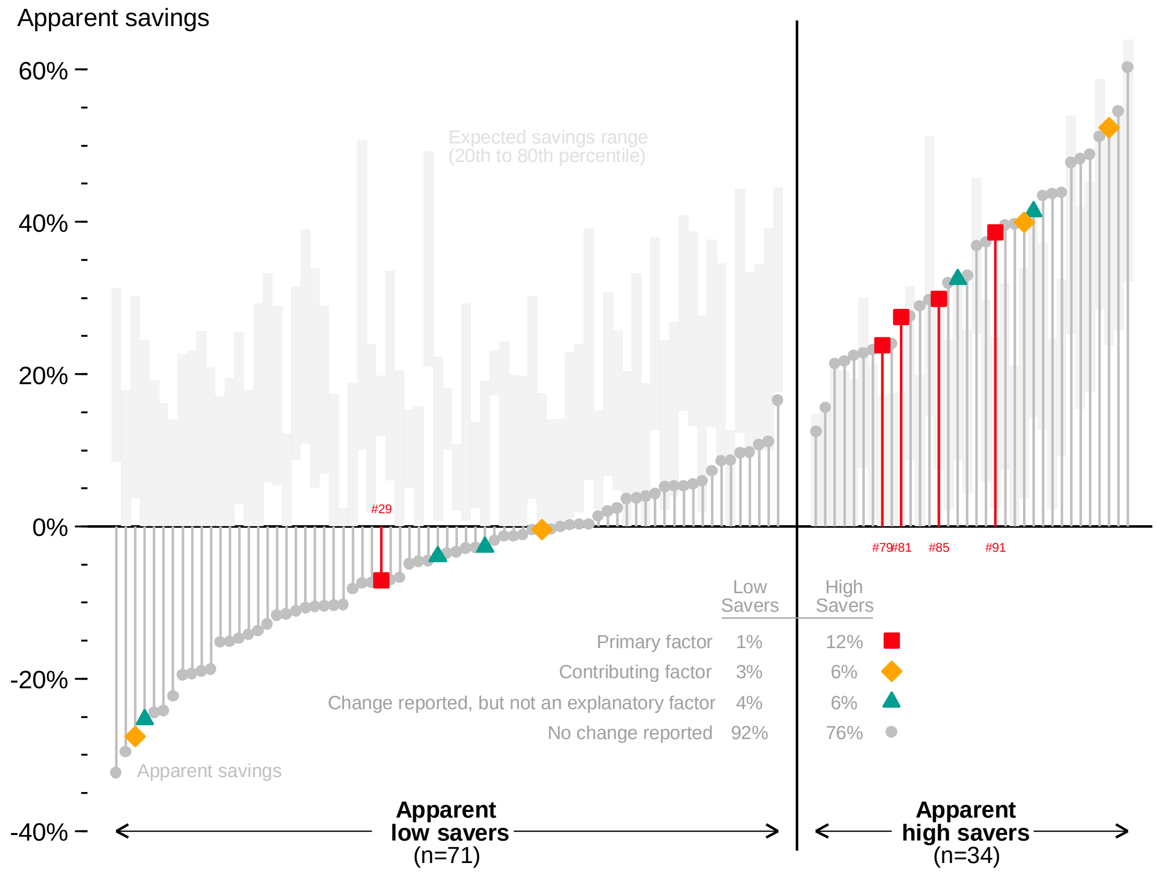

Fig. 7. Reported changes in thermostat settings as an explanatory factor for apparent low or high savings

Table 7. Cases where a change in thermostat settings was deemed a primary factor for apparent low or high savings.

Site	Description
#29	Client did not understand how to use new thermostat; kept it at a high setting
#79	Client reported practicing setback after weatherization
#81	Client reported reduction in setting from 78F to 76F following weatherization
#85	Client stated that the thermostat is kept at a lower setting following weatherization
#91	Client purchased a programmable thermostat as a result of weatherization education, and is using it.

Remodeling

Remodeling or other structural alterations to the homes in the study sample was rare: only two cases were identified. In the first (#55), the client finished the basement during the post-weatherization analysis period and added baseboard electric heat to the new space (the primary heat for the home is natural gas). This was a confounding factor from the stand-point of the original analysis that flagged the site as an apparent low-saver without knowledge of remodeling activity, though the addition of electric heat makes the direction of the impact unclear.

The second case (#87) involved a client who removed the sheetrock for 2nd story kneewalls, which caused weatherization-installed insulation to fall down. Because this occurred after the one-year, post-weatherization analysis period—and because the site in question was an apparent high-saver—it was not considered an explanatory factor here.

Idiosyncratic Consumption

A fraction of homes included in the sample had heating-fuel consumption that was not very well correlated with heating degree days.[4] This makes the estimates of pre- and post-weatherization annual consumption uncertain, thereby creating uncertainty in the calculated savings as well. A site could thus appear to be a low saver not because of anything to do with the program, but simply because the household chose to use less heating for a few months in the pre-weatherization period. As might be expected, this factor appears somewhat more frequently in warmer climates where there can be more discretion about whether and when to heat one's home.

Fig. 8 highlights the cases where idiosyncratic consumption was deemed to be a primary or contributing factor for apparent low or high savings. Sites with uncertain savings estimates were flagged for this factor only if the savings estimate was uncertain with no other evident explanation, such as supplementary fuel use. Idiosyncratic consumption was deemed a primary factor only if the uncertainty range for estimated savings substantially covered the range of expected savings; otherwise, it was flagged as a contributing factor.

The one site where idiosyncratic consumption was deemed a primary factor for an apparent high saver (#72) is worth noting, because a utility meter read error (which creates a characteristic pair of outliers in the monthly consumption history) rather than variation in actual consumption appears to lie behind the uncertain savings estimates. This case should perhaps properly be described as idiosyncratic "apparent" consumption.

[4] Note that the utility billing data analysis sample from which homes for the study were selected employed some conservative screening to eliminate cases with very poor correlation between usage and heating degree days. The idiosyncratic cases identified here were ones that passed this prior screening, but had variability in usage that was sufficient to create substantial uncertainty in the estimated savings.

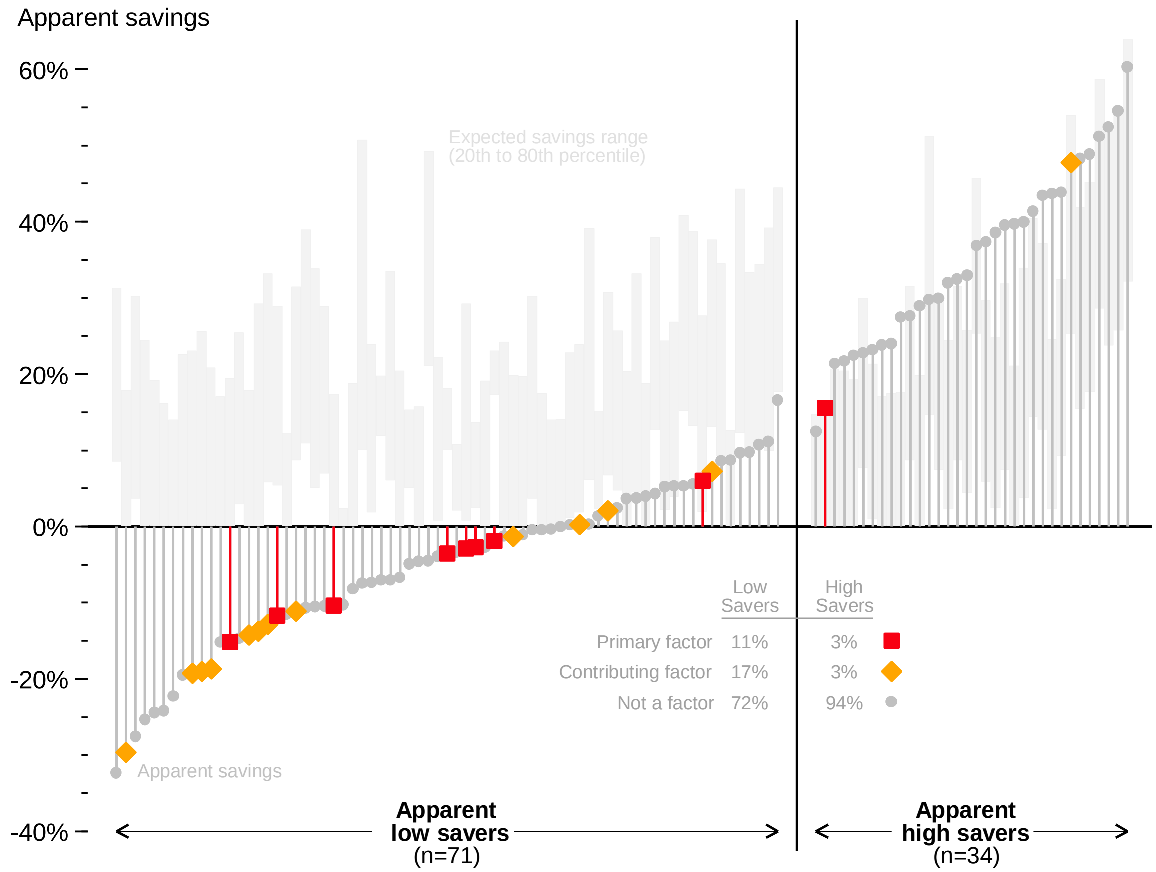

Fig. 8. Idiosyncratic consumption as an explanatory factor for apparent low or high savings

Atypical Insulation Applications

Leading the list of program-related explanatory factors for apparently low or high energy savings are atypical applications of major insulation measures, notably wall and ceiling treatments. An example of an atypical application would be a case where only a small wall area needed insulating. Because only binary indicators for measures like wall and ceiling insulation were available for the evaluation—and because a substantial portion of a home's wall area is typically insulated when the measure is applicable—a limited installation such as this would lead to lower-than-expected savings relative to other homes that receive wall insulation. On the flip side, some measures may yield higher-than-average savings, such as when insulation is added to a ceiling that lacks any existing insulation (most ceiling spaces in weatherization homes have at least some insulation). As such, this factor thus reflects limitations in the ability to tailor the expected savings range to the particular circumstances for each home rather than any issue with the weatherization work *per se*.

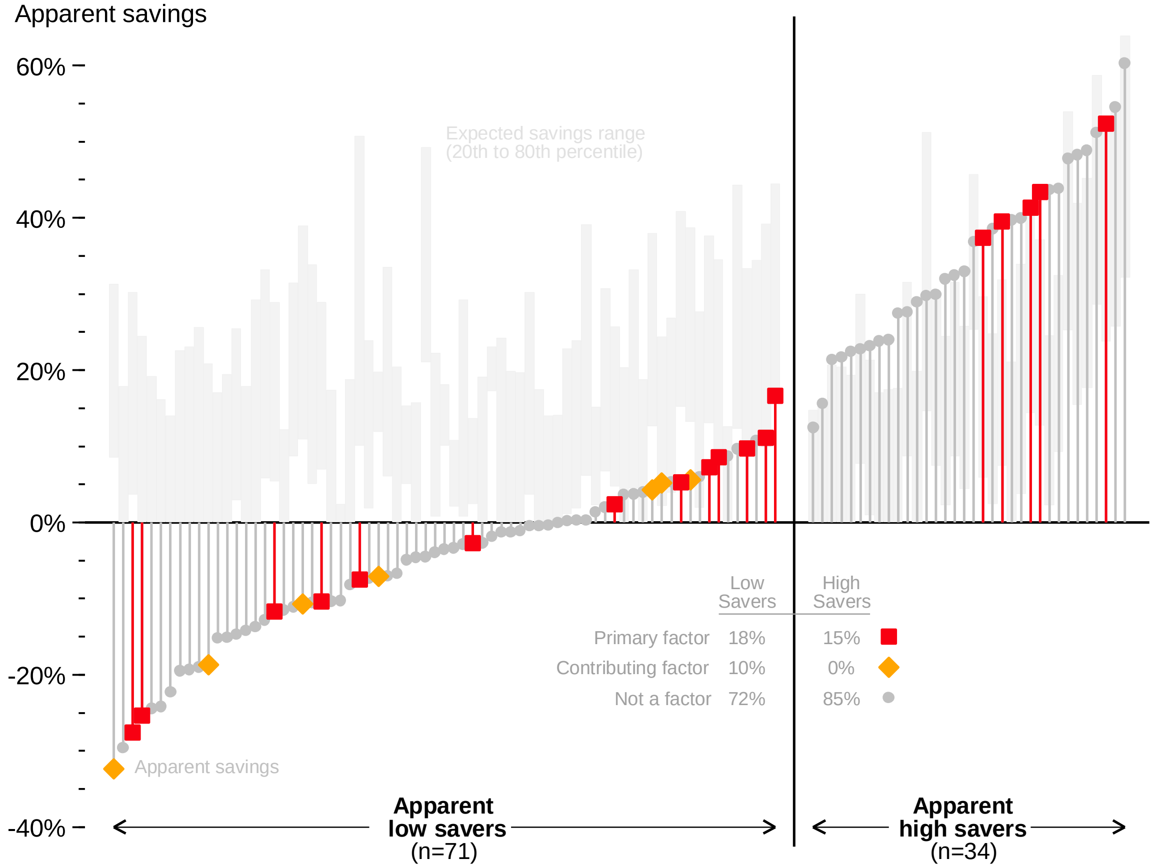

Fig. 9. Atypical measure application as an explanatory factor for apparently low or high energy savings

Fig. 9 highlights the cases where an atypical major measure installation was deemed to be a primary or contributing factor. The cases fall into three categories:

- Apparent low savers with negative savings – these involve cases where wall or ceiling insulation was installed, but only for a small area, or, in the case of ceiling insulation, in cases where there was a substantial amount of existing insulation. Since a partial insulation application like this would be expected to reduce but not *increase* heating consumption, all of these cases have additional explanatory factors related to the observed increase, and the atypical application simply contributes to the overall difference between apparent and expected savings.

- Apparent low savers with positive savings – these are also cases involving limited wall or ceiling insulation applications. However, unlike the negative apparent low-savers, the partial treatments in most of these cases were deemed to be the sole primary explanatory factor.

- Apparent high savers – these five cases all involved ceiling insulation that was added to spaces with little or no existing insulation. Four of the five cases also involved other primary explanatory factors.

Issues with Existing Heating System

A handful of sites shared a common theme in that an issue with the existing primary heating system led to reduced energy consumption prior to weatherization. Consumption then increased after the program resolved the problem, and the heating system could be used again. The weatherization thus solved a health and safety problem, but with the effect of savings appearing to be low or non-existent.

Fig. 10 and Table 8 provide the details about these sites. Of particular note is Site #59, in which the weatherization agency, following program health and safety policy, removed an unvented space heater, and installed a vented heater. Because unvented heaters release all of their heat–as well as potentially deadly combustion products– indoors, they are more efficient from an energy perspective. The replacement, while entirely appropriate, thus would be expected to have a downward impact on savings for the home.

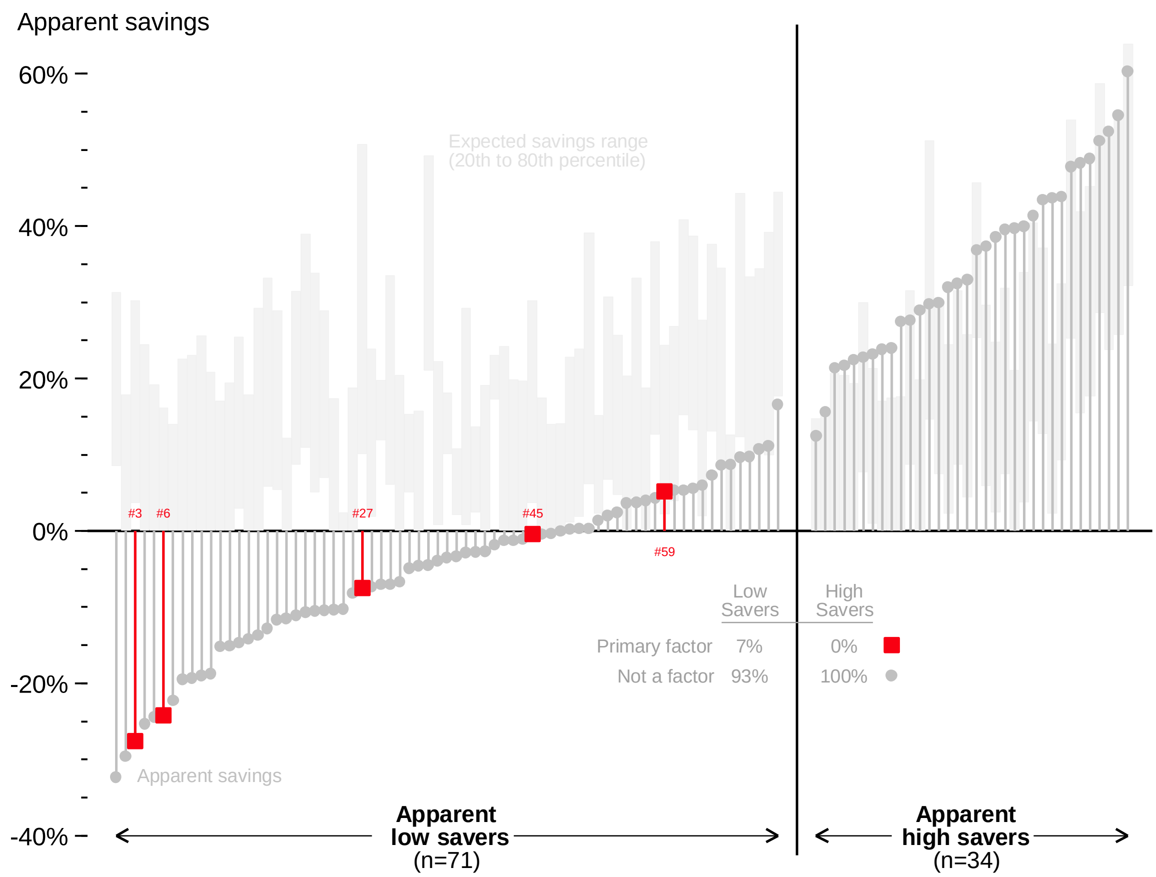

Fig. 10. Issues with the existing heating system as an explanatory factor for apparent low savings

Table 8. Cases where an issue with an existing heating system was deemed a primary factor for apparent low savings.

Site	Description
#3	Free-standing gas space heater malfunctioned during the pre-weatherization analysis period, and was used infrequently.
#6	Home had malfunctioning zonal electric heaters in two bedrooms; these were repaired by weatherization, and used following weatherization.
#27	Electric furnace in mobile home was non-functional prior to weatherization, and home was heated with electric space heaters. Weatherization work included installation of a new heat pump system.
#45	Boiler stopped working during the pre-weatherization analysis period, and home was heated with electric space heaters. Boiler was replaced by weatherization.
#59	Unvented space heaters were replaced with a vented space heater by weatherization.

In addition to these more dramatic examples of health-and-safety related HVAC work, there were a number of cases where a functional heating system was replaced for health-and-safety reasons with a new, standard-efficiency unit that would not be expected to yield as much savings as a high-efficiency replacement implemented as an energy efficiency measure. For example, the savings from replacing an existing 75 percent efficient furnace with a new unit at the federal minimum Annual Fuel Utilization Efficiency (AFUE) of 80 percent would be about six percent. This is roughly one-third the 18 percent savings that would be expected for installing a high-efficiency, condensing unit with a 92 percent AFUE rating in the same home.

A total of 20 such cases occurred in the study sample, most (16) of which occurred among apparent low savers. Notably, seven of these cases involved replacing electric furnaces, where no savings would be expected, since all electric furnaces are essentially 100 percent efficient at converting electricity to heat.

Measure Persistence

It stands to reason that if an installed measure fails prematurely, savings will be reduced. However the difficulty in this case is that the estimated savings are based on energy consumption data only for the years immediately preceding and following weatherization, but the site visits took place about three years after the work had been performed. A measure observed to have failed may not have done so until after the post-weatherization analysis period, in which case the lack of persistence, while still notable, would not be an explanatory factor for lower-than-expected first year savings.

Fortunately, lack of persistence among major measures was rare among the study homes. Only three homes were deemed to have a persistence issue with a major measure that may have affected first-year savings:

- Site #15 is a mobile home that received belly insulation work, but the client reported that the insulation job fell within a month. (This case is also noted later under Work Quality)

- Site #27 also involved insulation underneath a mobile home: the insulation at the time of the site visit was observed to have deteriorated considerably from animals and a water leak.

- Site #67 received air sealing as the only major heating measure, but the home was observed to have broken windows and other signs of deterioration. Measured air leakage at this site during the time of the study was considerably higher than that measured by the local weatherization agency prior to weatherization probably because of major house failures and poor maintenance, not because of lack of persistence of the air sealing measures.

The timing of the persistence for the first of the cases above clearly dates it to within the post-weatherization analysis period; the timing for the other two cases is more ambiguous.

One additional case of a mobile home belly being torn up by animals was noted by study technicians, but this involved a site with apparent high savings.

Additional measure-persistence issues were noted for the following cases, though these were not deemed to be primary explanatory factors:

- Two cases where infrared scans indicated that installed wall insulation had settled somewhat
- One case where a client was dissatisfied with a weatherization-installed wall furnace, and replaced it, though not until well after the period of analysis for first-year energy savings.
- One case where a water leak led to holes in the ceiling that adversely affected air sealing work.
- One case where duct insulation in a garage was observed to have fallen
- One case (noted above under Remodeling) where a client removed the sheetrock from second floor kneewalls, causing installed fiberglass-batt insulation to fall down.

Work Quality

Issues with work quality were noted for about a third of the sites. These ranged from relatively minor issues with uneven ceiling insulation to a small number of more substantial issues with significant voids in ceiling insulation and missed cavities for wall insulation. Work quality issues were only slightly more prevalent among apparent low savers (33%) than high savers (26%), a difference that is not statistically significant for this sample size.

Fig. 11 highlights all cases where a work quality issue was noted, and Table 9 provides details about the 12 cases where work quality was deemed to be a significant explanatory factor for apparent low savings.

Though work quality issues were mostly recorded from the standpoint of explaining apparent low savings, one site involved work quality as an explanatory factor for <u>high</u> savings. The work in question was for ceiling insulation in a home with complicated second story geometry involving many ceiling and kneewall surfaces. The job was noted by the field technician as exemplary in terms of the thoroughness of the treatment, and may have contributed to higher-than-average savings for this site.

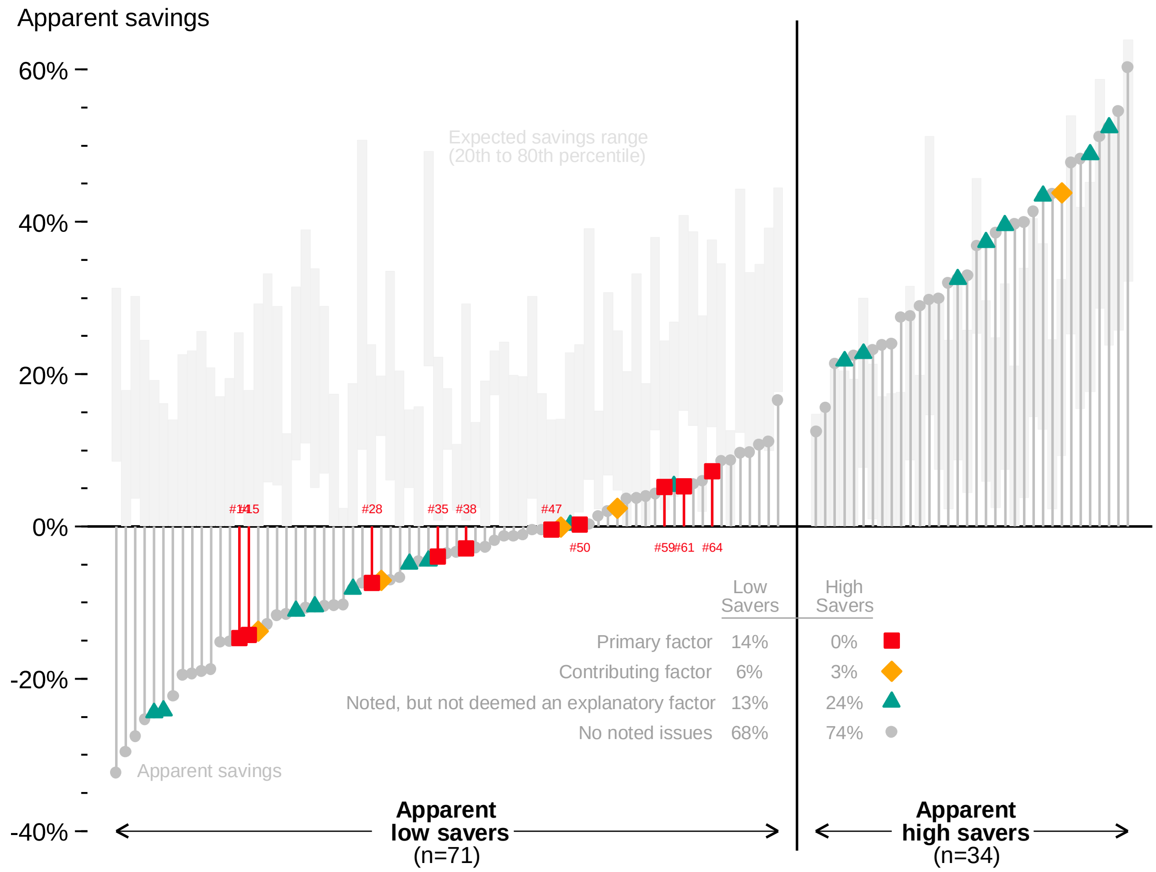

Fig. 11. Work quality as an explanatory factor for apparent low or high savings

Overall, the findings suggest that work quality was not a major driver of apparent low savings among the sites sampled for the study. However, this does not necessarily mean that an emphasis on work quality in the program as a whole is unnecessary. The study was designed to identify major drivers for a sample of program participants with significant departures from expected savings. Emphasizing work quality throughout the program could conceivably have a less-pronounced but broad effect on energy savings in a way that this study was not meant to assess.

Table 9. Cases where an issue with work quality was deemed a primary factor for apparent low savings

Site	Description
#14	Ill-defined thermal boundary between basement and tuck-under garage; duct leakage unaddressed
#15	Mobile home belly insulation fell shortly after Wx (also listed under Persistence)
#28	Observed voids in added ceiling insulation
#35	Minimal added ceiling insulation
#38	Incomplete wall insulation (25% voids); ceiling insulation voids; duct leakage
#47	Crawlspace wall insulation not complete; duct leakage
#50	Minimal added ceiling insulation, and installation issues (no baffles or hatch dam)
#59	Ceiling insulation has gaps and uneven spots
#61	Poor-quality installation of ceiling insulation
#64	Incomplete treatment of kneewalls

Air Leakage Measurements

Air leakage represents a special case for the study, because it is a parameter that is generally directly measured (via blower-door testing) both before and after weatherization by the weatherization agency, as well as during the site visits for the study. This allows for a direct quantitative assessment of air leakage at the time of the site visit to that recorded several years previously at the completion of weatherization. However, caution is warranted, because differences between these values could be attributable to several factors, not all of which are of interest to explaining apparently low or high savings. These include:

- Measurement recording error on the part of either the weatherization agency or the site-visit technician
- Differences in the configuration of the home during testing (e.g. whether the basement door is open or closed during testing)
- Differences in the conditions under which the testing occurred (wind, seasonally varying temperature and humidity have been shown to affect air leakage measurements)
- Degradation of the building shell (e.g. broken windows) or other changes since weatherization affecting air leakage.

The last factor is of most interest to the study, but may be difficult to distinguish from the others.

With this in mind, Fig. 12 shows how air leakage measured at the time of the site visit compares to the pre- and post-weatherization values recorded by the agency at the time of weatherization. In about two-thirds of the cases, the site-visit value is within 25 percent of the agency-recorded post-weatherization value. Of the remaining cases, nearly all are higher than the agency-recorded value. This imbalance is plausible: broken windows and other facets of home deterioration would tend to increase air leakage over time, and are probably more likely to occur in this population than home improvements or other changes that would tend to decrease air leakage.

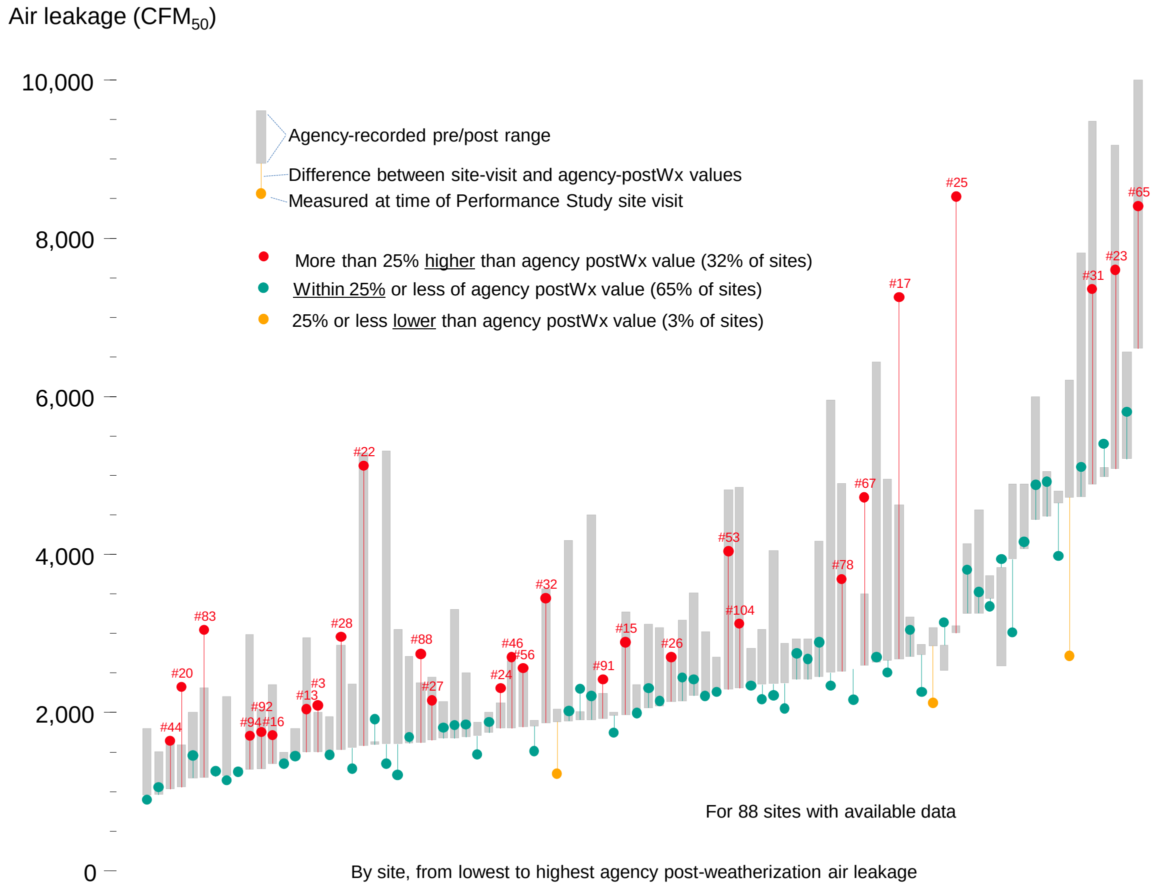

Fig. 12. Site-visit and agency-measured air leakage

At the same time, there are a few instances where the weatherization agency recorded a significant reduction in air leakage, but air leakage measured at the time of the Performance Study site visit is remarkably close to the agency-recorded pre-weatherization value. The most plausible explanation for these cases is that the agency-recorded post-weatherization value is in error, and little air sealing occurred at the site.

Fig. 13 shows where the 28 sites with measured air leakage that was at least 25 percent higher than the agency-recorded post-weatherization value lie in the distribution of observed savings: these are somewhat more likely to be found among under-performers (30%) than over-performers (21%), but the difference is not statistically significant. It is thus unclear the extent to which the measured differences owe to measurement error, configuration differences or issues with housing stock deterioration and persistence of air sealing measures.

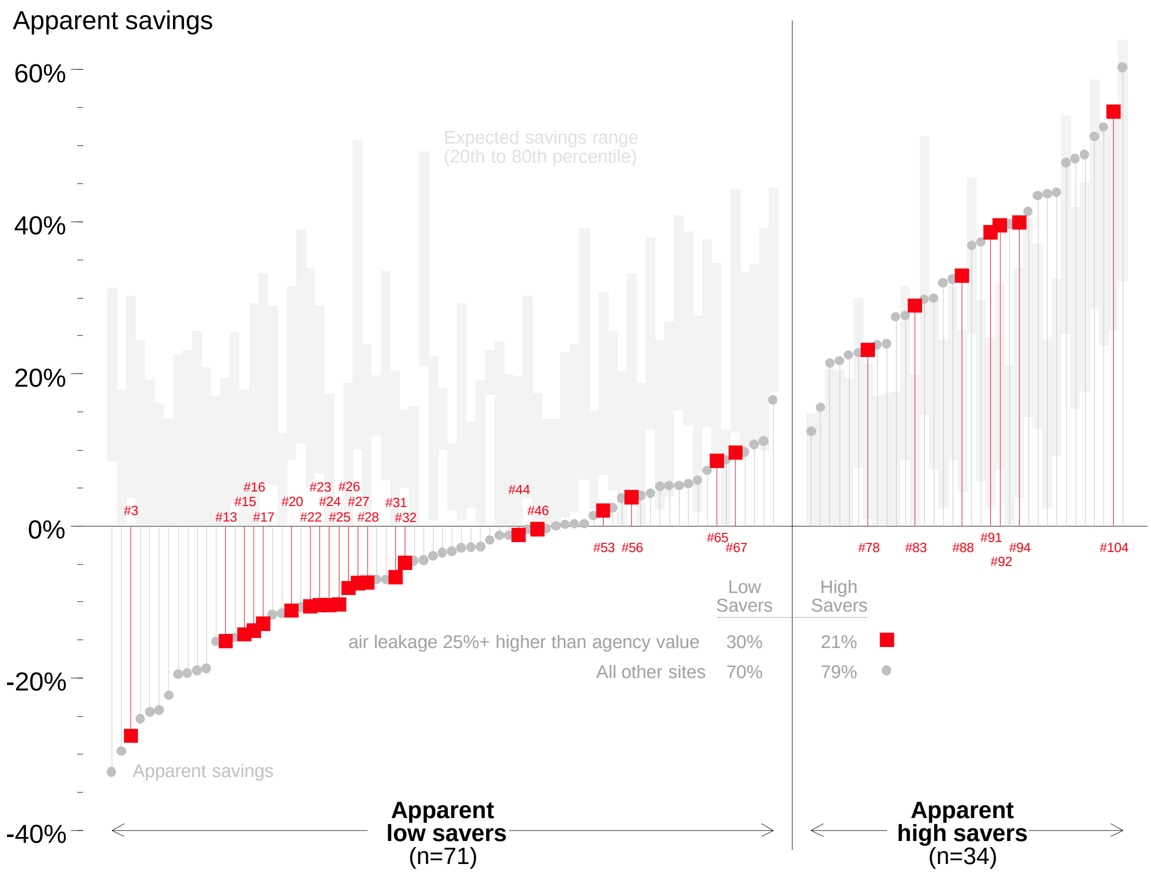

Fig. 13. Sites with measured air leakage that exceeded the agency post-weatherization value by 25 percent or more

Other Measures

As described previously, apparent low and high savers were selected by comparing apparent savings to expected savings based on a model that included five major measures: wall insulation, ceiling insulation, air sealing, heating system replacement and (for electrically-heated homes) refrigerator replacement. These measures are frequently installed and typically produce significant savings.

However, other less-common measures may produce significant savings as well. In particular, duct sealing can have a substantial impact on heating energy consumption if existing supply ducts have large leaks to unconditioned spaces like attics or crawlspaces. Foundation treatments, such as insulating floors over crawlspaces may also produce noticeable savings. Conversely, some health and safety measures implemented by the program, such as mechanical ventilation, may increase energy consumption.

When reviewed in these terms, about half of the apparent high savers received other significant measures that could contribute additional savings beyond those predicted by the model (Fig. 14). These included 11 homes with substantial foundation treatments, 6 that received significant duct sealing or repair and five that received other measures. The last group includes two homes where secondary space heating systems in largely unoccupied parts of the home were removed, and one site where weatherization was coupled with an extensive rehab that included new window, doors and siding with foam underlayment. Some of the measures occurred among apparent low savers as well, but at a lower incidence rate.

A few sites received measures that were deemed to be a factor for low apparent savings. These included one case in which a supply register was added to a crawlspace (presumably to deal with moisture issues), two cases where continuous mechanical ventilation was added and one case where dedicated combustion air was added. Only the supply-register addition was deemed a primary explanatory factor.

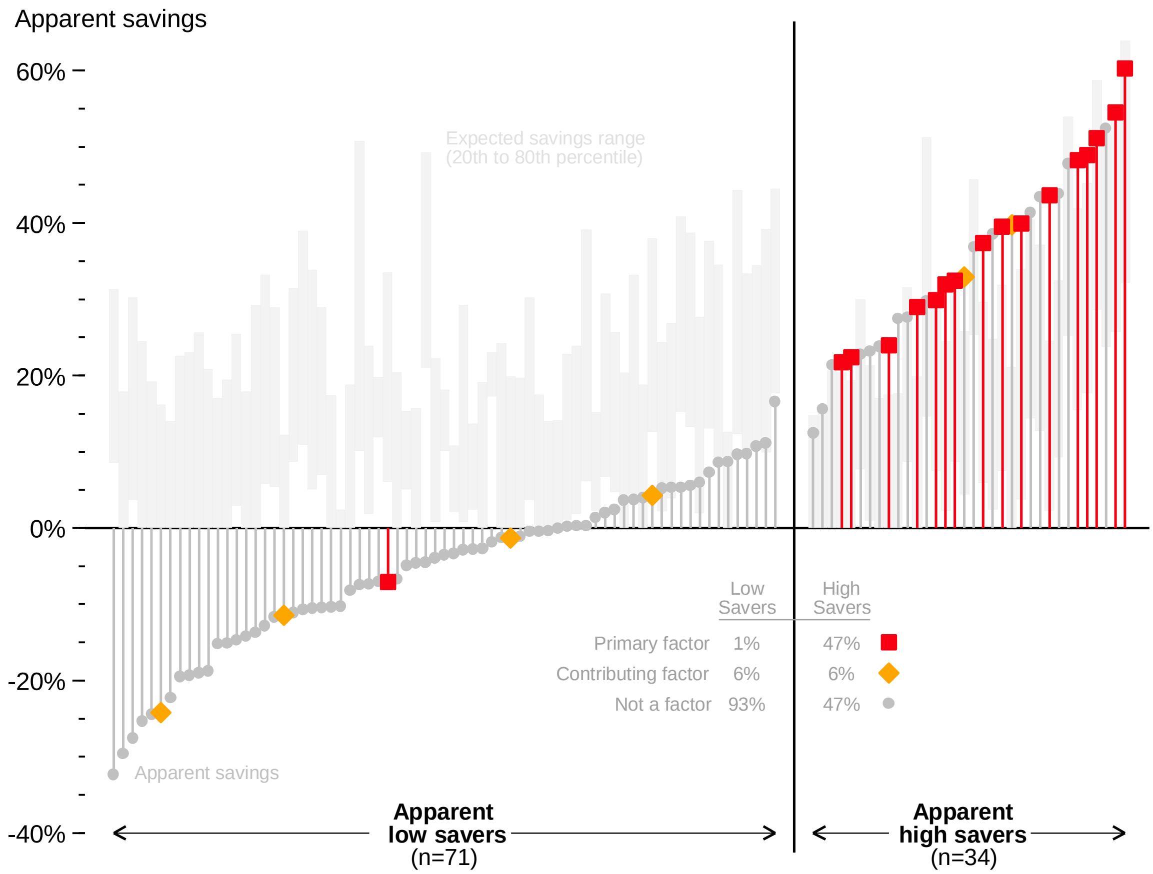

Fig. 14. Installation of other measures as an explanatory factor for apparent low or high savings

3.3 MISSED OPPORTUNITIES

Field technicians noted missed energy-savings opportunities as part of the site visit protocol. While these do not necessarily explain apparent low or high savings, they do provide an opportunity to explore the potential for additional savings from the program for several key measures. The scope of the study did not allow for formally assessing cost effectiveness, but the opportunities presented here are restricted to a small set of measures that are generally considered cost effective for the program:

- Wall insulation (Moderate, Cold and Very Cold climate regions only)
- Ceiling insulation
- Duct sealing
- Air leakage reduction

Insulation opportunities were based on visual inspection and infrared scans. Duct sealing opportunities were identified based on pressure-pan tests. Air leakage reduction opportunities were based on leakage pathways observed during blower testing.

At least one of the above measure opportunities was identified for about half of the apparent low savers, and a quarter of the apparent high savers (Table 10).

Table 10. Identified missed opportunities among study homes

Measure Opportunity	Apparent low savers	Apparent high savers
Wall insulation*	11%	3%
Ceiling insulation	27%	6%
Duct sealing	13%	9%
Air leakage reduction	32%	15%
Any of the above	54%	26%

*Considered for Moderate, Cold and Very Cold climate regions only

4. CONCLUSIONS

The field investigation revealed a variety of factors behind apparent low and high savings among weatherized homes. Certainly, the results confirm that household changes unrelated to the program can and do affect observed changes in consumption—and do so in both directions, creating both falsely low or high estimates of energy savings. Similarly, some cases of apparent low or high savings result from the fact that pre- and post-weatherization heating usage is not very well correlated with the weather for some homes. Standard statistical analysis techniques for estimating program impacts, however, account for this "noise" in the data, and there is no evidence that these changes create a bias in the estimates of average savings.

Of more interest are factors related to low savings that are related to the program itself. Here, the study is perhaps more revealing in what it did not find. In particular, the study found little evidence to support the notion that clients take back energy savings from the program by increasing their thermostat settings. Though reported changes in thermostat settings were not common in general, the study suggests that, if anything, the program is more likely to induce households to reduce thermostat settings. This could be the result of providing programmable thermostats and education about the savings from thermostat setpoint reduction or setback–or it could simply be that by insulating and air sealing homes, the incidence of cold walls and other surfaces is reduced, and occupants can reduce setpoints with the same (or better) level of comfort.

The study also did not reveal work quality as a major driver for low savings. Work quality was noted as a primary or contributing factor for apparent low savings for about one in five cases, but some work quality issues were also noted among apparent high savers. While this suggests that continuing efforts to improve installation practices are worthwhile and could have detectable impact on average impacts from the program, the study is not indicative of widespread quality issues under the program, and does not appear to be a primary driver of lower-than-expected savings among this sample of households with apparent savings that deviate strongly from expected levels.

Unsurprisingly, the study showed that high savers are much more likely to be comprehensive jobs with more opportunities. However, the study also revealed that many apparent low savers have additional savings opportunities that went unaddressed by the program. This suggests that there is potential to increase the average savings for the program.

APPENDIX A. REGRESSION MODELS FOR CLASSIFYING LOW AND HIGH SAVERS

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Quantile regression was used for the classification of low- and high-savers. The regression models were fitted to the full sample frame and used to predict the 20th and 80th percentile expected values for percent savings given the model inputs. Sites where the observed change between pre- and post-weatherization was less than the expected 20th percentile were classified as apparent low-savers; sites where the observed change exceeded the expected 80th percentile were classified as apparent high-savers. Separate models were fitted for homes with natural gas and electric heat.

The fitted coefficients for the models are shown below.

(Dependent variable: observed percent savings)	**Model Coefficients**			
	Gas heat		Electric heat	
Parameter	20th	80th	20th	80th
Mobile home? (binary indicator)	1.133	-0.169	-1.066	0.905
Heating energy intensity (Btu/sf/HDD65)	0.625	0.900	1.398	0.647
% reduction in air leakage	0.079	0.113	0.067	0.060
Wall insulation installed? (binary indicator)	6.578	7.274	4.960	3.594
Ceiling insulation installed? (binary indicator)	6.861	4.359	1.752	2.784
Heating system replaced? (binary indicator)	5.699	9.021	-0.945	4.922
Refrigerator replaced? (binary indicator)			3.091	-0.183
Model constant	-12.395	8.858	-11.963	12.028

APPENDIX B. FIELD INSTRUMENTS

APPENDIX B. FIELD INSTRUMENTS

WAP Performance Study Agency File Review Form

Site ID: 1234-5678   Agency: *Local Wx Agency Name Here*

Agcy Job *999999*

Name *John Doe*
Address *123 Main St*   *Anywhere*   *WI*

File review is based on: ☐ paper file ☐ computer records ☐ unable to review

	Eval data	Reviewed?	Correction (leave blank if no correction needed)
Own/Rent	*Owner occupied*	☐	
Occupants	*4*	☐	
Building type	*Site-built, detached*	☐	
Stories	*Two*	☐	
Decade built	*1990s*	☐	
Heated ft²	*1,744*	☐	
Audit date	*(not in eval. data)*	☐	‹ **needed!**
Work start date	*02/09/09*	☐	
Work end date	*02/12/09*	☐	
Heating fuel	*Natural gas*	☐	
Heating type	*Central furnace*	☐	
Suppl. fuels	*0*	☐	
Cooling	*None*	☐	
Water heater fuel	*Natural gas*	☐	
Measure selection	*Calculation procedure*	☐	
Computer audit tool	*NEAT/MHEA*	☐	

Shell diagnostics

	Eval data	Reviewed?	Correction
CFM50 pre	*1,250*	☐	
post	*867*	☐	
ZPD	*Yes*	☐	
room-room pressures	*No*	☐	

Duct diagnostics

	Eval data	Reviewed?	Correction
Pressure pan	*No*	☐	
Sum of Pa rdgs. pre		☐	
post		☐	
Other duct-leakage testing	*No*	☐	

Photo or copy of:

- ☐ footprint sketch / dimensions
- ☐ work order / measures list
- ☐ computer audit
- ☐ htg sys SSE tests
- ☐ ZPD
- ☐ room-room pressure tests
- ☐ pressure pan data
- ☐ other duct leakage tests

Notes

Insulation

	Eval data	Installed? (Y/N)	Qty	Units*	Initial R	Final R	Notes
Ceiling	*Yes*						
Wall	*No*						
Floor	*No*						
Foundation	*No*						
Rim/Bandjoist	*No*						
Other insulation (1)	*Yes*						
Other insulation (2)	*No*						

*sf, lb or bags

Mechanicals:

Htg sys replacement*	*Yes (EE)*		(check here ☐ if fuel switch)	* EE = replaced for energy efficiency
WH replacement*	*No*		(check here ☐ if fuel switch)	HS = replaced for health & safety

Other:

Duct sealing/repair	*Yes*		
New windows	*No*		Qty
Refr replacement	*Yes*		Qty
Lighting (CFLs)	*Yes*		Qty
Programmable tstat	*No*		
Standard tstat	*No*		
WH wrap	*No*		
Showerhead(s)	*No*		Qty
Aerator(s)	*Yes*		Qty
WH temp reduction	*No*		
Other baseload (1)	*No*		
Other baseload (2)	*No*		

Eval data:

PreWx use: *694* therms

Expected savings range: *5%* to *29%*

Observed: *4%*

Repairs:

			Describe:
Roof	*No*		
Ceiling	*No*		
Wall	*No*		
Floor	*No*		
Foundation	*No*		

Any other significant repairs?

Job Cost:			
DOE	*$0*		
non-DOE	*$6,790*		non-DOE funding source(s):
Total	*$6,790*		

Notes:

WAP Evaluation Performance Study Field Form (tech support 888-369-7711)

Site ID 1234-5678

Date

Agency Name *Local Wx Agency Name Here*

Arrival time

Occupant Name *John Doe*

Address *123 Main St*

City *Anywhere* State *WI*

Eval Tech

Agency Tech

Occupant Contact

Phone

House - Exterior

☐ *Take photos from opposite corners to show 4 sides in 2 shots*

Outdoor temperature °F

House type *(check one)*

☐ Basic ranch (1 story, plain)
☐ Split-level (raised ranch)
☐ Cape (1 1/2 story)
☐ Colonial (2 story)
☐ Other non-MH (e.g., has addition)
☐ Single-wide MH
☐ Double-wide MH

Siding type *(enter approx. %)*

Siding	%
Vinyl	
Aluminum	
Wood	
Brick	
Other	
Total:	100%

→ describe:

Wall construction *(check one)*

☐ framed
☐ unframed masonry/block

Heated area Reported as *1,744* ft^2 Looks reasonable? (Y/N) → If No Should be ft^2

(note: basement space should not be included in heated space unless it is fully conditioned.)

Garage *(check one)*

☐ Detached or none
☐ Tuck-under (living space above)
☐ Side-attach (no living space above)

Unusual features or other notes

Foundation spaces

Basement present? ___ Y/N able to assess? ___ Y/N

approx. % of footprint area: ___

(check one)
- [ ] unfinished
- [ ] partially finished
- [ ] finished

(check one)
- [ ] not intentionally conditioned
- [ ] partly intentionally conditioned
- [ ] fully intentionally conditioned

band joist is… *(check one)*	[ ] uninsulated	[ ] partly insulated	[ ] fully insulated	___ R-value
walls are… *(check one)*	[ ] uninsulated	[ ] partly insulated	[ ] fully insulated	___ R-value
floor above is… *(check one)*	[ ] uninsulated	[ ] partly insulated	[ ] fully insulated	___ R-value

Crawlspace present? ___ Y/N able to assess? ___ Y/N

approx. % of footprint area: ___

band joist is… *(check one)*	[ ] uninsulated	[ ] partly insulated	[ ] fully insulated	___ R-value
walls are… *(check one)*	[ ] uninsulated	[ ] partly insulated	[ ] fully insulated	___ R-value
floor above is… *(check one)*	[ ] uninsulated	[ ] partly insulated	[ ] fully insulated	___ R-value

MH belly present? ___ Y/N able to assess? ___ Y/N

approx. % of footprint area: ___

insulation condition [ ] good [ ] fair [ ] poor [ ] not applicable [ ] unable to assess

Other Pier foundation present? ___ Y/N able to assess? ___ Y/N

approx. % of footprint area: ___

floor above is… [ ] uninsulated [ ] partly insulated [ ] fully insulated ___ R-value

Describe any observed foundation insulation (or other) issues:

Primary Heating System

☐ distance photo ☐ nameplate photo

Type *(check one)*

☐ gas forced-air furnace → ☐ condensing ☐ non-condensing
☐ gas boiler (hydronic) → ☐ condensing ☐ non-condensing
☐ gas boiler (steam)
☐ electric forced-air furnace
☐ electric heat pump
☐ electric baseboard (other non-central electric) → *skip the remainder of this page*
☐ other ______

Location *(check one)*

☐ basment
☐ crawlspace
☐ living space
☐ attic
☐ garage

Distribution *(approx. %)*

basement	
crawlspace	
attic	
above-grade living space	
garage	
	100%

Age *(check one)*

☐ older than Dec 2007
☐ replaced Dec 2007 - Dec 2008 (yr prior to Wx) →
☐ replaced Feb 2009 (Wx)
☐ replaced Mar 2009 - Apr 2010 (yr after Wx) →
☐ newer than Apr 2010 →

replaced ______ (mm/yy or DK)
by ☐ occupant
☐ program: ______
(e.g. LIHEAP, utility)

Cooling

☐ distance photo ☐ nameplate photo

Type *(check one)*

☐ none ☐ central AC ☐ room AC ☐ heatpump ☐ evap. cooler

Age *(check one)*

☐ older than Dec 2007
☐ replaced/added Dec 2007 - Dec 2008 (yr prior to Wx) →
☐ replaced or added Feb 2009 (Wx)
☐ replaced/added Mar 2009 - Apr 2010 (yr after Wx) →
☐ newer than Apr 2010 →

☐ replaced ☐ added
replaced ______ (mm/yy or DK)
by ☐ occupant
☐ program: ______
(e.g. LIHEAP, utility)

Water Heater

☐ distance photo ☐ nameplate photo

Type

☐ gas, tank ☐ elec, tank ☐ boiler, indirect ☐ boiler, tankless coil ☐ gas, on-demand

Age

☐ older than Dec 2007
☐ replaced Dec 2007 - Dec 2008 (yr prior to Wx) →
☐ replaced Feb 2009 (Wx)
☐ replaced Mar 2009 - Apr 2010 (yr after Wx) →
☐ newer than Apr 2010 →

replaced ______ (mm/yy or DK)
by ☐ occupant
☐ program: ______
(e.g. LIHEAP, utility)

If replaced, fuel switch? ______ (Y/N)

IR Scan (prior to blower door)

Site ID: 1234-5678
page 4

Indoor temperature ______ °F

Area scanned
(check all that apply)

- [ ] ext walls
- [ ] ceiling (attic)
- [ ] ceiling (enclosed)
- [ ] kneewalls
- [ ] soffit areas
- [ ] floor over crawl/bsmt
- [ ] slab perimeter
- [ ] floor over garage
- [ ] shared garage wall
- [ ] chimney chase
- [ ] utility chase
- [ ] exterior duct runs

other describe
- [ ] →
- [ ] →
- [ ] →
- [ ] →
- [ ] →

Observed issues
(record missed opportunities and work-quality issues)

		affected ft^2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Notes:

IR Scan (<u>during</u> blower door operation)

Site ID: 1234-5678
page 5

Indoor temperature ______ °F

Area scanned
(check all that apply)

- ☐ ext walls
- ☐ ceiling (attic)
- ☐ ceiling (enclosed)
- ☐ kneewalls
- ☐ soffit areas
- ☐ floor over crawl/bsmt
- ☐ slab perimeter
- ☐ floor over garage
- ☐ shared garage wall
- ☐ chimney chase
- ☐ utility chase
- ☐ exterior duct runs

other / describe

- ☐ → ______
- ☐ → ______
- ☐ → ______
- ☐ → ______
- ☐ → ______

Additional observed issues *(exclude any issues recorded prior to blower door operation)*

		affected ft^2
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

Notes:

Air Leakage

Prep

- ☐ exterior windows/doors closed
- ☐ fireplace damper closed, ashes covered
- ☐ interior doors open
- ☐ combustion devices disabled
- ☐ air handler, exh. fans off
- ☐ basement door open *unless thermally isolated from house*

Blower door make ______ (Minneapolis, Retrotec)

Manometer model ______ (e.g. DG-700, DM-2)

CFM50 ______ **Blower door ring** ______ *("none" if not used)*

Description of any major air leakage areas

Pressure Pan (implement ONLY for ducts in unconditioned space)

Be sure to clear any baseline from air leakage testing

Locations *(check all that apply)* *(or check here* ☐ *if no ductwork in unconditioned space)*

- ☐ attic
- ☐ crawlspace
- ☐ uncond bsmt
- ☐ MH belly
- ☐ floor over garage
- ☐ exterior wall
- ☐ other→ ______
- ☐ other→ ______

Readings *(record number of readings in each category)*

	Supply	Return
<1 pa		
1 - 3 pa		
3 - 5 pa		
5 - 10 pa		
10 - 20 pa		
>20 pa		

Details for all readings of 5+ Pa:

	Pa	Location	Observed Issue *(e.g. disconnected duct)*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Above-Grade Walls, Ceilings and Attics

Above-grade walls

- [ ] appear to be fully insulated
- [ ] appear to be partially insulated → approx. % of gross wall area that is insulated:
- [ ] appear to be uninsulated
- [ ] unable to assess

Enclosed (cathedral) ceiling spaces

approx. total ft²:

(check one)

- [ ] not present in this home
- [ ] appear to be fully insulated
- [ ] appear to be partially insulated → approx. % of enclosed ceiling that is insulated:
- [ ] appear to be uninsulated
- [ ] unable to assess

Observed issues and add'l detail *(opportunities for add'l insulation, reason why can't be insulated, etc.)*

Attic spaces

(check one)

- [ ] not present in this home
- [ ] able to fully inspect
- [ ] able to partially inspect | reason:
- [ ] unable to inspect

Area #	ft²	Floored? (Y/N)	Insulation Type	Insulation Depth (in.)	Insulation R-value	Insulated by WAP? (Y/N/DK)	Observed Issues? (Y/N)
1							
Observed Issues →							
2							
Observed Issues →							
3							
Observed Issues →							
4							
Observed Issues →							
5							
Observed Issues →							

*e.g., voids (describe extent), uneven coverage (describe extent), asbestos, knob & tube, etc.

Thermostat

☐ photo (cover open) showing as-found settings

☐ programmable → ☐ program running ☐ hold ☐ temporary hold ☐ off
☐ non-programmable
☐ no central t-stat

Fan ☐ auto ☐ on ☐ not applicable (e.g. boiler)

Current setpoint: ____ °F

Client Interview

____ Y/N **Any changes in number of household members since Dec 2007?**

If Yes, describe and provide dates (mm/yy) if able

____ Y/N **Any changes in household schedule (e.g. job change) since Dec 2007?**

If Yes, describe and provide dates (mm/yy) if able

____ Y/N **Any remodeling since Dec 2007?**

If Yes, describe and provide dates (mm/yy) if able

Thermostat settings

(check all that apply)

☐ household currently does not set back
☐ household currently sets back when sleeping
☐ household currently sets back when away from home

____ Y/N Any changes between current practice and period since Dec 07?

If Yes, describe and provide dates (mm/yy) if able

Use of supplementary heating fuels

Household currently uses
(check one in each row)

	Never	Rarely	Occasionally	Frequently
electric space heater(s)				
gas fireplace				
wood fireplace				
wood/pellet stove				
oil/ker heater				
other				

Any changes since Dec 2007?
Y/N
If Yes, describe and provide dates (mm/yy) if able

Refrigerators and freezers

Number of refrigerators currently in home (exclude compact refrigerators)
Number freezers currently in home

Any replacements, removals, additions since Dec 2007?
Y/N
If Yes, describe and provide dates (mm/yy). Indicate replacement/removals by WAP or other program(s).

Other measures

Measure	# installed by WAP*	# removed by client	Notes
CFL			
Showerhead			
Aerator			

**or by another program concurrently with WAP. Enter "DK" if client does not recall receiving these measures*

Observed CFLs in high-use lighting locations (from walk-through): (check one)
none | a few | some | most | all

Energy Education

Interviewee involved in Wx work at the time it was done?
Y/N

If Yes → Interviewee recalls tips or other instructions on how to save energy at time of weatherization?
Y/N

If Yes → Household has implemented or practiced at any time after weatherization?
Y/N

If Yes → describe actions, whether still practicing

Overall assessment of client recall

(check one)

excellent | good | fair | poor

Overall Assessment

1a. Confirm whether the information below (from Evaluation database) is correct

___ All WAP measures installed Feb 2009 (Y/N)
___ The heating system WAS replaced (Y/N)
___ Ceiling insulation WAS installed (Y/N)
___ Wall insulation WAS NOT installed (Y/N)
___ The Wx as-found air leakage was about 1,300 CFM50 and the final air leakage was about 900 CFM50 (Y/N)

If No to any of the above, describe

1b. If Ceiling and/or wall insulation were installed, were either of these less than full treatments?
("full treatment" means that insulation was added to at least 75% of the wall or ceiling area)

___ Y/N → If Yes, describe:
or
___ not installed in this home

2. Were there any other measures installed at the time of weatherization that might have had a significant impact on heating-fuel use? (e.g. duct sealing, substantial foundation or floor insulation)

___ Y/N → if Yes, describe:

3. Were measures installed in this home by any program other than WAP?

___ Y/N → if Yes ___ Y/N were these measures installed concurrently with the WAP treatments?
if No, when were they installed? ___ (mm/yy)

___ Y/N were these measures included in the evaluation data for the home?
if No, what measures were not included?

4. Any notable quality issues with the insulation and/or air sealing work performed in this home?

___ Y/N → if Yes, describe:

5. Any household or appliance changes or remodeling since Dec 2007 that might have significantly affected heating-fuel use?

Y/N → If Yes, describe:

Effect on heating fuel (check one for each row)

	What	When (mm/yy)	Increased use	Decreased use	Don't know
1			☐	☐	☐
2			☐	☐	☐
3			☐	☐	☐
4			☐	☐	☐
5			☐	☐	☐

6. Any significant <u>missed opportunities</u> for reducing heating use in this home?

Y/N → If Yes, describe:

1
2
3
4
5

7. Any other important considerations for this house with regard to assessing energy savings?

Y/N → If Yes, describe:

8. Top three under/over-performance factors (if any):

	Under		Over
1		1	
2		2	
3		3	

Final Checklist

☐ Combustion appliances re-enabled

☐ Incentive check provided to client

Departure time