# THE EFFECT OF HOUSE INDOOR TEMPERATURE ON MEASURED AND PREDICTED ENERGY SAVINGS

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## ABSTRACT

In many major residential weatherization studies, the average measured energy savings have been less than the predicted savings. Additionally, large scatter in the measured energy savings has been observed. Changes in the indoor temperatures of the houses before and after weatherization have often been cited as a possible explanation for these results. This paper draws upon results from two studies conducted by the Oak Ridge National Laboratory in an attempt to determine if the variation and lower than expected performance in energy savings are attributable to house indoor temperature levels.

Our analysis indicated that only in isolated cases did occupants significantly change their indoor temperature following the installation of conservation measures. The average change for the large number of houses studied was 0, and increases in temperature were as likely to be observed as decreases. Thus, these results do not support the supposition that changes in house indoor temperature significantly contribute to lower than expected savings observed in retrofit programs. They do, however, indicate that the isolated changes contribute to the variation observed in measured savings. The average measured indoor temperature was found to be about 70°F, a value that is typically assumed when predicting energy savings. However, the indoor temperature in one-third of the houses differed from this value significantly, further contributing to the variation in measured savings.

We found from our studies that the difference between predicted and measured savings can be reduced in individual houses by 20-60% if the measured savings are adjusted on the basis of the same indoor temperature conditions assumed in making the predictions. For such an adjustment, indoor temperature must be measured and a house model which includes indoor temperature must be developed. Other factors also contribute to the differences because only a portion of the differences were accounted for using the indoor temperature. Calculating a predicted savings in individual houses using a "correct" value of the indoor temperature is the desired goal. Self-reported indoor temperatures are not consistent with measured values, and an average indoor temperature value cannot be modified based upon house or occupant characteristics. Therefore, determining a "correct" indoor temperature must be based on some form of measured value.

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## INTRODUCTION

Most conservation programs rely on audit predictions of energy savings attributable to specific conservation measures to pre-judge the economic worth of those measures. The audit is performed before installation to guide the selection of appropriate measures for individual households and to serve as marketing tools to promote their installation. However, in program after program, the actual savings have differed significantly from the audit predictions. The average measured savings in many programs (Hirst, 1986; Sebold and Fox, 1985; Herendeen et al., 1983; Hirst and Goeltz, 1984; Hirst, White, and Goeltz, 1983) are only two-thirds of the predicted amounts. In addition, substantial variation in actual energy savings and in the ratio of actual to predicted savings across households is observed. For example, in a Minnesota program (Hirst and Goeltz, 1984), differences in actual natural gas savings were greater than +/- 50% of the audit estimate in 55% of the homes studied. In a Bonneville Residential Weatherization Program (Hirst, White, and Goeltz, 1983), more than 10% of the homes increased energy consumption, while savings were more than double the audit estimates in another 10% of the homes.

The causes for the differences between actual and predicted savings and their variation among households are uncertain, but several factors have been proposed (Hirst, 1986):

1. errors [and limitations] in audit methodology,
2. errors in auditor data collection and interpretation,
3. installation of inappropriate measures,
4. use of poor quality retrofit materials,
5. sloppy installation of measures,
6. changes in occupant energy-related behavior after retrofit,
7. errors in electricity billing data [used in analysis], and
8. errors in methods used to analyze energy-use data.

The indoor temperature both before and after weatherization affects the energy use in a house. Because many audit methods implicitly assume an indoor temperature, perhaps through a degree-day approach, the actual indoor temperature is an important variable in factor 1. The actual indoor temperature is also an important variable in factors 6 and, as we will demonstrate, 8. First, differences between the actual indoor temperature and the indoor temperature assumed in the predictive calculations can contribute to prediction errors in the audit methodologies. Second, the indoor temperature may change following weatherization, especially if recipients of weatherization alter their management of the thermostat or change their window or door opening patterns. For example, occupants may lower the indoor temperature while maintaining the same comfort in response to higher radiant temperatures or decreased draftiness of the house brought about by the conservation measures installed. On the other hand, the occupants may choose to maintain more comfortable conditions by increasing the indoor temperature at the expense of reduced savings (referred to as take-back effect).

The Oak Ridge National Laboratory (ORNL) performed two studies (Ternes and Wasserman, 1987; Stovall and Fuller, 1988) examining the effect of the house indoor temperature on the comparison between actual and predicted savings. One used data collected from the Hood River Conservation Project (HRCP), and the other used data collected from a field test performed in Wisconsin. In this paper, we present results of (1) indoor temperature changes that occurred in the test houses following retrofit and (2) the distribution of the indoor temperatures maintained in the test houses. We also examine the ability of selected occupant and house characteristics to identify those houses in which the indoor temperature is likely to change or to be different from the average. Finally, we investigate the degree to which the difference between actual and predicted savings might be reduced by incorporating the indoor temperature in an improved analysis technique.

## RESULTS FROM THE HOOD RIVER CONSERVATION PROJECT

The data source used for one study was part of the HRCP. The HRCP involved retrofitting about 3000 homes in Hood River, Oregon, in an effort to define the maximum electrical conservation potential achievable in a short time in a small geographical area. The conservation measures applied to the homes varied based on the economics of the savings projections made during a pre-retrofit audit and were installed without charge to the occupants. The HRCP evaluation included monitoring indoor temperature in 319 homes, 187 of which were heated primarily by electricity, with possibly some supplemental wood heat (as reported by the homeowner). The homes were monitored on a 15-minute basis over a 2-year period (spring 1984 to spring 1986). Each temperature monitor was placed in a frequently occupied room and was positioned near an inside wall. The accuracy of these measurements was estimated to be about 2$^{o}$F. Outdoor temperature data and extensive survey data collected in 1984 describing each household was also available.

Analyses of the indoor temperatures in the 187 houses were based on pre-retrofit data collected between December 1984 and February 1985. The winter period was chosen to avoid milder weather when the influences of solar gain and natural ventilation on indoor temperature would be greater.

The average indoor temperatures of the 187 houses ranged from about 60 to 80$^{o}$F, with the average being 70.3$^{o}$F. Approximately 70% of the houses had average indoor temperatures between 66 and 74$^{o}$F, 15% >74$^{o}$F, and the remaining 15% <66$^{o}$F.

Statistical regression techniques were applied to only the weekday data to examine the variation in average pre-retrofit temperature among the households that could be explained by the occupant and house characteristics listed in Table I (PRELOAD, PRETEMP, SPECTRHI, SPECTRLO, SQFT, and TOTCOST were not used in this analysis but were used in a subsequent analysis to be

Table I. Independent variables.

| Variable name | Definition |
|---|---|
| ATTITUDE | = 0 if survey respondent agrees "people have a right to use as much energy as they want and can pay for," otherwise = 1 |
| BASEBOARD | = 1 if baseboard heating system, otherwise = 0 |
| CENTRAL | = 1 if central resistance furnace, otherwise = 0 |
| DISHWASH | = 1 if house has an automatic dishwasher, otherwise = 0 |
| HEATPUMP | = 1 if heat pump heating system, otherwise = 0 |
| HIEDUCAT | = 1 if householder #1 had at least some college education, otherwise = 0 |
| HIINCOM | = 1 if the household combined pre-tax income is greater than $40,000, otherwise = 0 |
| INCOM | self-reported household income, dollars |
| LOEDUCAT | = 1 if householder #1 had never gone past elementary school, otherwise = 0 |
| LOINCOM | = 1 if the combined pre-tax income is less than $14,000, otherwise = 0 |
| MOBIL | = 1 if mobile home, otherwise = 0 |
| MULTI | = 1 if multi-family housing, otherwise = 0 |
| PEOPLE | number of people who live in the house |
| PORTHEAT | = 1 if one or more portable heaters are in the house, otherwise = 0 |
| PPL | = 1 if serviced by Pacific Power and Light, = 0 if serviced by Hood River Co-op |
| PRELOAD | average total load of the house before retrofit |
| PRETEMP | average 5 a.m. indoor temperature before retrofit |
| SENIOR | = 1 if any senior citizens live in the house, otherwise = 0 |
| SPECTRHI | = 1 if a spectral analysis of the space heating and total energy use of the house indicates a lifestyle pattern with fundamental frequencies of 6 h or less (cooking and clean-up), otherwise = 0 |
| SPECTRLO | = 1 if a spectral analysis of the space heating and total energy use of the house indicates a lifestyle pattern with fundamental frequencies of 24 h or greater (daily activities), otherwise = 0 |
| SQFT | house area, $ft^2$ |
| TEEN | = 1 if any teenagers live in the house, otherwise = 0 |
| TOTCOST | total cost of measures applied to the house |
| YOUTH | = 1 if any children under 13 years old live in the house, otherwise = 0 |

discussed). We found that the tested variables explained only 6% (adjusted $R^2$) of the variations among households. Weekend temperatures were not examined because residents tend to manage their houses according to different, less fixed schedules. The small effects we were looking for would have been masked by this variation.

The ability of occupants to correctly provide indoor temperature data was examined using indoor temperatures reported by the homeowners for the sleeping hours. As Figure 1 clearly shows, the measured nighttime temperatures (defined to be the average indoor temperature between 11 p.m. and 6 a.m.) were consistently higher than the reported temperatures.

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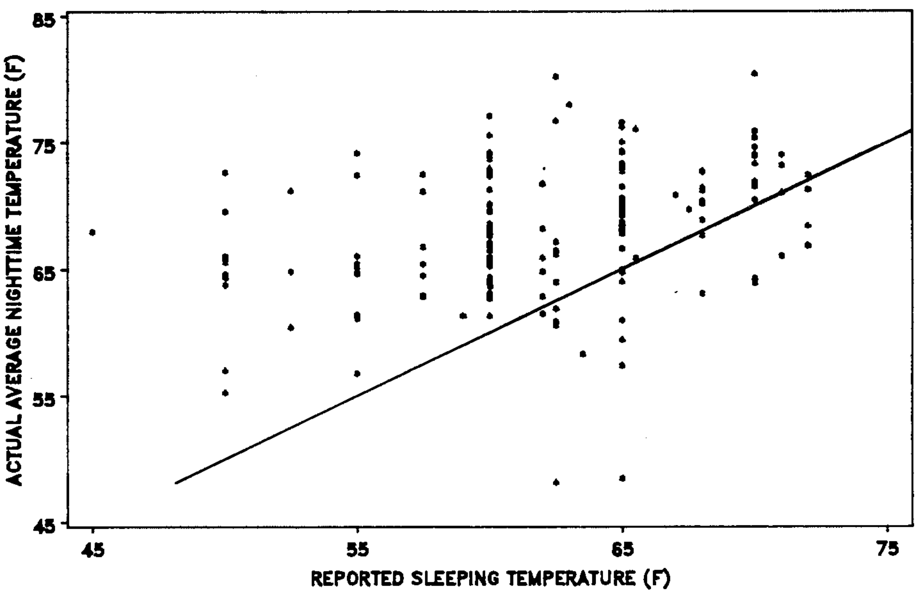

Figure 1. The average nighttime temperatures measured in the Hood River Conservation Project houses during the winter of 1984-85 were consistently higher than the sleeping temperatures reported by the occupants (The straight line marks the point at which the reported and measured temperatures would be equal).

Comparison of the pre- and post-retrofit indoor temperatures in 185 of the 187 houses was based on data collected during about 40 days selected from the 1984-85 winter and 40 comparable days from the 1985-86 winter, which were selected to eliminate the effect of outdoor temperature on the results. Days were defined as comparable if both their average and minimum temperatures matched within 5°F (most days were matched much more closely) and if their day of the week was the same.

Daytime, nighttime, and average temperature changes between the pre- and post-retrofit periods were calculated for each of the 185 houses. A paired t-test showed that the temperature changes averaged across all the households (daytime average increase of 0.08°F, nighttime average increase of 0.37°F, and overall average increase of 0.11°F) were not statistically different from 0.0 at the 90% confidence level. This observation is supported by the results from another examination of the Hood River data base which also showed no statistically significant changes in the average measured indoor temperatures (Dinan, 1987).

We examined the distribution of the daytime and nighttime temperature changes that occurred in the individual houses and found that the indoor temperature in about two-thirds of the houses did not change by more than 2°F following weatherization (see Figure 2). Further, among the houses in which an indoor temperature change of more than 2°F did occur, almost as many houses were colder as were warmer.

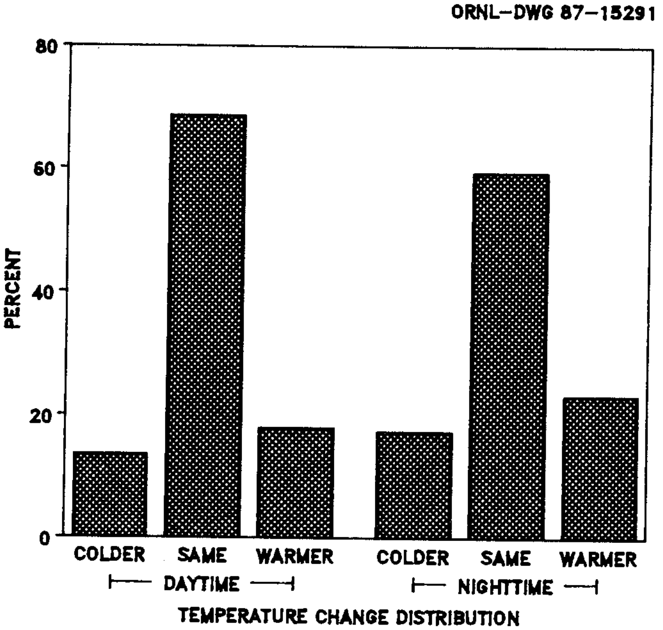

Figure 2. Distribution of the daytime and nighttime indoor temperature changes that occurred in the Hood River Conservation Project houses between the pre- and post-retrofit period.

Examination of pre- and post-retrofit indoor temperature profiles showed that indoor temperature differences between the two periods were greatest, on average, at about 5 a.m. We developed a model to test whether all the house and occupant characteristics listed in Table I help explain the difference between before and after temperature choices at 5 a.m. A reduced version of this model, which included only the variables found to be statistically significant, explained about 33% (adjusted $R^2$) of the variation in the indoor temperature difference across the 185 households. Table II lists these significant variables and their associated effect on the post-retrofit temperature choice.

Table II. Significant variables explaining the variation in before and after indoor temperatures in the Hood River Conservation Project.

| Significant variable | Effect on the temperature difference (after - before) | Confidence level[a] |
|---|---|---|
| Intercept | 27.5°F | |
| College-educated householder | -1.4°F | >99% |
| 5 a.m. pre-retrofit indoor temperature | -0.37°F/°F | >99% |
| House area | -0.0011°F/ft$^2$ | 98% |
| Total cost of installed measures | 0.19°F/$1000 | 93% |
| Average total pre-retrofit load | -0.4°F/kW | 98% |

[a] based on a t-test

## RESULTS FROM THE WISCONSIN FIELD TEST

The data source for the second study was a field test performed by ORNL and other organizations in 79 low-income, single-family homes in Madison, Wisconsin, during the winter of 1985-86. The homes in this field test were divided into three groups: (1) 28 homes received different combinations of envelope and mechanical system retrofits chosen by an audit procedure based on economic considerations, (2) leakage areas in 15 houses were sealed following a blower-door-guided infiltration reduction procedure, and (3) 36 homes served as a control group for the retrofitted houses. The conservation measures and infiltration reduction work were performed in the retrofitted houses in late January.

As part of this field experiment, hourly indoor temperature, outdoor temperature, and furnace run-time data were collected in a subset of 15 houses: 7 audit houses, 3 blower-door-treated houses, and 5 control houses. Because of the small sample sizes, the houses in the three groups are not necessarily equivalent. For example, all the blower-door-treated houses were two-story, while 4 of the 7 audit houses and 3 of the 5 control houses were one-story. The indoor temperature measurements represent the temperature at the thermostat controlling the central heating equipment in the house. Approximately 5 to 9 weeks of pre-retrofit data and about 14 weeks of post-retrofit data were collected in the 15 houses. In examining the outdoor temperature data, we found that the average daily outdoor temperatures during the later part of the post-retrofit period were appreciably warmer than those during any part of the pre-retrofit period; therefore, the indoor temperature data collected during the latter part of the post-retrofit period were not included in the analysis.

We calculated average pre-retrofit indoor temperatures for each house by averaging the hourly indoor temperature data available for the period; thus, these values were not weather normalized. As indicated in Table III, the average pre-retrofit indoor temperatures ranged from 58 to 75°F, with 9 houses being between 67 and 73°F, 4 houses <67°F, and 2 houses >73°F.

Table III. Pre-retrofit indoor temperatures and indoor temperature changes in the 15 Wisconsin Field Test houses.

| Site number | House category | Pre-retrofit temperature | Temperature change[a] |
|---|---|---|---|
| 1 | control | 74.0 | 1.1 |
| 2 | control | 72.3 | 2.0 |
| 3 | audit | 67.3 | 0.9 |
| 4 | audit | 69.4 | 0.6 |
| 5 | audit | 66.8 | 0.1 |
| 6 | audit | 68.9 | -0.3 |
| 7 | audit | 72.0 | -0.2 |
| 8 | control | 68.1 | 0.3 |
| 9 | blower-door | 58.7 | 0.6 |
| 10 | blower-door | 70.0 | 0.7 |
| 11 | blower-door | 66.6 | 1.1 |
| 12 | audit | 66.5 | 9.0 |
| 13 | audit | 72.0 | -0.7 |
| 14 | control | 74.7 | -0.9 |
| 15 | control | 67.1 | 0.1 |

[a] The temperature change is equal to the post-retrofit temperature minus the pre-retrofit temperature.

The pre- and post-retrofit indoor temperatures (Table III) can be normalized to a common winter period using linear regression techniques, thereby reducing the influence of the outdoor temperature on indoor temperature differences. Assuming that only changes in the indoor temperature of 1°F or greater were significant (due to measurement errors and regression considerations), we identified 4 houses that experienced a change in indoor temperature (all having an increase): 1 audit house, 1 blower-door-treated house, and 2 control houses. Examining the 7 audit houses and disregarding the 1°F significance level, we did not observe a discernible pattern in the change in the indoor temperature (4 of the houses increased in temperature, while 3 decreased). Similar examinations of the other houses revealed that all the blower-door-treated houses increased in temperature, while 4 control houses increased in temperature and one decreased.

The average increase of all 7 audit houses was 1.3°F, 0.8°F for the blower-door-treated houses, and 0.5°F for the control houses. The average increase of the audit houses was dominated by the change at Site 12 (9°F). The average increase of the audit houses would be 0.1°F if Site 12 was excluded from the average. Because of the significance of isolated cases in small samples, the number of homes changing temperature is likely a better indication of indoor temperature changes for this study than average values.

To make our program evaluation more complete, we attempted to reduce the difference between actual and predicted savings in individual houses by incorporating the indoor temperature in an improved analysis technique. Nine houses having the necessary information were actually used in this analysis. We calculated a normalized annual savings (NAS) by correlating daily pre- and post-retrofit fuel consumption with ambient temperature, normalizing for outdoor temperature using 36-year average weather data, and subtracting the normalized pre-retrofit value from the post-retrofit value. We calculated a second NAS by correlating daily fuel consumption to the difference between indoor and ambient temperature; normalizing to a 65°F pre-retrofit balance point, constant indoor temperature, and 36-year average weather data; and subtracting the normalized pre-retrofit value from the post-retrofit value. A 65°F pre-retrofit balance point was used in the latter normalization (rather than using an actual indoor temperature, such as 70°F) to place the normalized measured savings on an equal basis with the predicted savings.

Table IV lists the savings predicted by the audit for the audit houses (by definition, predicted savings for the control houses is 0) and the NASs calculated with and without the indoor temperature. The confidence intervals of the savings listed in Table IV indicate the uncertainty of the NAS estimates at about a 66% confidence level.

In 3 of the 5 control houses (Sites 1, 2, and 14) and all 4 audit houses, the predicted values do not fall within the confidence intervals of the NASs normalized without considering indoor temperature. When the NASs are based on normalizations including the indoor temperature, the difference between the predicted and normalized value is reduced by 20-60% in all but one case. In this case, the difference could not be accounted for using the indoor temperature in this manner. In the remaining 2 control houses, normalizing using the indoor temperature increased the difference between predicted and measured savings slightly but still within their respective confidence intervals.

## DISCUSSION

### Indoor Temperature Changes Following Retrofit Installation

The average indoor temperature change following weatherization in the Hood River Study was not significant; additionally, the daytime and nighttime temperature in approximately two-thirds of the houses did not change by >2°F.

Table IV. Normalized and predicted annual savings.

| Site number | House type | Predicted savings (therms) | Normalized measured savings[a] NAS1 (CI) (therms) | NAS2 (CI) (therms) |
|---|---|---|---|---|
| 1 | Control | 0 | -72 (43) | -38 (45) |
| 2 | Control | 0 | -153 (60) | -126 (59) |
| 8 | Control | 0 | 24 (49) | 41 (52) |
| 14 | Control | 0 | 353 (158) | 156 (120) |
| 15 | Control | 0 | -10 (25) | 22 (55) |
| 3 | Audit | 222 | 354 (112) | 318 (75) |
| 5 | Audit | 360 | 217 (60) | 291 (65) |
| 7 | Audit | 207 | 132 (34) | 174 (35) |
| 12 | Audit | 448 | 625 (81) | 1001 (98) |

[a] Normalized annual savings (NAS) in therms: NAS1 - using only ambient temperature correlation; normalized for 36-year average weather data. NAS2 - using indoor-ambient temperature correlation, with the thermostat temperature used to represent the indoor temperature; normalized for 65°F balance point, constant indoor temperature, and 36-year average weather data. CI - confidence interval of the savings indicating the uncertainty at ~66% confidence level.

From the Wisconsin study, we observed that the indoor temperature increased >1°F following weatherization in only 1 of 7 audit houses and 1 of 3 blower-door-treated houses; furthermore, neglecting the 1°F significance level, the indoor temperature increased in half the audit homes and decreased in the other half. From these results, we believe that indoor temperature changes do not generally occur in houses in response to receiving conservation measures. Furthermore, we believe that the overall effect of indoor temperature changes on the average measured savings is small and is not the cause for observed differences between predicted and measured savings. To the extent that these observations are applicable to other retrofit programs, the explanation that indoor temperature changes contribute significantly to poorer than expected retrofit performance is not supported.

Although average changes in pre- and post-retrofit indoor temperature were not observed, we conclude that such changes do occur in isolated houses after installation of retrofit measures. In HRCP, we observed that indoor temperature in one-sixth of the households increased by >2°F and one-sixth decreased. Because approximately the same number of homes were colder as were warmer, the average change is 0 . Significant indoor temperature changes were also observed in isolated houses in the Wisconsin experiment. Although these changes cannot explain the program-wide trend to overestimate savings, they probably do contribute to the variation observed in the actual energy savings and the ratio of actual to predicted savings in individual houses.

If the houses likely to experience a change in indoor temperature could be identified at the time the savings predictions are made, predictions could be improved. From HRCP, we found that such identification may be possible because several house and occupant variables accounted for 33% of the variation in temperature differences. The significant determinants of this change were (1) the presence of a college-educated householder, the average pre-retrofit indoor temperature at 5 a.m., the area of the house, and the average pre-retrofit load of the house, higher values of which lead to lowered post-retrofit temperatures and (2) total cost of installed measures, a higher value of which leads to increased post-retrofit temperature. Identification of variables that are not significant can be as important as identifying variables that are. Interestingly, the following variables were not significant in explaining indoor temperature changes: age distribution of residents, type of heating system, income level, family size, attitudes, or service utility (based on a comparison of customers served by two different utilities with different rates). Further studies would be needed to determine the applicability and magnitude of these variables in other programs.

## Pre-Retrofit Temperature Values and Selection

A second contributing factor to the variation observed in retrofit performance of individual houses is the difference between the actual house temperature and the value assumed in making the prediction. The average indoor temperature in about a third of the houses in each of the two studies were significantly different from 70°F (>4°F for the HRCP houses and >3°F for the houses in Wisconsin); 70°F represents the average value of the indoor temperature for the houses in each study and a value which might typically be assumed in making predictions.

Because the accuracy of predicted savings is inherently limited by the accuracy of the assumed indoor temperatures, a means of identifying an appropriate temperature for an individual house rather than using an average value is needed. We believe that the indoor temperature will likely have to be based on a measured value (even if the measured value is collected over a short period) because values of indoor temperature reported by the occupants are not consistent with measured values and an assumed average value cannot be modified based upon important house or occupant characteristics.

In the HRCP data, measured indoor temperatures were generally higher than reported values. Furthermore, additional analysis of the Wisconsin Field Test data (Ternes and Wasserman, 1987) has shown that (1) self-reported thermostat setpoints are consistent with both measured indoor temperature and measured thermostat setpoint only about half the time, and (2) self-reported changes in the thermostat setpoint following weatherization are not consistent with either measured indoor temperature changes or measured setpoint changes. Two points must be considered when evaluating these results. First, the self-reported values may represent either temperature or setpoint values, even though one specific value is requested. Other studies using the Wisconsin Field Test data have indicated that thermostat setpoint and indoor temperature are distinct parameters such that the value or pattern of one cannot necessarily be inferred from the other (Ternes and Wasserman, 1987). Second, the occupants' estimate of the daytime or nighttime indoor temperatures likely represents the steady-state temperature maintained, on average, during the period. This response does not consider temperature drifts to reach the steady-state values after a step change or irregular behavior which may actually occur several days a week; and because an average daily indoor temperature (rather than a separate daytime or nighttime temperature) is ultimately needed in a simplified audit predictive technique, obtaining a reliable value from the occupants is further complicated. More complex, open interviewing techniques employed by other researchers (Kempton and Krabacher, 1984) may provide better responses, although the time required to conduct this type of interview and interpret responses may make it impractical for a large weatherization program.

In the HRCP study, only 6% of the variation in the pre-retrofit indoor temperature among the households could be accounted for by selected occupant and house characteristics. Thus, an improved indoor temperature cannot be incorporated into a predictive technique by modifying an average temperature based on selected characteristics.

### Comparison of Predicted and Measured Savings With and Without Indoor Temperature Included in the Analysis

Our analysis showed that a comparison between predicted and measured savings can be improved in individual houses by considering indoor temperature when measured savings are normalized; this consideration of indoor temperature accounts for indoor temperature fluctuations during the pre- or post-retrofit periods, indoor temperature changes following the installation of the conservation measures, and differences between the assumed and actual pre-retrofit temperatures. We draw three important implications from this result. First, indoor temperature should be monitored in field studies and included in the analysis. A measured savings normalized only to outdoor temperature could be compared to the predicted savings if programmatic questions were of interest. Additionally, a measured savings normalized to outdoor and indoor temperature could be calculated to investigate the actual performance of the conservation measures and the accuracy of the predictive algorithms. Second, because 40-80% of the difference between predicted and measured savings cannot be explained by indoor temperature normalizations, other important factors are contributing to the difference. Third, although including indoor temperature in post-retrofit analysis is useful in analyzing retrofit performance, the benefit that could be obtained from including a correct indoor temperature in the original prediction is also demonstrated.

## SUMMARY

Our analysis of data collected from two different field tests has indicated that only in isolated cases did occupants significantly change their indoor temperature following installation of conservation measures. The average change for most of the houses studied was 0, and increases were as likely to be observed as decreases. Thus, these results do not support the supposition that indoor temperature changes are a significant contributor to lower than expected savings observed in retrofit programs. They do, however, indicate that the isolated changes contribute to the variation observed in measured savings. Average measured indoor temperature was found to be about 70°F, a value typically assumed when predicting energy savings. However, the indoor temperature in one-third of the houses differed from this value significantly, further contributing to the variation in measured savings.

We found that the difference between predicted and measured savings can be reduced in individual houses by 20-60% if the measured savings are adjusted using the same indoor temperature conditions assumed in making the predictions. Other factors are also important because only a portion of the differences was accounted for using the indoor temperature. Calculating a predicted savings in individual houses using a "correct" value for indoor temperature is the desired goal. Self-reported indoor temperatures are not consistent with measured values and an average indoor temperature cannot be modified based upon house or occupant characteristics. Therefore, the "correct" indoor temperature must be based on some form of measured value.

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