Research Report

199-1

Energy and Housing in Wisconsin

A Study of Single-Family Owner-Occupied Homes

Volume 1: Report and Appendices

November 2000

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Volume 1: Report and Appendices

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Preface

Energy use and savings estimates in this report are based on prices for natural gas, electricity, and other fuels in 1998. However, prices for natural gas, propane, and fuel oil have risen dramatically during the few months the report was being finalized. If sustained, these higher prices will increase expenditures for household energy beyond what is reflected in the report, as well as reduce the payback for implementing measures that save energy.

For example, prices for fuels other than electricity are currently predicted to average about 50 percent higher in the coming year. The effect of a sustained increase of this magnitude would be to increase the average household energy cost from about $1,400 dollars per year to about $1,700. Similarly the average annual savings from adding wall insulation would rise from about $150 per year to about $210, and the payback for wall insulation would be reduced from 7.5 years to five years.

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Tables and Figures

Findings at a Glance

This study of a representative random sample of 299 single-family owner-occupied homes in Wisconsin shows the following:

Energy Use and Cost

- The average Wisconsin homeowner spends about $1,400 per year on energy used in the home, or two to three percent of annual household income.

- New homes use 23 percent less heating energy per square foot than older homes, but they are also 22 percent larger.

- Low-income homeowners use more heating energy per square foot, but their homes are smaller on average: their average energy bills are about the same as other households, but they spend seven to 10 percent of annual income on energy, compared to two to three percent for all homeowners.

Energy Savings Opportunities

- From an examination of a dozen common energy efficiency measures, we found that more than 90% of homes have at least one energy efficiency measure that would pay for itself in energy savings within ten years, about two-thirds of homes have at least one opportunity with a 5-year payback, and 30 percent have an opportunity with a 2-year payback or less.

- Of the homes with opportunities, the median savings are $68 per year at an investment cost of $308 for measures with at least a ten-year payback, and $30 per year worth of savings at an investment cost of $72 for measures with at least a five-year payback.

- Energy efficiency opportunities are not uniformly distributed through the population: the least efficient 20 percent account for 60 percent of the aggregate total savings opportunities, and the least efficient half of homes account for 90 percent.

- Heating and cooling savings in older homes that are inadequately insulated or excessively leaky account for the majority (70 percent) of the savings opportunities.

- Energy savings opportunities are a strong function of the age of the home: homes built before 1930 have an average of more than $200 per year worth of energy opportunities (with at least a 10-year payback), whereas homes built in the 1990s have an average of less than $30 worth of opportunities.

- A quarter of Wisconsin homes are excessively leaky to air infiltration (more than 0.5 air changes per hour).

- Fifteen percent of Wisconsin homes have uninsulated walls.

- One in five Wisconsin homes have under-insulated ceiling areas.

- Of the 82 percent of homes that have a forced-air furnace, half are already high-efficiency models.

- Homeowners are more likely to identify leaky windows and doors as the most important effective energy saving opportunity in their homes than they are to point to inadequate insulation or general air infiltration.

- The potential for savings from programmable thermostats is low: of the two-thirds of homeowners that do not already have one, most either already set back their thermostats manually or are resistant to doing so.

- Three quarters of homes have at least one lamp or light fixture that could be cost-effectively retrofitted with a compact fluorescent lamp: CFLs are currently present in 13 percent of Wisconsin homes, and represent five percent of high-use lamps and light fixtures.

Homeowner Attitudes and Behaviors

- Most Wisconsin homeowners have favorable attitudes toward conserving energy and using it efficiently.

- Homeowners who are "conservation oriented" keep their thermostats set lower than those who are not so oriented.

- For the most part, homeowner attitudes toward energy or perception of energy savings potential for their homes have no relation to the presence or absence of energy efficiency opportunities identified on the basis of site visits: homeowners who are highly conservation-oriented are just as likely to have uninsulated walls or other opportunities as those who are not so oriented.

Comfort

- Forty-three percent of homeowners have no complaints about the comfort of their homes in the winter.

- Five percent of homeowners say their homes are too cold or drafty in the winter most or all of the time: most of these homes have high measured air leakage or are substantially uninsulated, and about half are low-income households.

Safety

- Of the 83 percent of homes that have one or more atmospheric combustion appliances, 17 percent have an appliance with either elevated carbon monoxide levels, poor draft or both.

- About a quarter of Wisconsin homes have their water heaters set to provide hot water at a temperature of 135F or higher, well above the recommended setpoint of 120-125F.

Energy Ratings

- The average home in Wisconsin has a rating score of about 78, on a scale of zero to 100. New homes achieve a score of 85 on average, and low-income homes rate lower, with an average score of 73.

- The software used in Wisconsin to estimate energy use and calculate rating scores (REM/Rate) overestimates heating energy use by a median of 20 percent when compared to utility billing records. The overestimates are most pronounced for homes that are lacking in insulation or otherwise energy inefficient.

Summary

This report presents the results of a study of energy characteristics of single-family, owner-occupied homes in Wisconsin. The basis for the study is a statistically representative random sample of 299 Wisconsin homes recruited in 1998 and 1999. Each home in the study received an on-site audit to document the structural and appliance characteristics of the home as they relate to energy use. Homeowners completed an extensive questionnaire that dealt with issues such as attitudes about energy and indoor comfort. We also obtained utility usage data for most of the homes in the study.

The results indicate that Wisconsin homeowners spend about $1,400 on average each year on energy to heat and cool their homes, provide hot water, and operate lights and appliances (based on 1998 prices). In aggregate, the 1.4 million Wisconsin households within the scope of the study spend about $2 billion annually on home energy use. Energy for heating in the winter is the largest single energy expense for most Wisconsin homes, averaging $540 per year. New homes cost about 23 percent less to heat per square foot, because they are better insulated and air-sealed. But these homes are also 22 percent larger on average, so total heating costs for these homes are about the same as older homes. Similarly, homes occupied by low-income households are smaller but less likely to be well insulated or air sealed; these homes also have heating bills that are comparable to the overall average.

We examined the study sample for the applicability of a dozen typical energy efficiency improvements. These ranged from no-cost measures, such as reducing the water heater temperature setpoint, to major retrofits such as adding wall insulation. The results indicate that homeowners in Wisconsin could save about $140 million each year by implementing the measures we defined with a payback of 10 years or less, at a total cost of about $680 million. Implementing all of these measures would reduce residential energy bills by about eight percent in aggregate. Measures that save on heating and cooling bills dominate: these account for 70 percent of the total savings.

The analysis shows that while almost all Wisconsin homes have *some* energy efficiency opportunities, these opportunities are not uniformly distributed. Homes in the top quartile of savings opportunities could save an average of about $280 per year in energy costs by implementing the measures on our list that have a 10-year payback or less. These homes account for almost 70 percent of the aggregate energy savings potential. In contrast, homes in the bottom quartile have an average of less than $5 worth of energy efficiency opportunities, and account for less than 1 percent of the total savings potential.

What distinguishes the homes with substantial energy savings opportunities? In general, it is home age and household income. The older the home, the higher the probability that it does not have adequate insulation or is excessively drafty. Homes built before 1950 have energy savings opportunities that are worth about $200 per year, compared to an average of about $30 for homes built since 1980. In addition, low-income homeowners are about twice as likely to have an important building shell defect, such as inadequate wall insulation. These households—though smaller than average—have an average of $150 worth of annual energy savings opportunities.

Most Wisconsin homeowners profess attitudes that are favorable toward saving energy, and these attitudes do appear to translate into action in how homeowners set their thermostats during the winter. "Conservation-oriented" homeowners set their thermostats at a lower temperature in the winter, and have observably lower heating energy use. At the same time, except for having somewhat lower air leakage, these homeowners are no less likely to have uninsulated walls, lack a high efficiency heating system, or have other energy efficiency improvement opportunities in the home.

The potential for aggregate savings from promoting the installation of setback thermostats appears to be low. One third of homeowners already have a programmable thermostat, and more than half of homeowners with manual

thermostats manually set back their thermostats. Most homeowners who do not set back their thermostats are not interested in doing so.

Homeowners who live in homes that lack wall insulation or are excessively drafty are more likely to report comfort problems during the winter. While 43 percent of homeowners report that their homes are rarely or never too cold or drafty during the winter, more than half of households report that winter comfort problems occur at least some of the time, and about five percent of households say that their homes are too cold or drafty most or all of the time. More than half of these homes with significant comfort problems either lack wall insulation, have high measured air leakage or both. Almost half of these homes are occupied by low-income households, which have higher air leakage than other homes in general.

Finally, we found that the home energy rating system (HERS) software used in this study—and used for the state Home Performance Program—overestimates heating energy use on average. For most homes the overestimate is moderate, with a median of about 20 percent, but the overestimate is substantial for inefficient homes that are predicted to have high heating energy intensity.

Introduction and Methods

Background

Wisconsin homes use about one-third of the total non-transportation energy in the state (Wisconsin Energy Bureau 1999), and government- and utility-funded programs have sought to increase the energy efficiency in homes since the 1970s. In the fall of 1999, the Wisconsin Legislature passed a bill to create a mechanism for public funding for energy efficiency programs that—with the exception of low-income weatherization—have largely been implemented by the state's electric and gas utilities throughout the 1980s and 1990s. This sets the stage for a new era of state-government administered energy efficiency programs, and a consequent need for publicly available data for policy making, program planning and evaluation.

In anticipation of these needs, in 1997 the Energy Center of Wisconsin initiated an effort to characterize Wisconsin housing from an energy use perspective. Though many research studies and program evaluations have been conducted over the years on different aspects of energy use in Wisconsin homes, no single study had attempted to comprehensively examine a statewide random sample of homes. By doing so, we sought to provide a set of data that could be used for public policy making and program planning, as well as establish a baseline against which future public benefits efforts could be judged.

The primary objectives of the study were:

1. Characterize key residential housing and household behavioral factors in Wisconsin:
    - housing structural, mechanical system, and major appliance characteristics;
    - people's usage of mechanical systems and appliances;
    - people's knowledge and attitudes about energy efficiency, conservation, and energy costs.
2. Combine data on people's attitudes toward energy efficiency and conservation with data on where opportunities exist, in order to develop more realistic estimates of the market potential for structural and hardware improvements or social marketing campaigns to change behavior.

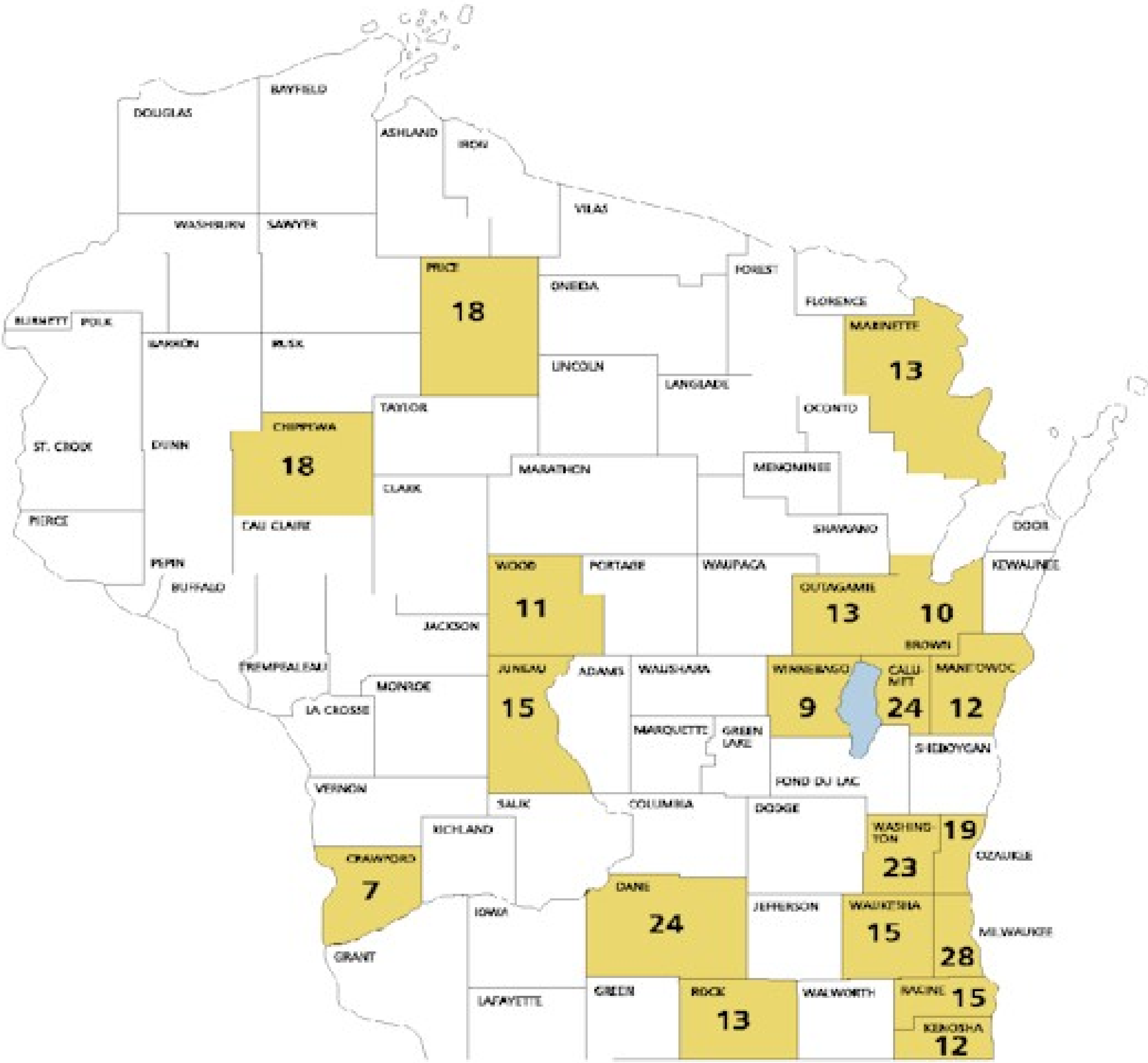
Early on, we decided to limit the scope of the study to single-family, owner-occupied housing in the state. These 1.4 million households constitute about 70 percent of all households in the state.

Study Design

Appendix A contains the details of the design of the study, which we summarize here. We first conducted a pilot study (in 1998) of 40 homes in Milwaukee and Dane counties to develop and refine the data collection instruments. Based on the results of the pilot study, we developed a sampling plan in which we first drew a (stratified) sample of counties in the state, and then recruited individual households at random by telephone within each sampled county. We offered a cash incentive of $50 for homeowners to participate in the study. Two subgroups were of particular interest to us: low-income households (at or below 150 percent of the 1998 Federal Poverty Guideline) and new construction (built in 1994 or later). We offered a cash incentive of $100 to these households, and attempted to boost the proportion of these households beyond what would be expected to occur by chance. Figure 1 shows the number of participants in each sampled county. In the end, with the pilot study included, 299 households participated in the study. Forty three were low-income and 44 were new construction. We also developed weighting factors to ensure that the overall results would be representative of the state's population of owner-occupied single-family households.

We were fortunate in being able to piggy-back some survey questions from our study on to a separate large-scale (n=2,214) telephone survey of Wisconsin homeowners that was conducted during the summer of 1999 as part of ECW's biennial Appliance Sales Tracking (AST) survey series (ECW, 1999). This allowed us to assess the representativeness of the final study sample vis-a-vis a larger sample of Wisconsin homes. The results show that the

Figure 1: Sampled counties and number of site visits per county



Sampled counties shown in bold
Numbers represent sampled households within each county

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Data Collection and Analysis

For each participating household, we collected three types of data: (1) trained home energy raters conducted an on-site audit of the home to collect data on the structure and appliances; (2) homeowners were asked to complete a 32-page questionnaire; and (3) we obtained natural gas and electricity monthly usage histories from the participants' utilities.

The on-site audits were organized around a standard home energy rating system (HERS) rating, conducted by certified raters under the Wisconsin HERS program, and typically lasted 2 to 3 hours. The standard HERS rating provides detailed information about the geometry of each home, insulation levels, and heating, cooling, and water heating equipment. Raters were also trained to collect additional data that are not typically recorded as part of a HERS rating, such as conducting a lighting survey and measuring showerhead flow rates. (The field data form used for the study can be found in Volume 2 of this report.) The HERS software provides an overall energy rating for each home on a scale of zero to 100, and also estimates (on the basis of size, insulation levels, and other factors) the annual energy use for heating, air conditioning and water heating.

The homeowner survey solicited information on basic household demographics, appliance use, comfort, attitudes toward energy and energy efficiency, and maintenance practices for heating and cooling equipment (the questionnaire is included in Volume 2 of the report). All but three homeowners completed the questionnaire, which was typically filled out while the rater was in the home. In addition, 30 households were randomly sampled for later depth interviews.

We were able to obtain natural gas usage histories for 199 of the 206 households with natural gas service, and electricity histories for 270 of the 299 households. Budget and time constraints precluded us from obtaining data on other fuels. We statistically analyzed the utility billing data to break out space heating and air conditioning use, and used this data to impute missing fuel use data (see Appendix B).

Organization of Report

The report is divided into two volumes. This volume contains the major results of the study, along with appendices that detail how some of the analysis was conducted. The second volume consists of a "data book" that provides statistics and tabulations of most of the data that was collected as part of the study. The second volume also contains copies of the data collection instruments that were used in the study

Results

Characteristics of Wisconsin Homes and Households

We first look at some of the basic characteristics of the homes and the participants in the sample. If one were to define a typical Wisconsin home, it would be something along the lines of a single-family ranch house with a basement and about 1600 square feet of living space, occupied by three people who have lived in the home for more than five years (Table 1). There is however, substantial variation across the sample in the size and layout of the homes. The homes range in size from a tiny 500 square-foot home in Madison, to a 5,600 square-foot home in a wealthy Milwaukee neighborhood. Though most are detached site-built homes, a small proportion of the homes in the sample are mobile homes, and one home is an attached townhouse. Figure 2 shows some of the variety of homes included in the study. As best we can determine, the sample of homes in the study does generally reflect the overall housing stock in the state.

The size of a Wisconsin home is a function of the age of the home (Figure 3). Homes that date to the 1920s or earlier tend to be comparable in size to the homes that are built today. The smallest homes date to the 1950s. The average home size has been increasing since the 1960s.

Figure 4 shows some of the basic characteristics of heating, cooling and water heating equipment found in Wisconsin homes. Most homes in the state are heated with a forced air furnace, and the vast majority of these are fueled with either natural gas or propane. More than three-quarters of all households have some form of air conditioning, and over half have central air conditioning. A handful of solar systems aside, Wisconsin homes overwhelmingly use conventional tank-storage water heaters for hot water, of which 28 percent are electric and almost all the rest are either natural-gas or propane-fired models.

Energy Costs

We were able to obtain actual electricity use data for most of the homes in the sample, and natural gas use for nearly all of the 205 homes that use natural gas. We statistically imputed use and costs for 112 homes that use propane, fuel oil, or heat with wood, or for which we did not have adequate utility billing data (see Appendix B).

Overall, our data indicate that Wisconsin homeowners pay $2 billion annually in energy costs (excluding fuel costs for vehicles), or an average of about $1,400 per household. This puts Wisconsin about five percent below the national average for single family homes (EIA, 1999). Ninety percent of Wisconsin homeowners pay somewhere between $800 and $2,200 annually in energy costs. About $120 dollars of this amount are devoted to monthly utility service charges that are not dependent on how much energy is used each month. The variable portion of household energy bills is about $1,280.

Table 1: Basic home and demographic characteristics

	Overall (n=299)	General (n=212)	Low-income (n=43)	New construction (n=44)
House Type				
single-story	46% ± 5	48% ± 6	33% ± 15	44% ± 15
multi-story	45% ± 7	44% ± 7	49% ± 16	43% ± 18
bi/tri-level	5% ± 2	6% ± 3	0%	6% ± 7
mobile home	3% ± 2	1% ± 1	18% ± 9	7% ± 8
attached townhouse	<1% ± 1	<1% ± 1	0%	0%
Square Footage (mean)				
w/ basement	2640 ±100	2660 ±110	1980 ±180	3230 ±230
w/o basement	1630 ±60	1630 ±60	1370 ±140	1950 ±160
Decade of Construction				
pre 1930	18% ± 5	18% ± 6	36% ± 14	0%
1930s	4% ± 3	5% ± 3	0%	0%
1940s	8% ± 3	10% ± 4	5% ± 3	0%
1950s	10% ± 4	11% ± 5	12% ± 8	0%
1960s	10% ± 4	11% ± 4	9% ± 8	0%
1970s	20% ± 6	22% ± 8	23% ± 6	0%
1980s	11% ± 4	12% ± 5	11% ± 8	0%
1990s	19% ± 6	11% ± 4	5% ± 6	100%
Number of Occupants				
(mean)	3.2 ± 0.2	3.1 ± 0.3	3.4 ± 0.7	3.4 ± 0.4
Years lived in home				
<1 year	9% ± 3	5% ± 4	6% ± 6	37% ± 18
1 to 2 years	9% ± 4	7% ± 4	5% ± 8	28% ± 12
3 to 4 years	11% ± 2	7% ± 3	22% ± 15	30% ± 10
5 to 10 years	31% ± 5	36% ± 7	17% ± 14	5% ± 6
>10 years	40% ± 7	44% ± 8	50% ± 16	0%

(error bands are 90 percent confidence intervals)

Figure 2: Types of homes in the study

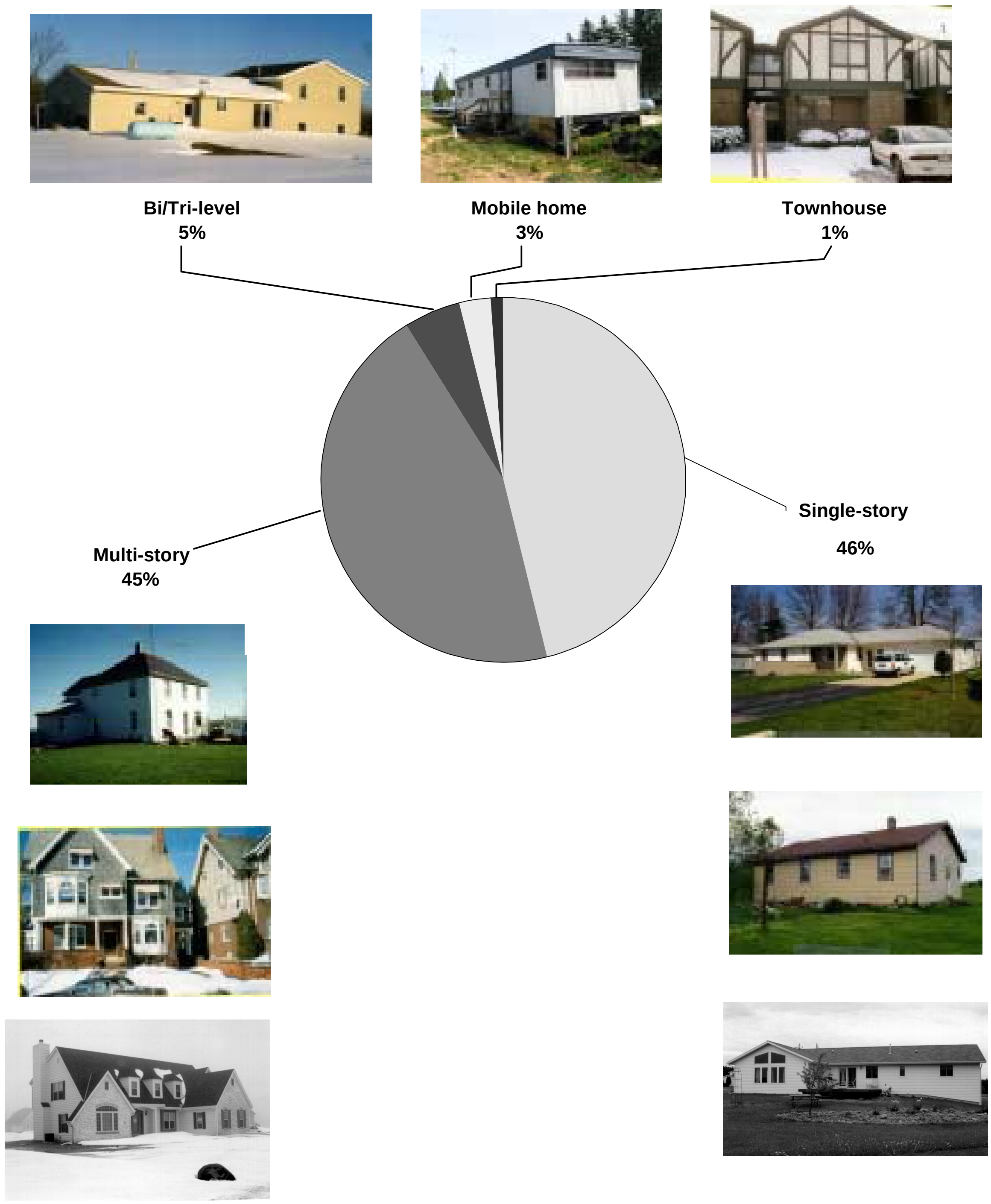


Figure 3: Home size versus decade of construction

Figure 4: Heating system, air conditioning, and water heater characteristics

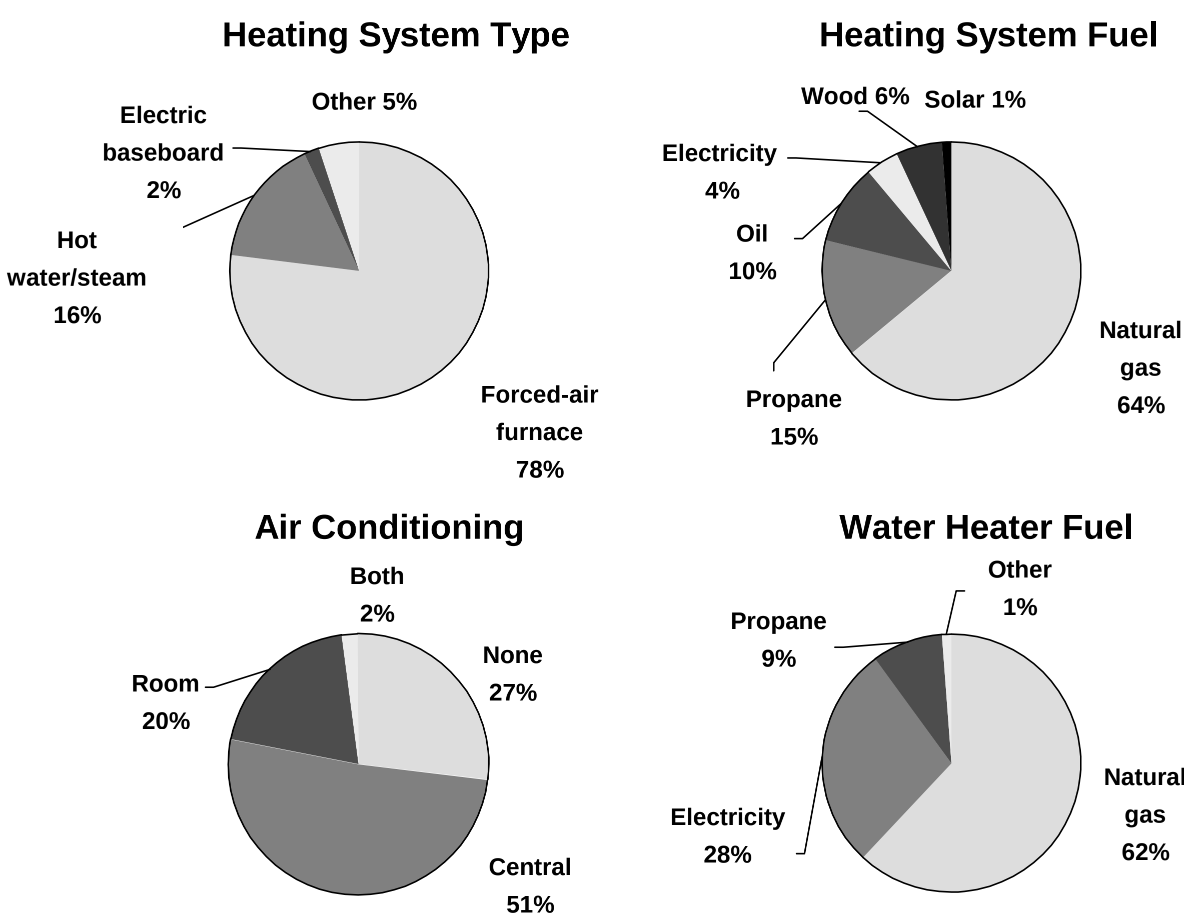


Table 2 shows these expenditures break out by fuel type. Electricity use dominates household energy expenditures. This is followed by natural gas, which is used in over two-thirds of Wisconsin homes, and is used for space heating in most of these. Propane and fuel oil represent significant costs for the minority of homes that use them. A small proportion of Wisconsin households rely on wood for part or all of their home heating needs.

We were also able to derive estimates of average energy use for some of the dominant end-uses in Wisconsin homes. Table 3 shows our estimate of how energy use and costs break out for some of the major end-uses in Wisconsin homes, which we discuss in the following sections.

Heating

Energy use for heating constitutes the single biggest energy cost for most Wisconsin homes, making up 42 percent of total energy costs for the average home. Because of the state's cold climate, Wisconsin homeowners pay 11 percent more to heat their homes than the national average for single-family homes.

How much energy a home needs for heating depends on a variety of factors, including the size of the house, the climate zone within the state, insulation levels, and the efficiency of the heating system. One indicator of the efficiency with which a home is heated is its heating energy intensity, which is the amount of heating energy (Btu) used each year per square foot per heating degree day. The study sample shows an average heating energy intensity of 7.5 Btu/(ft^2-HDD), with most homes requiring between 4 and 13 Btu/(ft^2-HDD) for heating.

Heating energy intensity is a function of the age of the house. Energy codes that stipulated minimum insulation levels in new homes were first enacted in 1978 in Wisconsin in the wake of the energy crises of the 1970s. As a result, homes built in the 1980s and 1990s have substantially lower heating energy intensity than homes built in earlier decades (Figure 5). This does not mean that these homes are less expensive to heat, however. Although homes in our new construction subgroup (built in 1994 or later) use 23 percent less energy per square foot for heating than other homes, they are also 22 percent larger on average.

The same phenomenon holds true in reverse for low-income homes. As we will show later, homes in our low-income subgroup are much less likely to be adequately insulated. Consequently, these homes use about 12% more energy for heating per square foot. But they are also 16 percent smaller, so heating bills are about 5 percent lower than the statewide average.

Air Conditioning

Over half (53 percent) of single-family, owner occupied Wisconsin homes have central air conditioning, and 20 percent have room air conditioners. We found that 12 percent of homes with central air conditioning use it so little that we could not discern its use from summer utility bills. Similarly, the impact of room air conditioners on summer electricity bills was not discernable in 25 percent of homes with these units. For homes that did show a discernable increase in summer electricity use, we found that annual air conditioning costs for homes that use central systems averaged $76, compared with $49 for homes with room air conditioners. Both of these figures fall well below the national average cost for air conditioning ($150) due to Wisconsin's relatively short cooling season.

Table 2: Average use and cost by fuel type

	Percent of homes using fuel	Average annual use	Average annual cost
Electricity			
homes with electric heat	4.6%	24,600 kWh	$1670
homes without electric heat	95.4%	9,960 kWh	$720
Natural gas	70%	1026 therms	$612
Propane	17%	994 gallons	$754
Fuel oil	10%	708 gallons	$569
Wood	6%	88 million Btu	$340

Annual cost for electricity and natural gas includes monthly fixed service charges.

Propane, fuel oil, and wood use estimated (see Appendix B).

Wood use represents wood used for heating in homes that regularly rely on wood for space heating.

Figure 5: Heating energy intensity by decade of construction

Table 3: Average energy use and cost by end-use

Category (% of homes)		Overall (n=299)	General (n=212)	Low-income (n=43)	New construction (n=44)
Heating[a] (100%)					
	10^6 Btu	88 ± 7	89 ± 8	87 ± 7	82 ± 7
	Btu/sf/HDD	7.5 ± 0.6	7.6 ± 0.6	8.3 ± 0.7	5.8 ± 0.4
	$	540 ± 30	540 ± 40	510 ± 40	530 ± 80
Air conditioning[b] (62%)					
Central (47%)					
	kWh	1160 ± 170	1130 ± 180	(c)	1210 ± 310
	$	76 ± 11	74 ± 11		78 ± 19
Room (15%)					
	kWh	780 ± 180	760 ± 230	840 ± 290	(c)
	$	49 ± 10	49 ± 14	51 ± 15	
Use unrelated to space conditioning					
Electricity (100%)					
	kWh	9330 ± 530	9420 ± 610	8920 ± 970	9040 ± 900
	$	610 ± 50	610 ± 50	580 ± 80	580 ± 70
Other Fuels[d] (78%)					
	10^6 Btu	23 ± 1	23 ± 2	27 ± 8	22 ± 5
	$	129 ± 7	124 ± 8	158 ± 42	130 ± 23
Utility service charges ($)		117 ± 5	117 ± 5	120 ± 10	120 ± 5
Total annual energy cost ($)		1410 ± 70	1410 ± 80	1380 ± 100	1410 ± 140

(Error bands are 90% confidence intervals.)

[a]Heating use and costs are based on statistically adjusted model estimates for 112 homes, and are derived directly from utility data for 187 homes.

[b] Excludes homes that either do not have or do not use air conditioning.

[c] Sample size is too small to report results.

[d] Includes gas, propane, and fuel oil use for water heaters, ranges/ovens and dryers.

Water Heating

Statistical analysis of natural gas and electricity data for the study sample indicates that water heating energy use is a function of the number of people in the home as well as the setpoint temperature of the water heater. We estimate that the average fuel-fired water heater (mainly natural gas and propane water heaters present in 72 percent of homes) uses about 20 million Btu per year of fuel and costs about $110 per year to operate. Electric water heaters—which are present in about 28 percent of Wisconsin homes—use about 3,250 kWh per year and cost about $210 per year to operate. These figures may be on the low side because of limitations of the statistical technique we used to derive them from the utility billing data. The nationwide averages for water heaters in single-family homes are 25 million Btu for natural gas water heaters and 3,700 kWh for electric water heaters.

Refrigeration

From short-term metering during the audit of the homes in the study, we estimate that the average refrigerator uses about 990 kWh annually. Similarly, the average stand-alone freezer uses about 815 kWh in a year. Because about one in five Wisconsin homes has two refrigerators, and nearly two-thirds have one or more stand-alone freezers, the average Wisconsin home uses a total of about 1,700 kWh per year for refrigeration, at a cost of about $113.

Other Uses

Electricity used for lighting and electric appliances, energy use for stoves, ovens, and clothes dryers together constitute a little more than a third (36 percent) of household energy expenditures for energy in Wisconsin. We estimate that these remaining uses cost the average homeowner $455 dollars per year.

Energy Ratings

The energy ratings that were conducted as part of the study provide an initial picture of the overall efficiency of Wisconsin homes. To perform an energy rating, auditors enter detailed information about the configuration of the home, insulation levels, air leakage, and heating, cooling and water heating equipment into a software package (REM/Rate, version 8.46). The software estimates the energy use of the home, and assigns a rating score between zero and 100 based on the difference between the estimated energy use and the calculated energy use of an efficient home of the same size and configuration.

Three important to points to keep in mind with these ratings are:

(1) the ratings are based on estimated rather than actual energy use

(2) the ratings are meant to be independent of occupant behavior

(3) the rating scores are independent of the size of the home: two homes with the same rating may use substantially different amounts of energy if they differ in size.

Figure 6 shows the distribution of the rating scores for the homes in the sample. Most homes have a rating score of 70 or higher, but homes with lower ratings constitute about 15 percent of the population. These are mostly homes that are inadequately insulated, have high air leakage, or are judged to have inefficient heating systems. It is perhaps not surprising that low-income homes tend to cluster in the lower tail of the distribution, and new homes tend to cluster in the upper tail. In fact the age of the home is an important factor in the rating score: older homes tend to be leakier and less well insulated and therefore have lower average ratings (Figure 7).

Figure 6: Distribution of HERS rating scores

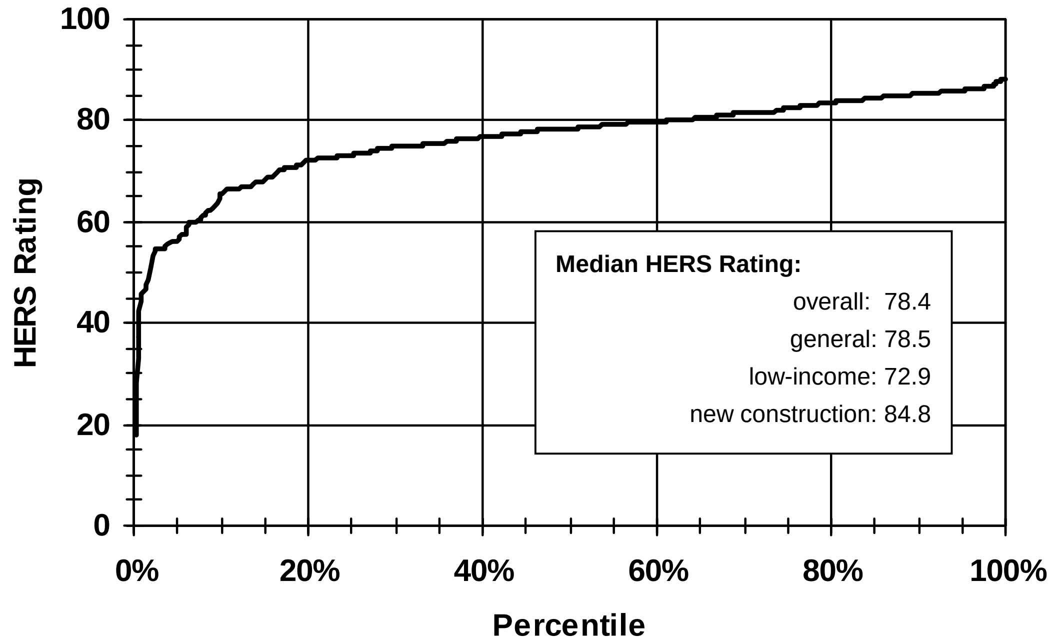


Figure 7: Median HERS rating versus decade of construction

The accuracy of these ratings depends on the accuracy of the information being fed into the software as well as the software's ability to reliably estimate energy use from the data fed into the program. With respect to the former, because the ratings were conducted as part of a research project with multiple levels of data review, we believe that the information used for the ratings was as good or better than a typical home rating. Nonetheless, some important determinants of energy use (such as the quality of insulation in the walls and the seasonal efficiency of older heating systems) are impossible to capture with much precision. This can lead to errors in the ratings for individual homes.

To look at the issue of whether the software used for the ratings reliably estimates energy use, we compared the estimates of heating energy use from the software with those derived from actual utility billing records for 147 homes that we knew used only natural gas for heating. The rating scores take into account air conditioning, water heating, and appliance energy use as well, but heating is the largest end-use, and is one of the few that can be easily disaggregated from utility gas use data. The details of this analysis can be found in Appendix B.

The results (Figure 8) indicate a systematic error in the estimates of heating energy use: the greater the predicted heating energy intensity, the greater the error. For most homes, the error is a moderate overprediction in heating use (on the order of 20 percent), but the software substantially overestimates heating use for a minority of homes that are predicted to have high heating energy intensity. These are mostly homes that have some combination of large uninsulated wall or ceiling areas, high measured air leakage, or heating systems with low estimated seasonal efficiency.

It has been suggested that the difference might arise from a tendency for people who live in older inefficient homes to keep their thermostat set lower to save on their heating bills (these homes are indeed more likely to be occupied by low-income households). The questionnaire data show just the opposite, however: people in older homes keep their thermostat set somewhat higher, probably to overcome comfort problems associated with drafts and cold wall surfaces.

One phenomenon that might explain this tendency is if uninsulated walls have a slightly higher effective R-value than assumed in the software. At the other end of the scale, our results indicate that the software somewhat underpredicts the heating energy use of very efficient houses. This may be because insulation defects degrade the effective R-value of these homes from the assumptions.

The effect of this error is to distort the difference between high- and low-scoring homes. Correcting this difference would make the distribution of rating scores in Figure 6 flatter. A home that would score a 50 based on the uncorrected analysis would score a 70 after taking the bias into account.

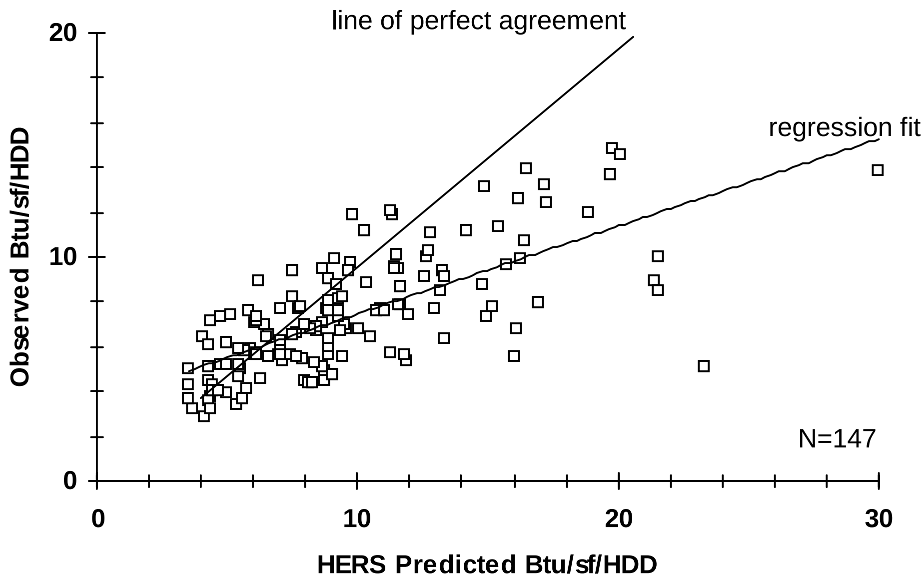
Even after removing this systematic difference, there is still considerable scatter between the estimated heating use from the rating software and what we derived from the utility data. We found that this can partly be explained by what the auditors used for the thermostat setpoint.[1] As we discuss later in this report, homeowners reported winter thermostat settings to us that ranged from 59 ^{o}F to 74 ^{o}F. Yet, most auditors modeled the home at the default value of 68 ^{o}F. The difference between these two values is a statistically significant predictor of the error between the two estimates of heating energy use. Each degree F of error creates about a 2.5 percent error in the predicted heating use.

Some of the observed scatter between the predicted and observed heating energy use is no doubt due to the fact that the billing-data based estimates of heating use have statistical uncertainty associated with them. But the overall

[1] Because the rating score is meant to be occupant neutral, the temperature at which homeowners keep their thermostats is not used for the rating score calculation. But the rating software also estimates the actual heating use of the home in order to estimate the savings from various improvement measures. We compared this estimate against what we derived from utility billing data.

impression is that the rating-software based predictions of heating use should not be taken as more than rough approximations of actual usage, even after accounting for the systematic error noted above.

Figure 8: HERS-software predicted versus observed heating energy intensity



Energy Efficiency Opportunities

To examine the potential for energy savings in Wisconsin homes, we defined a number of energy efficiency opportunities, and then looked at how prevalent these opportunities were in our sample of homes. These opportunities, which are described in more detail in the sections that follow, represent some of the more common energy measures typically recommended for homes, though it is by no means an exhaustive list. The list also does not include things that people can do to save energy as part of their daily routine, such as thermostat setbacks—we cover these activities in a later section.

For each measure, we defined criteria as to whether the measure was applicable for each home in the sample. We also estimated the cost and energy savings associated with the measure (these are documented in more detail in Appendix B). For most of the measures on the list, the savings and cost were customized for each home; for example, our estimates of the energy savings and cost of wall insulation are based on the area to be insulated.

Most of these measures are generally considered to be cost effective retrofits for existing homes on a life-cycle cost basis. Nonetheless we looked at the prevalence of these opportunities with 10-year and 5-year simple payback screens. As we will demonstrate shortly, most measures have at least a 10-year simple payback; fewer meet a 5-year simple payback screen. It is also important to note up front that the estimated prevalence of some of the savings opportunities depends strongly on the assumptions that go into defining the measure; we note these later in the discussion of individual measures.

Tables 4 and 5 show the measures, along with their prevalence and average estimated savings and cost under the 10-year and 5-year simple payback screens. In aggregate, we estimate that an investment of about $674 million in the measures with a 10-year payback or less would save Wisconsin homeowners $139 million in energy costs each year, or an average of about $100 ± 30 per household. This average is misleading, because the savings potential is not uniformly distributed throughout the population but rather concentrated in a minority of homes. While more than 90 percent of homes have *some* savings opportunities, the least efficient 20 percent of homes (in terms of savings potential) account for over 60 percent of the total, and more than 90 percent of the total savings potential we estimated occurs in half of the homes (Figure 9). Because of this skewed distribution, the median savings per home—an arguably better representation of the savings potential for a typical home—is much lower: $38 per year (or $68 per home if we exclude homes without any opportunities). While homes in the top quartile of savings potential have an average of $275 per year worth of savings opportunities (at a cost of $1400), homes in the bottom quartile have an average of only about $5 per year of opportunities (at a cost of $25).

It is largely measures that save on space heating (and cooling) that shape this distribution, because these represent the bulk of the total potential energy savings, and are concentrated in a minority of homes. Our data indicate that the energy savings potential is a strong function of the age of the home (Figure 10). This is mostly driven by a steady increase with house age in the proportion of homes with inadequate wall or ceiling insulation—or excessive air leakage (Figure 11). Energy codes first enacted in 1978 have required minimum insulation levels for homes built in the last two decades, but many homes built prior to that time are inadequately insulated or are excessively leaky.

The average savings per home drops rapidly when the payback criterion is less than about nine years (Figure 12). If homeowners require shorter paybacks, there are fewer savings opportunities in Wisconsin homes. About two-thirds of homes have one or more opportunities with a payback of 5 years or less, and the median savings for these homes is $30 per year.

Low-income homes also have about twice the overall average worth of energy saving opportunities, and this difference also appears to be driven by building shell deficiencies. It is reasonable to suppose that while heating systems and water heaters break down and must be replaced, shell deficiencies tend to go untreated among homeowners who cannot afford the remedies.

In the sections that follow, we discuss some of these individual measures in more detail.

Table 4: Prevalence, savings and cost of energy efficiency opportunities for measures with 10-year payback or less

	Percent of homes with opportunity				Estimated annual energy savings		
Measure	**Overall**	**General**	**Low-income**	**New construction**	**Average**	**Percent of aggregate total**	**Estimated average cost**
Wall insulation	14%	15%	20%	0%	$147	21.5%	$1,097
Ceiling insulation	21%	21%	40%	2%	$82	17.8%	$403
Floor insulation	3%	1%	11%	2%	$163	4.2%	$446
Rimjoist insulation	21%	22%	33%	4%	$10	2.1%	$68
Infiltration reduction	19%	17%	46%	9%	$94	18.4%	$278
Furnace replacement	9%	11%	7%	0%	$68	6.2%	$500
Any heating/cooling measure	*49%*	*49%*	*74%*	*14%*	*$144*	*70.2%*	*$762*
Water heater fuel switch	4%	5%	4%	2%	$108	4.7%	$600
Water heater temperature reduction	23%	21%	32%	29%	$12	2.8%	$0
Water heater wrap	21%	24%	15%	0%	$9	2.0%	$20
Low-flow showerhead	2%	2%	3%	0%	$16	0.4%	$6
Any water heating measure	*42%*	*42%*	*52%*	*31%*	*$23*	*9.9%*	*$72*
Refrigerator replacement	10%	11%	9%	2%	$107	10.9%	$541
Compact fluorescent lights	76%	76%	69%	83%	$12	9.0%	$58
Any measure	*91%*	*91%*	*94%*	*87%*	*$108*	*100%*	*$544*

Savings and cost of furnace replacement based on incremental upgrade from standard efficiency to high efficiency. Water heater fuel switch cost based on incremental cost of conversion

See Appendix B for definition and estimation details.

Table 5: Prevalence, savings and cost of energy efficiency opportunities for measures with 5-year payback or less

	Percent of homes with opportunity				Estimated annual energy savings		
Measure	**Overall**	**General**	**Low-income**	**New construction**	**Average**	**Percent of aggregate total**	**Estimated average cost**
Wall insulation	0%	0%	0%	0%	na	0%	na
Ceiling insulation	8%	7%	25%	0%	$125	20.3%	$441
Floor insulation	2%	1%	11%	2%	$163	8.0%	$446
Rimjoist insulation	<1%	0%	2%	0%	$10	<0.1%	$25
Infiltration reduction	16%	15%	31%	9%	$108	33.8%	$303
Furnace replacement	<1%	<1%	0%	0%	$103	0.7%	$500
Any heating/cooling measure	*24%*	*21%*	*55%*	*11%*	*$137*	*62.8%*	*$416*
Water heater fuel switch	2%	3%	2%	0%	$126	5.8%	$600
Water heater temperature reduction	23%	21%	32%	29%	$12	5.5%	0$
Water heater wrap	21%	24%	15%	0%	$9	3.8%	$20
Low-flow showerhead	2%	2%	3%	0%	$16	0.7%	$6
Any water heating measure	*40%*	*40%*	*52%*	*29%*	*$20*	*15.9%*	*$45*
Refrigerator replacement	6%	6%	7%	2%	$108	11.8%	$470
Compact fluorescent lights	33%	34%	27%	38%	$15	9.6%	$54
Any measure	*69%*	*69%*	*77%*	*60%*	*$74*	*100%*	*$233*

Savings and cost of furnace replacement based on incremental upgrade from standard efficiency to high efficiency. Water heater fuel switch cost based on incremental cost of conversion

See Appendix B for definition and estimation details.

Figure 9: Distribution of total savings per home

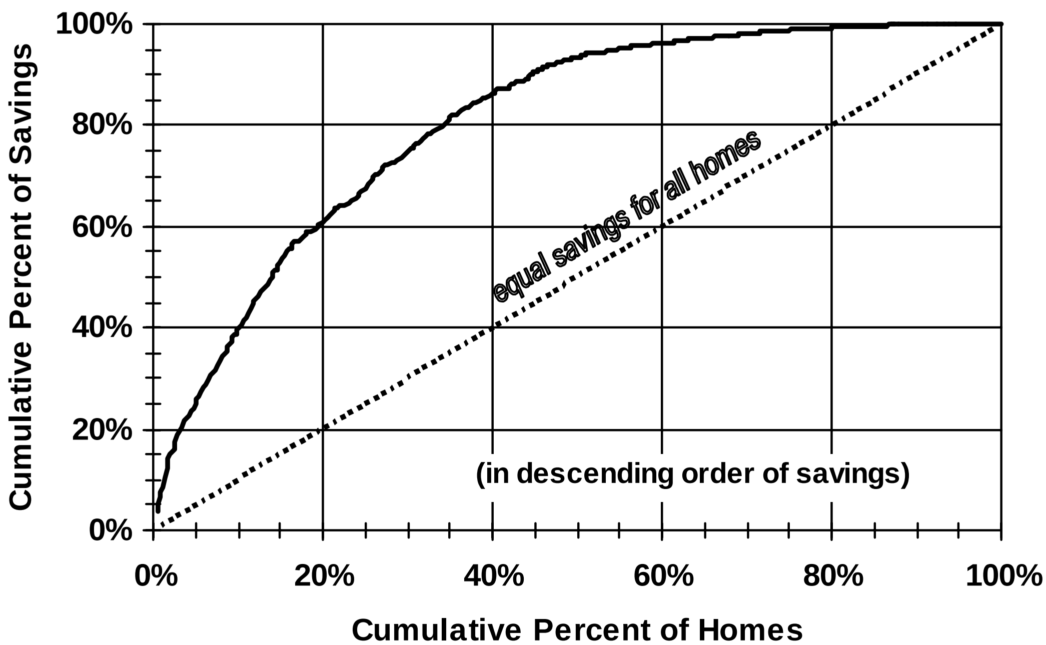


Figure 10: Energy saving opportunities by age of home

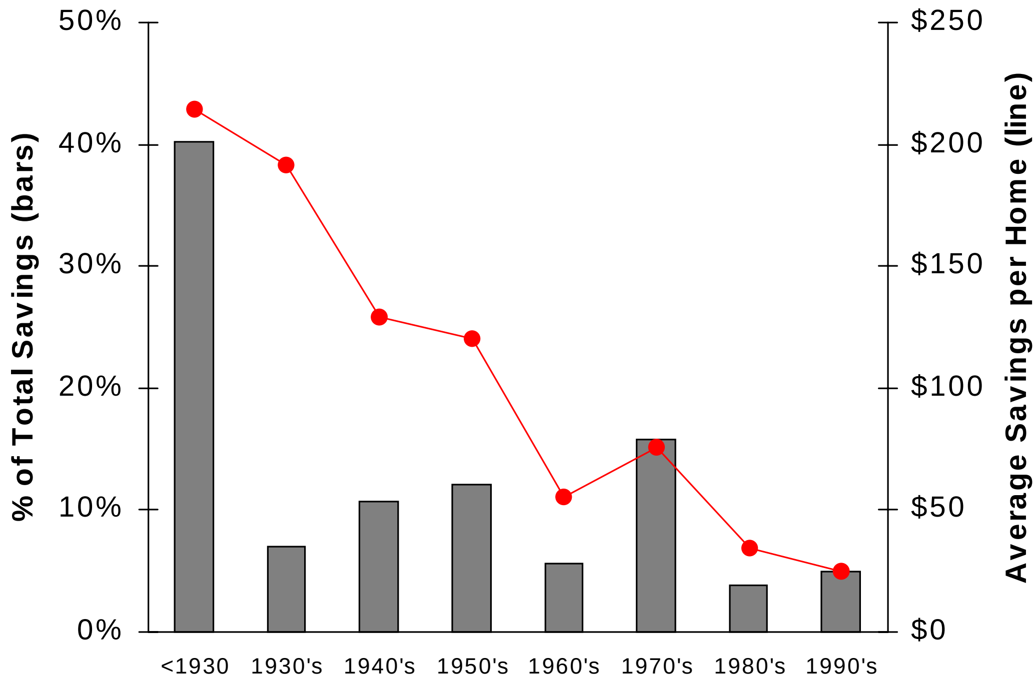


Figure 11: Prevalence of wall insulation, ceiling insulation, and infiltration reduction opportunities by age of home

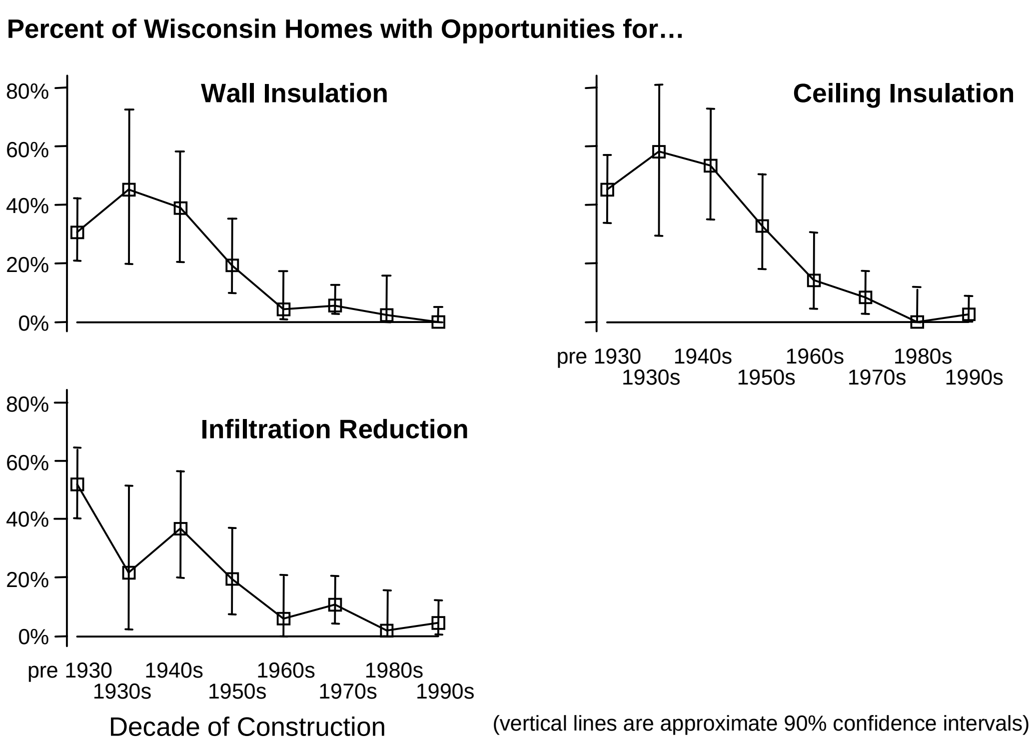


Figure 12: Average savings per home as a function of simple payback period

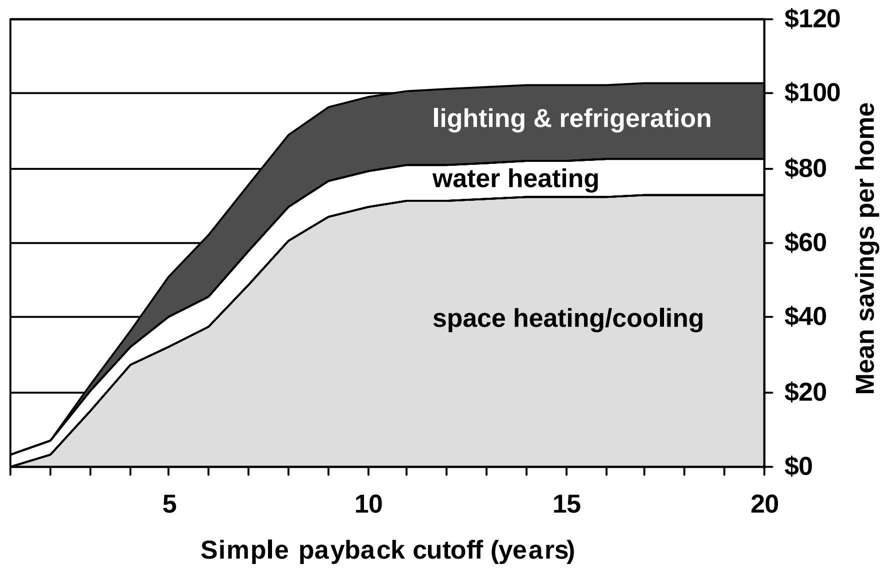
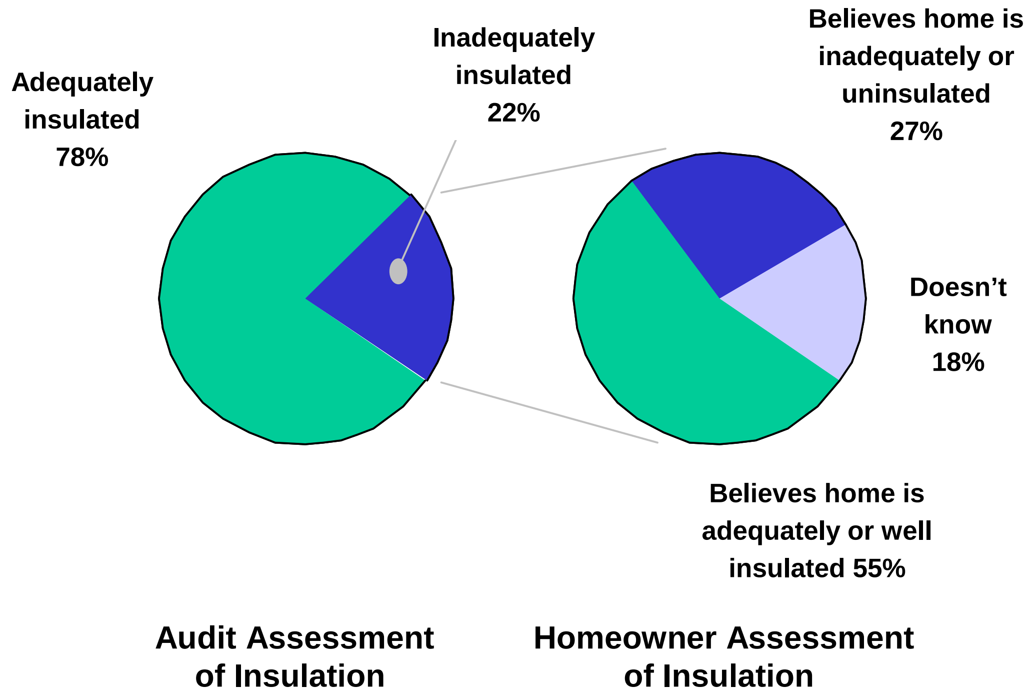


Figure 13: Homeowner and auditor perception of insulation levels



Insulation

Because walls and ceilings make up a large proportion of the total surface area of the home, the amount of insulation in these areas has a substantial impact on how much energy is needed for heating and cooling. Evaluations of low-income weatherization programs have shown that adding insulation to uninsulated walls reduces heating energy use by about 15 percent and adding insulation to under-insulated ceilings saves from 5 to 12 percent on average (WECC 1994, Blasnik 1999). Adding insulation to uninsulated ceilings saves even more, but we found few such homes in our sample.

The audits of the homes in the study sample suggest that about 15 percent of Wisconsin homes have uninsulated walls. We found that wall areas that are faced with brick or other masonry on the exterior are much more likely to be uninsulated than other siding types. Masonry walls constitute 38 percent of the *uninsulated* wall area, compared to only 11 percent of the total wall area of all homes. This probably reflects the greater difficulty (and cost) for insulating these walls.

With respect to ceilings, while very few homes have completely uninsulated ceilings, many are insulated to far less than what the current state energy code requires (R-38). About 14 percent of the aggregate ceiling area is insulated to R-11 or less, and about a quarter of the total ceiling area is insulated to R-19. While most would agree that an R-11 attic is underinsulated, an informal poll of energy efficiency professionals reveals mixed opinions about whether an R-19 attic represents a cost-effective energy efficiency opportunity. We took a middle-of-the-road approach and defined R-19 attic space as an energy efficiency opportunity only in homes that also have wall insulation or infiltration reduction opportunities. Using this definition, we estimate that about a quarter of Wisconsin homes have ceiling insulation opportunities.

The state's energy codes have stipulated minimum insulation levels in homes built since the late 1970s; as a consequence, new homes are generally well-insulated. Older homes are much more likely to have opportunities for wall and ceiling insulation (Figure 11). Moreover, our data indicate that homes occupied by low-income households are about twice as likely to be inadequately insulated as other homes.

We also looked at opportunities for insulating rim and band joists (the areas where joists below floors connect the outside) and underneath floors that are overhangs or over crawlspaces. While a significant number of homes could use rim/band joist insulation (22 percent), the savings are modest. And the fact that few homes have floors exposed directly to the elements limits the savings potential for floor insulation.

Insulation can also be added to the outside or inside of basement foundation walls, but the former requires excavating around the foundation, and the latter usually involves attaching a stud frame to the foundation wall. Moreover, many Wisconsin basements are not intentionally conditioned. Given these difficulties, we did not attempt to assess the prevalence of foundation insulation opportunities.

We also asked on the questionnaire how well insulated respondents felt their homes were. The results suggest that most homeowners living in homes that we felt to be inadequately insulated (i.e., walls insulated to less than R-11 or ceiling areas insulated to less than R-19) either did not know how well insulated their homes were or felt that their homes were adequately- or well-insulated (Figure 13).

Infiltration

Infiltration refers to the uncontrolled leakage of outdoor air into a home. Some fresh outdoor air is needed to remove stale indoor air, but excessive infiltration represents both an energy burden and a comfort problem. The infiltration rates of the homes in the study were estimated from blower door tests, in which the house is depressurized in a controlled way that allows measurement of total air leakage into a home. Though the blower door measures air leakage under artificial conditions, one-twentieth of the blower-door based air leakage at a pressure difference of 50 Pascals is commonly taken as an estimate of the average infiltration under natural conditions. This leakage can be expressed in absolute terms (cubic feet per minute) or in relation to the size of the house (air changes per hour).

We set 0.5 natural air changes per hour as the threshold for excessive infiltration. By this criterion, about a quarter of the homes in the study have excessive infiltration. We found that the older the home, the higher the probability of having excessive air leakage (Figure 11). Conversely homes built in the last 20 years are much less likely to be leaky in terms of air changes per hour. But because these homes are larger, they have only slightly lower absolute air leakage. As with insulation, low income homes are also much more likely than other homes to be leaky: over half of the homes in the low-income subgroup exceeded our threshold for excessive air leakage.

Infiltration reduction is one measure for which the prevalence of the opportunity depends on one’s assumptions. In this case, the important assumptions have to do with one’s vision about a market for reducing air leakage. Our fairly conservative criteria of infiltration reduction implicitly assume that only households with substantial air leakage problems would be motivated do anything about it. But in a market for whole-house treatment or house doctoring, the aggregate savings potential might be much larger. Most homes have some air leakage opportunities, and, under this scenario, infiltration would be addressed in most homes using a blower door as a diagnostic tool to eliminate leaks until the blower readings indicate that the work is no longer cost-effective. This is in fact how most cold-climate low-income weatherization programs operate, with more than 90 percent of treated homes receiving some infiltration reduction work. Under this scenario, we estimate that more than 80 percent of Wisconsin homes would have some infiltration reduction opportunities, and the aggregate savings from these opportunities would be approximately double what we show for high air-leakage homes alone.

Not surprisingly, owners of homes with very high measured air leakage were among the small minority of homeowners who reported substantial comfort problems during the winter. We also found that homeowners who scored high on an index of conservation orientation tended to have lower air leakage than homeowners who scored low on this index. As we discuss later, this was the only place where we found a statistically significant correlation between peoples’ attitudes toward energy and the physical condition of their homes. Presumably, homeowners who are very interested in conserving energy have done a better job of sealing their homes against air leaks. Curiously, these homeowners did not report a higher incidence of caulking and weatherstripping on the questionnaire.

Heating Systems

Most Wisconsin heating systems (77 percent) are forced air furnaces fueled by either natural gas or propane. The majority of the remaining homes are heated with a boiler that circulates hot water or steam. Though there are energy efficiency opportunities for boiler systems, we focus here on the much larger population of forced air furnaces.

Forced air furnaces can easily be classified into two efficiency groups; standard efficiency (about 80 percent efficient) and high efficiency condensing units (90 percent efficient or more). The study sample indicates that about half of all forced air furnaces in Wisconsin homes are high efficiency models. Given this statistic, one might be tempted to say that half of Wisconsin homes with furnaces (40 percent of all homes) have an energy efficiency opportunity in the form of replacing a standard efficiency furnace with a high efficiency model. But it is not generally worthwhile to replace a standard efficiency furnace that has many years of life left on it in order to get some heating cost savings. In addition, a significant proportion of the lower-efficiency furnaces that remain are units that burn fuel oil (for which high efficiency replacements are not widely available). These units represent opportunities only in homes that also have natural gas or propane available for a replacement unit. Taking these restrictions into account, we estimate that in the near term about nine percent of Wisconsin homes have an opportunity in the form of an older furnace that could be replaced by a high efficiency model.

More than a third of the homes that we classified as candidates for heating system replacement said on the questionnaire that it was somewhat or very likely that they would purchase a new heating system in the next year (compared to 11 percent of all participants). Many of these replacements will likely be high-efficiency models, because these make up the majority of the furnaces that are sold in the state each year. Other ECW tracking data show that, statewide, more than three-quarters of furnaces sold in 1999 were high-efficiency models.

Water Heating

Though we defined four potential water heating measures, only two of these appear to offer substantial savings opportunities in Wisconsin homes in aggregate: switching the water heater fuel and reducing the water heater setpoint. We will look at these each in turn.

Switching Water Heater Fuel

Replacing an electric water heater with a natural gas or propane model can provide significant energy cost savings because gas and propane are much less expensive ways to heat water than electricity—even though they are less efficient at doing so because much of the heat content of the fuel goes up the flue. The annual energy cost for an electric water heater is on the order of $200 per year, compared to about $100 for a natural gas water heater. About 28 percent of the homes in the study have electric water heaters, and a majority (58%) of these already have natural gas service or propane in the home, so in theory about 16 percent of all homes have an electric water heater that could be switched for a natural gas or propane model.

But as with furnaces, homeowners are unlikely to replace a functional water heater just to save energy. If we restrict the definition of a fuel switch opportunity to water heaters that are more than ten years old, the near-term potential for water heater fuel conversions is on the order of seven percent of all households.

About 12 percent of the households that we classified as having near-term potential for water heater fuel switch said on the questionnaire that they were somewhat or very likely to replace their water heater within the next year. This proportion is no different from that of all owners of electric water heaters.

Data from the last Appliance Sales Tracking survey indicates that most homeowners with electric water heaters do not switch fuels when they replace the water heater. Of 50 surveyed households that replaced an electric water heater, only seven (14 percent) switched to natural gas (two did not know what fuel the new water heater used). This suggests that there is room to promote switching water heater fuel source beyond that which occurs naturally in the market.

At the same time, targeting these homeowners may be difficult: most people replace a water heater only when it starts to leak or fails in some other way—and when that happens they are usually in a hurry to do so. Past programs to promote water heater fuel switching have sought to identify candidate households ahead of time, and seek a commitment to convert to a fuel-fired water heater when it comes time to replace the electric water heater.

We looked into identifying these households on the basis of their electricity and natural gas use. One would expect that homes with electric water heaters should use more electricity than homes without, especially during the shoulder months between the heating and cooling seasons. And these homes should use less natural gas during the summer because they do not have gas water heaters. The difficulty is in defining a usage level that best discriminates the two groups.

We found that electricity use is not a good indicator of the presence or absence of an electric water heater for an individual home. On average, homes with an electric water heater do use more electricity than homes with a fuel-fired water heater. But the variation from house to house in electricity use due to other appliances is so large that there is no single usage criterion that can neatly discriminate homes with electric water heaters from those without.

On the other hand, it does appear to be feasible to identify natural gas homes that lack a gas water heater on the basis of summer use. A cut-off of six therms per month appears to us to provide a reasonable balance between picking up as high a proportion of homes with electric water heaters as possible without overly diluting the list with homes that already have gas water heaters (Table 6). Setting the threshold lower would eliminate more of the homes with gas water heaters, but also fail to pick up some homes that have electric water heaters. Setting it higher includes a higher proportion of homes with electric water heaters, but also includes many homes with gas water heaters that have low summer use.

Table 6: Summer natural gas use and electric water heaters

Threshold for summer gas use (therms per month)	Percent of homes with an electric water that are above threshold	Percent of all households at or below threshold that have an electric water heater
10	0	50
8	5	60
6	10	75
4	30	80
2	40	90
0	70	95

Based on analysis of gas use for 18 homes with electric water heaters and 151 homes with gas water heaters.

Percentages rounded to nearest 5 percentage points.

Water Heater Temperature Reduction

Measurements of hot water temperature show that a significant proportion of households have their water heaters set to deliver hot water that is hotter than the typical recommendation of 120-125°F. Nearly a quarter of the homes (23%) in the study have a hot water temperature at the tap of 135 °F or more. This represents both a no-cost energy efficiency opportunity and a safety hazard, especially for the 20 percent of households with a child under the age of six in the home.

Having an older automatic dishwasher that lacks its own booster heater has been cited as one reason for a higher water heater setpoint, but the study data show that older dishwashers (10 or more years old) are no more likely to be found in homes with high setpoints than homes with lower setpoints.

On the other hand, homeowners who find they don't have enough hot water may turn up the setpoint on their water heaters in order to stretch the capacity of their tanks (by mixing a smaller proportion of hotter water to get the desired water temperature). We did find a statistically significant inverse relationship between the probability of having a high setpoint temperature and the number of gallons of water heater capacity per person in the household. The more gallons of hot water available per person in the home, the less the likelihood that the temperature will be set over 135F. We also found that homes with electric water heaters are about half as likely (12%) to have a high temperature setting than homes with a fuel-fired water heater (28%).

Refrigerators and Freezers

Every home in the sample has one refrigerator, and about 1 in 5 homes has a second refrigerator. In addition, about 60% of homes have at least one stand-alone freezer. Auditors metered the running wattage and energy use of up to two primary units per home wherever possible over the duration of the audit. Based on units that were monitored for at least 90 minutes, we estimate that the average refrigerator draws about 200 Watts and uses an average of about 1000 ± 50 kWh per year. The average stand-alone freezer draws about the same wattage, but runs slightly less, using an average of 800 ± 90 kWh per year.

Although the brevity of the metering period leaves some uncertainty in the data, a threshold of 5 kWh/day for refrigerators and 4 kWh/day for freezers suggest that about 10 percent of Wisconsin homes have an older refrigerator or freezer that would be a good candidate for replacement because of high energy use. Thirty nine percent of the households that we classified as candidates for replacing a refrigerator because of high usage stated on the questionnaire that it was somewhat or very likely that they would purchase a new refrigerator in the next year, compared to 18 percent of all respondents. For stand-alone freezers, the difference is much less (19 percent and 13 percent, respectively). This suggests that high-use refrigerators are more likely to be replaced in the existing marketplace than high-use freezers.

Lighting

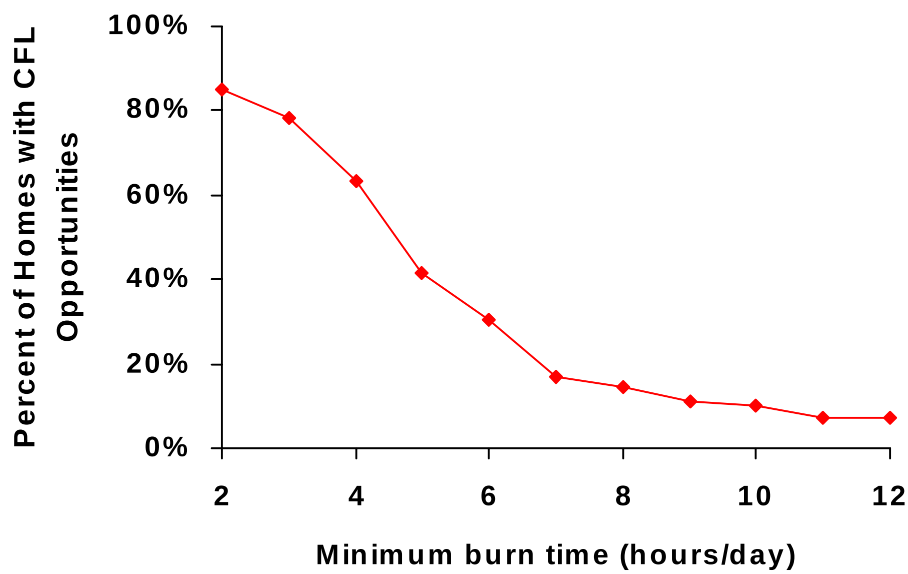
A survey of high-use lighting in each home was conducted as part of the audit, using a rough criterion of about two hours/day of use. An average of 3.5 lights per house were recorded, mostly in kitchens (29%), living rooms (22%), recreation rooms (11%), and outdoors (7%). Ceiling fixtures make up about half of the recorded sample, and table and floor lamps make up over a third. Altogether, a median of 340 Watts of lighting per home was recorded. When combined with homeowners' self-reports of how many hours per day each light is used, we estimate a median of about 500 kWh per year of high use lighting. This is about one-quarter what has been measured for total lighting electricity use in homes in the Pacific Northwest (Tribwell 1997).

Compact fluorescent light bulbs have been promoted for more than a decade by government and utility energy efficiency programs. Despite these efforts, the study shows that only 13 percent of homes have one or more CFLs installed in a high-use location, representing about five percent of all lights recorded in the study. This low saturation does not appear to be a lack of awareness: in ECW's 1999 AST survey (ECW, 2000), 72 percent of respondents reported that they were aware of CFLs. And both the AST survey and the Residential Characterization sample indicate that one in three households have installed a CFL in the past.

Dissatisfaction with CFLs may be a factor in this low saturation. CFLs were mentioned more frequently than anything else for the 16 percent of study questionnaire respondents who said that they had installed energy-saving items or measures and then been dissatisfied with them: over a quarter (28 percent) of these households specifically mentioned CFLs. Moreover, of the six households that participated in more extensive open-ended interviews and reported having installed CFLs at some point, only one household was unequivocally happy with their CFLs. Three households expressed dissatisfaction with some or all of the CFLs they had installed because they were too dim, but used them anyway. And two households were unequivocally unhappy with the CFLs due to the dimness of the light.

Based on a minimum burn time of two hours per day, we estimate that three-quarters of homeowners could cost-effectively retrofit one or more incandescent lamps with CFLs. The payback period for a CFL retrofit is a function of how much the lights are used. Many lights are used for two hours per day; far fewer are used for six hours per day or more (Figure 14):

Figure 14: Prevalence of CFL opportunities versus minimum burn time threshold



Energy, Home Health and Safety

Several aspects of home energy use are also related to the health and safety of the people who live in the homes. We examine here health and safety issues associated with carbon monoxide (CO) and draft for combustion appliances, and hot water temperature.

Carbon monoxide and combustion draft

We tested the carbon monoxide levels and flue draft for fuel-fired heating systems and water heaters with atmospheric combustion (i.e., not power vented). We also measured CO levels for natural gas and propane ovens and ranges. The results show that—of the 83 percent of homes that have at least one of these atmospheric combustion appliances in the home—about one in five has an appliance with either high carbon monoxide production or poor draft (Table 7). Most of these are homes with water heaters that have poor draft. A little fewer than half (43 percent) of the households with a draft or CO problem have a carbon monoxide detector installed in the home, a rate that is somewhat higher than the overall proportion of homes with CO detectors (36 percent), but not statistically distinguishable.

The age of the heating system or water heater is not a good predictor of carbon monoxide problems. The 12 heating system with elevated CO levels ranged in age from three to 39 years old, and the eight water heaters with high CO ranged from three to 19 years old.

Hot water temperature

It is generally recommended that water heaters be set to provide hot water from the tap at 120 to 125°F. As noted previously, though, we found a significant fraction of homes with hot water temperatures that exceeded 135°F. At this temperature, first-degree burns can occur within seconds. This is a particular concern for households that have young children. Our sample of homes indicates that about one in five homes has a child under the age of six, and this proportion is no different for homes that have hot water temperatures over 135°F. Reducing the set-point of these water heaters would both save energy and mitigate a safety hazard for small children.

Table 7: Prevalence of elevated carbon monoxide and poor draft for combustion appliances

Appliance (percent of homes with fuel-fired atmospheric units)	**Overall**	**General**	**Low-income**	**New Construction**
Elevated carbon monoxide (>100 ppm)				
Heating system (42%)	**11%** ± 7	11% ± 7	17% ± 14	0%
Water heater (66%)	**4%** ± 4	5% ± 5	0% ±	0%
Oven (33%)	**1%** ± 1	0% ± 1	4% ± 6	0%
Range (35%)	**0%**	0%	0%	0%
Any CO problem above (83%)	***7%*** *± 5*	*8% ± 6*	*10% ± 12*	*0%*
Poor draft[a]				
Heating system (42%)	**4%** ± 3	4% ± 4	0%	NA
Water heater (66%)	**11%** ± 4	12% ± 5	5% ± 8	9% ± 12
Any draft problem above (79%)	***12%*** *± 4*	*13% ± 5*	*4% ± 6*	*10% ± 11*
Any of the above (83%)	***17%*** *± 5*	*19% ± 8*	*11% ± 13*	*9% ± 9*

[a]Draft measured with and without exhaust devices (such as exhaust fans and dryers) running. Poor draft recorded for any draft reading less than cut-off value which varies (by outdoor temperature) from 2 to 5 Pascals.

Energy-Related Attitudes and Actions

In this section, we examine homeowners' attitudes toward energy conservation the kinds of behavior they report taking to save energy, and their reasons for taking these actions.

Energy Attitudes

On the questionnaire we asked homeowners how much they agreed with more than two dozen statements about energy. Statistical analysis of their responses (see Appendix B) suggests that how people respond to the following four statements measures an underlying attitude that we call "conservation-orientation":

- "I am not interested in making energy-saving improvements to my home."

- "It's just not worth putting on more clothing in the winter to try to save a little energy."
- "I would only conserve energy if I could not afford to pay for it."
- "I am not interested in making my home more efficient."

We created an index from the responses to these statements. Households with low scores for this index are less inclined to exhibit favorable attitudes toward energy conservation; households with high scores, more inclined.

The distribution of the index indicates that most households are favorably oriented toward energy conservation (Figure 15)—though our sample may overrepresent these households somewhat. High-scoring households show some tendency to be more highly educated (and have higher incomes), but are otherwise demographically diverse.

We found a good correlation between this index and the average temperature at which homeowners report keeping their thermostat set (we discuss thermostat-setting behavior in more detail later). Homeowners who score high on the conservation-orientation index keep their thermostats set lower than those with low scores. Over the range of the index, the difference appears to be about 3 F^o.

But with one notable exception, the conservation-orientation index is not correlated with the prevalence of energy efficiency opportunities discussed earlier or with actions that homeowners report taking to save energy in their homes. The exception is air leakage: we found a tendency for higher scoring homes to have lower measured air leakage than low scoring homes. We do not know whether this is a real cause-and-effect phenomenon—in which homeowners who score high on the index take actions to more effectively seal their homes against air infiltration—or is just a spurious correlation. The conservation-orientation index is not correlated with the frequency with which homeowners report caulking and weatherstripping their homes, but those activities only partly affect air leakage in homes.

Figure 15: Distribution of conservation-orientation index

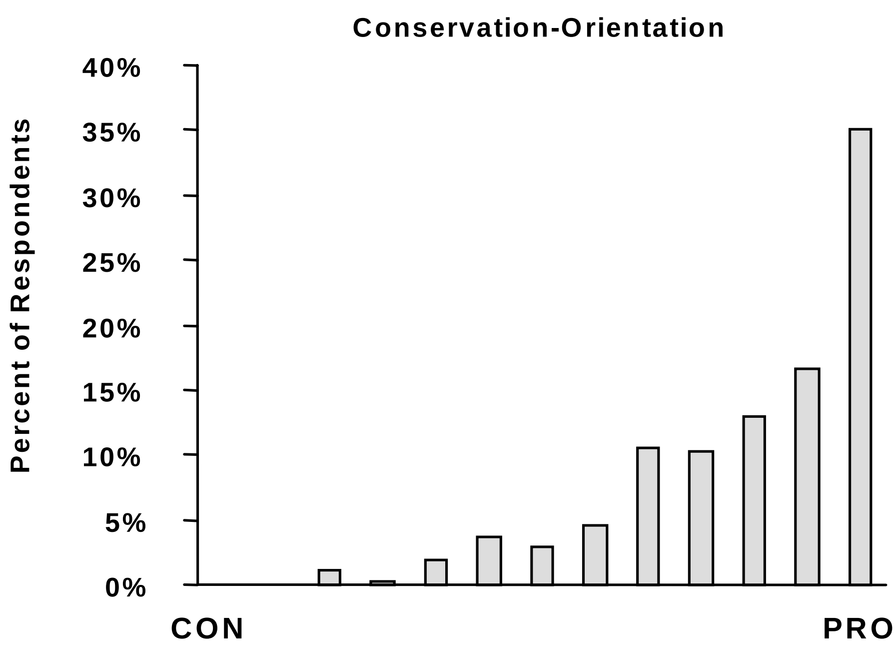
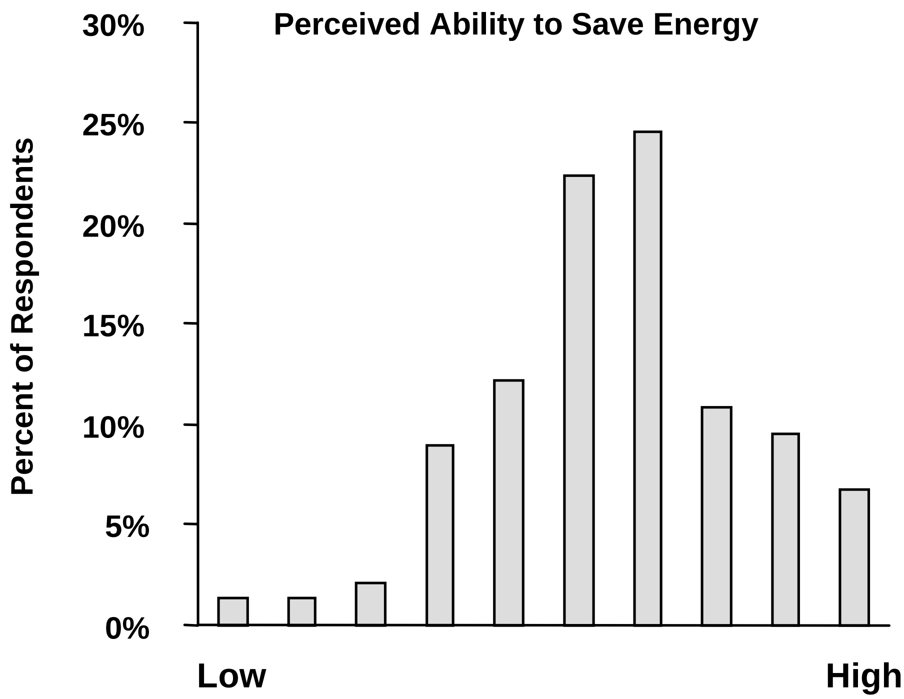


Figure 16: Distribution of index of perceived ability to save energy



We also used homeowners' responses to three other statements to create an index of respondents' perceived ability to save energy. The statements that went into this index are:

- "I only use electricity when it's really needed; there's no way I could cut down."
- "There's nothing more I can do to cut back on my home's energy use."
- "My energy bills are about as low as they can get."

The distribution of this index (Figure 16) shows that most homeowners fall between the two extremes. We found that older respondents perceive their homes as having less opportunity to make energy-saving changes. Conversely, more educated respondents perceive more opportunity. This could be because those who are more educated are more aware of opportunities, but the high correlation between education and income in our sample may also indicate that highly educated respondents perceive their households as having more opportunity to make energy-saving changes because they are able to consider spending more to do so. Similarly, low-income homeowners in the sample scored lower than others on this index, though the difference is not statistically significant.

For the most part, there is no correlation between homeowners' score on this index and either the total savings potential that we estimated for the home for our dozen measures or the likelihood of any individual opportunity being present. This may be because the wording of the statements that go into the index do not clearly distinguish between behaviors that people might engage in as part of their everyday routines (such as turning out lights in empty rooms) versus actions that they might take for the purpose of saving energy (such as adding insulation). It is only the latter that are represented in the measures we defined.

A notable exception to this lack of correlation is the opportunity for retrofitting lights with CFLs. People who perceive more opportunities to save energy in the home have a higher prevalence of CFL retrofit opportunities.

Finally, and not surprisingly, the attitude data also showed clearly that low-income homeowners are much more inclined to view their energy bills as a financial hardship compared to other households.

Energy Conservation Behavior

We look first (and in the most detail) at how homeowners report managing their thermostats, as this is the single action that probably has the most effect on home energy use. We follow this with a look at other behaviors that people regularly engage in—and actions they report having taken—to save energy.

Thermostat Behavior and Programmable Thermostats

Because heating is the single largest end-use of energy in most Wisconsin homes, how people manage their thermostats in the winter is an important lifestyle factor for household energy use. A widely used rule of thumb is that over the course of a heating season keeping the thermostat set lower saves three percent for each degree the thermostat is turned down. Similarly, setting the thermostat back for an eight-hour period each day is predicted to save one percent for each degree of setback.

In our questionnaire, we asked homeowners to provide information about the temperature at which they set their thermostats during sleeping hours, during the day when someone was home, and during the day when no one was home. Combined with information about the hours per week that someone was home, we calculated an estimated average winter setpoint temperature (Table 8). The results show a 15 F^o range across houses, from 59 ^oF to 74 ^oF, with an average of 68 ^oF.

Moreover, we found that our estimated average setpoint was highly correlated with the observed heating energy intensity for the 147 gas-heated homes for which we had good ability to isolate heating usage from monthly gas usage data (Appendix B). After controlling for differences across houses in insulation levels and air leakage, our model suggests that each degree in the thermostat setpoint is associated with an average 0.18 ± 0.11 Btu/ft^2/HDD difference in heating energy intensity. This is about $2.5 \pm 1.6\%$ of the average heating energy intensity of this group of homes, so the results are generally in line with the above rule of thumb. Applied to the 15 F^o range of calculated average setpoints, this finding implies that differences in people's preferred thermostat setting can create almost a 40 percent difference in annual heating energy use based on their preferences for indoor temperature

We mentioned above that the average thermostat setpoint is significantly correlated with our index of conservation orientation. Homeowners with high scores on this index have lower average thermostat settings during all periods of the day compared with homeowners with low scores. It appears that people's attitudes about energy do translate into action at the thermostat in a way that makes for a real difference in heating energy use.

But what about programmable thermostats, which have been promoted for years as a way to save energy by automatically setting back the thermostat at night or when the home is unoccupied during the day? From questions posed as part of ECW's Appliance Sales Tracking surveys in 1995, 1997 and 1999, we know that the proportion of homeowners who report having a programmable thermostat has risen at an average rate of about 2.5 percent per year. About a third of the homes that participated in the study have programmable thermostats, and most (82 percent) of these homeowners report using the programmable features of the thermostat.

Indeed, based on the reported thermostat settings during different times of the day, households with programmable thermostats are more likely to report setbacks at night and when no one is home (Table 8). But these households also report slightly *higher* settings during the day when someone is home, which occurs over half of the time on average (though this difference by itself is not statistically significant in our data). The result is virtually no difference between the two groups in our calculated average setpoint.

After accounting for differences in insulation levels and air leakage, homes with programmable thermostats in our sample have 2.5% lower heating energy intensity than homes with manual thermostats—but the statistical uncertainty associated with this figure is on the order of ± 7 percentage points (Appendix B). This suggests that the aggregate effect of programmable thermostats is unlikely to be more than ten percent. Even this range may be high, because we know that households with programmable thermostats in our sample are more likely to report using the programmable features (82%) than similar households that responded to the last two Appliance Sales Tracking surveys (75%).

Overall, these findings indicate that people with attitudes in favor of conserving energy will tend to do so at the thermostat regardless of whether it is manual or programmable, and people who are not so inclined will not use programmable thermostats to save energy even if they have one in the home. Though this seems like common sense, the implicit assumption behind savings estimates for setback thermostats is often that the homeowner who installs one was not doing any thermostat management prior to installing the thermostat. This is unlikely to be the case.

Table 8: Thermostat settings by type of thermostat

	n	Manual thermostat	Programmable thermostat
		(percent)	
Type of thermostat used	297	67	33
Mean reported temperature during . . .		*(degrees F)*	
Sleeping hours	281	66.9	65.7*
When someone is awake at home	287	68.7	69.4*
When no one was home during the day	268	66.4	65.8
When the household was away on vacation	198	61.2	60.9
Self-reported thermostat setpoint (weighted for weekday hours house is occupied; excluding vacation settings)	249	67.8	67.7
Mean hours someone is at home weekdays between 8 a.m. and 5 p.m.	261	28.9	28.1

† Two households without thermostats are not included in the percentages reported on this table.

* p<.05

Table 9: Thermostat setbacks by type of thermostat

	Manual	Programmable
Night setback practices (n=278)		
Set up	6%	1%
No change	50%	17%
Setback 1-4 degrees	22%	47%
Setback 5+ degrees	22%	34%
Day setback practices (n=269)		
Set up	<1%	1%
No change	53%	27%
Setback 1-4 degrees	21%	40%
Setback 5+ degrees	26%	32%

Furthermore, the savings potential from encouraging more homeowners to install programmable thermostats appears to be low. Of the 19 homeowners with manual thermostats who participated in more detailed interviews, 14 had no interest in installing a programmable thermostat, and only two homeowners expressed an interest in programmable thermostats (the subject did not come up for the remaining three). Of the two interested homeowners, only one might actually save energy from the thermostat; the other homeowner already set back manually, and was just interested in the convenience of having it done automatically.

A few quotations from the interviews help to explain why so few of our study subjects were interested in installing a programmable thermostat. Several respondents offered rationales similar to this one: “My uncle put one in his house, and he said he didn’t even notice the difference on his bills. . . . Why let the house cool down only to have to burn [extra fuel] in the morning to warm the house back up to comfortable again?” A few expressed concerns over the well-being of pets: “We’d put [the thermostat setting] down lower, except we have a cat and a dog, and we figured well, you can’t put it down too low, you have to keep the animals comfortable, too.” The following exchange, which we had with one respondent regarding an audit recommendation to install a programmable thermostat, illustrates a reaction that was common among respondents.

> Respondent: “Why would that help us? . . . As a matter of fact, when you say how much it would save us a year—how much was that?”
>
> Interviewer: “Ten dollars a year.”
>
> Respondent: “Yeah, for $10 a year . . . and how much would it cost?”
>
> Interviewer: “$110.”
>
> Respondent: “So it would take us 11 years to pay that. I’ll use my hand.”

Other Energy-Saving Behaviors and Actions

On the questionnaire, respondents were asked to tell us the frequency with which they engage in a variety of energy saving actions (such as turning out unused lights) and why they engage in these activities. We also asked them whether they had installed any of a number of energy-saving features (such as insulation or low-flow showerheads) in their homes.

The data indicate that most homeowners report engaging in the lifestyle-related activities a high proportion of the time (Figure 17). We have no way to confirm the veracity of these reports, but it is notable that respondents reported the highest rates of participation in the energy-saving behaviors that involve the least sacrifice of comfort or convenience. For example, more than 90 percent of respondents reported turning off unused lights, while fewer than 60 percent reported lowering the heating thermostat at night and 66 percent reported limiting the use of the air conditioning to very hot days with such frequency.

Homeowners report very high rates of turning out unused lights and turning off unwatched TVs. The responses to a later item on the questionnaire suggest that the reasons for the high rates of turning off the lights and unwatched TVs might also stem from a perception that turning off these devices saves a lot of energy. Here respondents were asked to tell us in their own words what would be the most effective thing they could do to save energy in their homes. About 16 percent of respondents offered some variation of "turn off lights or appliances"—about the same proportion of homeowners who responded "turn down the thermostat." Some homeowners thus appear to believe that managing their lights and appliances saves them a significant amount of energy.

Respondents report having installed energy-saving features since moving into their homes at considerably lower rates than they report engaging in energy-saving behaviors, but nonetheless a substantial proportion of households report taking various actions to save energy (Figure 18).

We asked respondents to choose the top three reasons for engaging in energy savings behaviors or taking energy saving actions from among the following five categories:

1. Home comfort
2. Health and air quality
3. Save money
4. Help the environment
5. Don't like to waste

"Save money" and "don't like to waste" are what came up most frequently on most peoples' lists (Figure 19), though home comfort is associated with behaviors and actions related to heating and cooling homes. When asked to choose the primary reason for these behaviors and actions, "saving money" clearly dominates among all of the behaviors, typically accounting for 50 to 60 percent of responses. For actions that affect the building shell such as caulking and weatherstripping or adding insulation, "home comfort" and "save money" account for about the same proportion of responses each (typically 40 to 45 percent).

The message seems clear: saving money on energy bills is the primary reason that people engage in activities to save energy, except when it comes to actions that people take to improve the thermal performance of their homes, where comfort considerations take on equal weight.

Figure 17: Reported frequency of energy saving behaviors

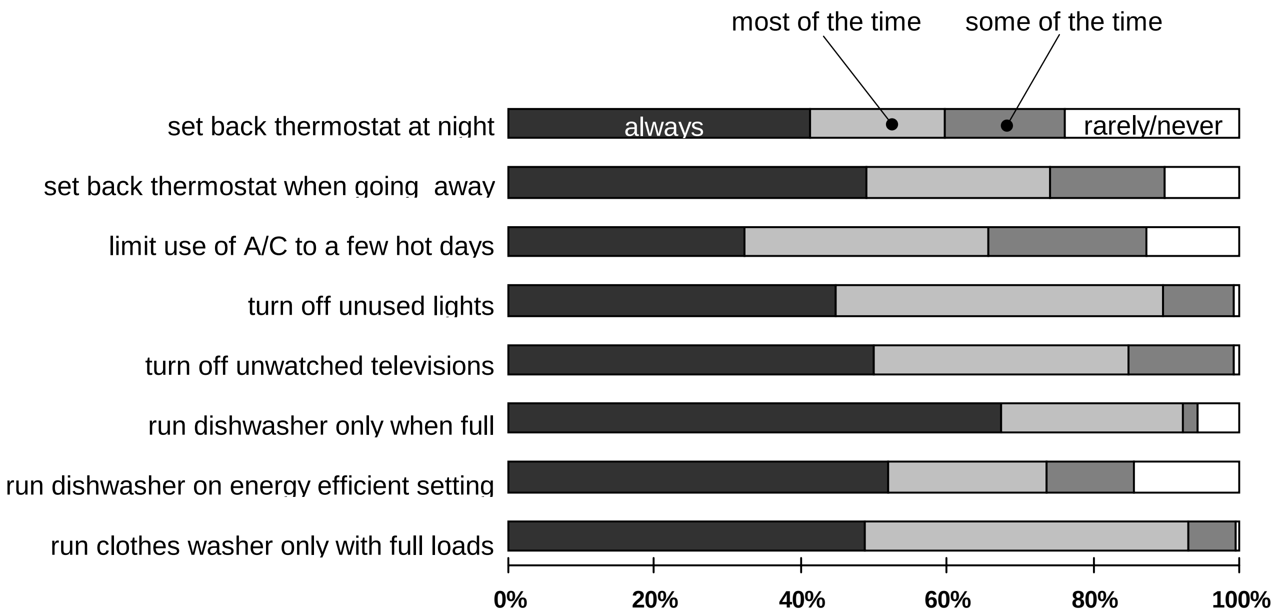


Figure 18: Reported frequency of energy-saving actions

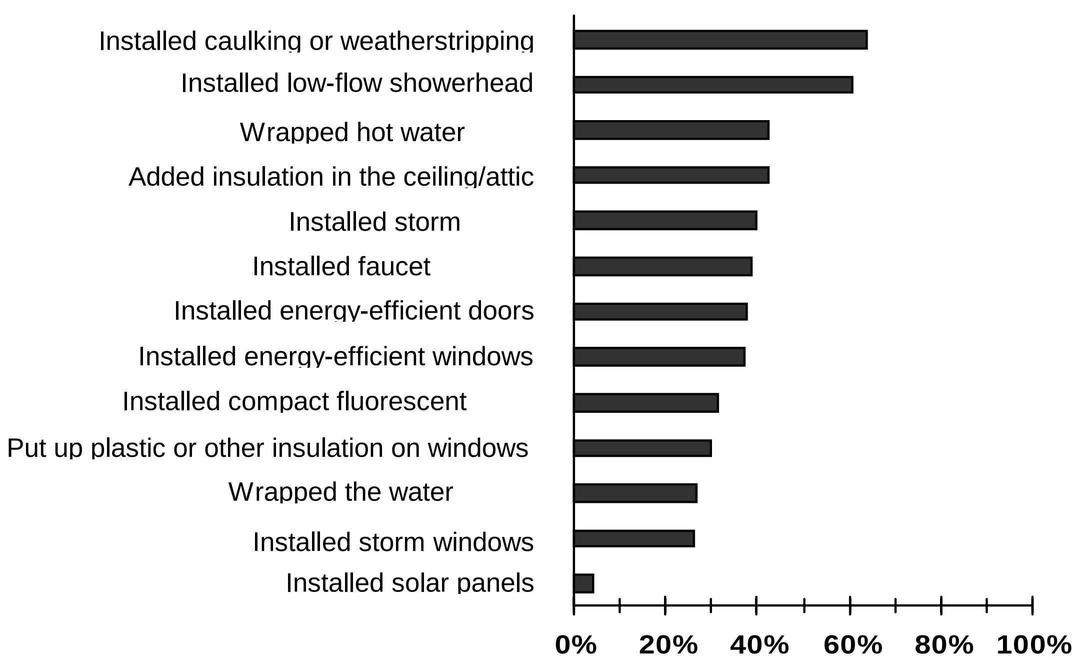
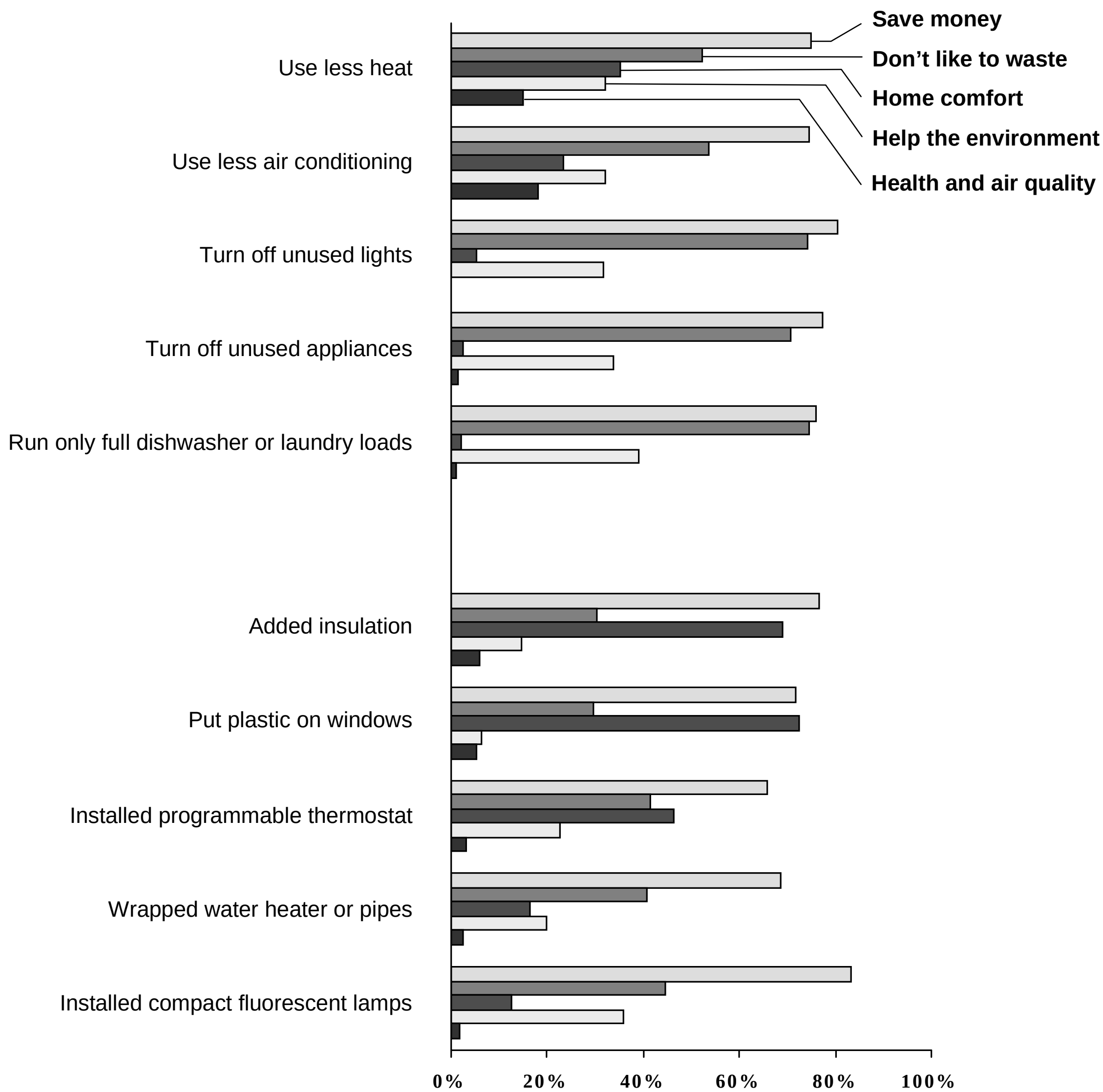


Figure 19: Stated reasons for energy-saving behaviors or selected actions



(Respondents allowed to circle up to three of the five categories for each behavior or action)

Perceptions of Savings Opportunities

We asked the survey respondents to tell us how much they thought they could reduce the amount of energy used in their homes by changing behavior and by investing in energy-efficient technologies, respectively. The means of the answers to the two questions are nearly identical: on average, respondents think they can save 11 percent by developing more energy efficient practices, and 12 percent by investing in more efficient technologies. For both questions about a quarter of respondents answered “five percent” or “ten percent” each, so these two responses alone make up about half of the total.

A small proportion of households (fewer than 10 percent) said that they could not reduce their energy use at all in these ways. However, about a quarter of low-income respondents gave this response. These homeowners may feel they’re already doing everything they can lifestyle-wise to conserve energy, and cannot afford to invest in home improvements to save energy. In either case, the results here mesh with our earlier finding of lower perceived ability to save energy among low-income households.

Measures Perceived to be Effective

We also asked homeowners "What is the most effective thing you could do to save energy in your home?" as an open-ended question. The results are shown in Table 10. Despite the fact that respondents could interpret the word “effective” in different ways (e.g, “biggest energy savings” or “most cost-effective energy savings”), it is striking that the most often cited response was to improve or replace windows or doors—a step that most energy efficiency professionals do not consider to provide substantial or cost-effective energy savings. We suspect that the reason respondents think that this is an effective energy-saving measure is that leaky windows and doors are among the most *noticeable* areas of heat loss from the home, particularly when they are near locations where people tend to congregate. Half of the homeowners who gave us this answer also specifically cited leaky windows or doors as a problem on an open-ended question in the comfort section of the questionnaire (compared to 15 percent of all respondents). It is noteworthy that these same homeowners were nearly three times more likely than the rest of the study sample to have substantially uninsulated walls.

At the same time, reducing air leakage in general does not seem to be in the forefront of most homeowners’ minds. Though we estimate that nearly a quarter of homes have significant infiltration reduction opportunities, this was volunteered as the most effective thing they could do to save energy by only six percent of respondents, most of whose homes did not show high air leakage at the time of the audit. An example of this lack of awareness regarding the impact of reducing air leakage comes from a family with high measured air leakage: “[My husband] put . . .on [plastic over the windows]. . .one year and we just hated it . . . we took them down. . . . They’d billow with the wind, and it’s just not nice.”

The 39 homeowners (14 percent) who said that adding insulation was the most effective thing they could do to save energy were indeed about four times more likely than other homeowners to have substantially uninsulated wall or ceiling areas in the on-site audit. When asked on the follow-up question “What are the reasons you haven’t done this?” about half said something along the lines that they could not afford it, or it was too costly—a response that was nearly universal for the low-income households in this group.

Table 10: Responses to "What is the most effective thing you could do to save energy in your home?"

	Overall (n=272)	General (n=190)	Low income (n=40)	New construction (n=42)
Improve/replace windows or doors	**22%** ± 5	23% ± 6	27% ± 12	11% ± 12
Turn off lights/appliances	**16%** ± 4	14% ± 5	25% ± 13	22% ± 12
Turn down thermostat	**14%** ± 5	14% ± 5	4% ± 5	28% ± 13
Insulate	**14%** ± 4	14% ± 5	23% ± 10	3% ± 5
Install more efficient lighting	**9%** ± 3	8% ± 4	7% ± 7	17% ± 11
Replace appliances	**8%** ± 4	10% ± 5	4% ± 5	0%
Reduce infiltration	**6%** ± 2	5% ± 3	9% ± 6	13% ± 10
Make physical changes to water heater	**4%** ± 3	5% ± 4	0%	2% ± 4
Switch fuel source of an appliance or use renewables	**3%** ± 2	3% ± 2	3% ± 4	3% ± 5
Abandon/reduce use of appliances	**2%** ± 2	2% ± 2	2% ± 3	3% ± 4
Change behavior to use less hot water	**2%** ± 2	2% ± 2	2% ± 3	2% ± 3
Other	**3%** ± 2	3% ± 2	2% ± 3	5% ± 6
Can't do anything more	**6%** ± 6	6% ± 7	5% ± 6	6% ± 7
Don't know what to do	**6%** ± 2	6% ± 3	8% ± 5	3% ± 5

Question was asked open-ended and was back-coded

Since respondents were allowed to give more than one answer, totals may exceed 100 percent.

Reactions of Interview Households to Audit Recommendations

Eighteen of the 30 households that were sampled for depth interviews had been recommended shell measures (wall or ceiling insulation, or infiltration reduction). The transcripts of the interviews with these households suggest that homeowners with shell opportunities can be roughly divided equally into three groups:

1. already aware of the opportunity, and planning to pursue it
2. not previously aware, but not interested in pursuing the opportunity
3. not previously aware, and interested in pursuing

Two of the households that were not interested in pursuing a shell measure were responding to a recommendation to increase the amount of attic insulation (from R-6 in one case, and R-19 in the other). Both of these households stated that their attics were already insulated, and didn't see any need to add additional insulation. One of these households was also low-income, and said they didn't have the money to do anything about it anyway. Two households did not believe the savings estimates for reducing air leakage; one of these households had just spent $11,000 replacing windows and did not see how their house could be that leaky (the blower door data for this home suggest 0.55 natural air changes per hour of air infiltration).

Responses from households that were not previously aware of shell opportunities, but were interested in pursuing them included: one low-income owner of a mobile home who had not thought about the need for controlling air leakage (this home had 0.75 estimated natural air changes per hour of air infiltration); two homeowners who did not know that their walls or ceilings had uninsulated areas; and one homeowner who did not know that it was possible to add insulation to existing walls.

Energy and Comfort

We developed scales of self-reported winter and summer comfort based on the responses to several of the questions on the questionnaire addressing the comfort of the home in winter and summer. In this section, we discuss the most important associations between home comfort and the rest of our data. For a more detailed look at all of the associations, and an explanation of how we assigned values to winter and summer comfort, see Appendix B.

Winter Comfort

Based on what homeowners said about how often their homes were too cold or drafty in the winter, we divided the sample into three groups:

(1) homeowners who said they rarely or never had problems being too cold or drafty in the winter (42 percent);

(2) homeowners who reported occasional problems (53 percent); and

(3) homeowners who said their homes were too cold or drafty most of the time (5 percent).

To further differentiate the more than half of homeowners who reported occasional problems with winter comfort, we subdivided this group into homeowners who volunteered specific information about winter comfort problems on a separate open-ended question (35 percent of all respondents), and those who did not (18 percent), creating a four-point winter comfort scale (Table 11).

In general, low-income homeowners appear to be more likely to have serious comfort issues with their homes, and less likely to have no comfort problems. This finding holds even after controlling for the fact that the low-income group has a higher proportion of elderly people than the rest of the population. Owners of new homes are the most likely to rarely or never feel their homes are too cold or drafty; however, it is noteworthy that nearly half report occasional comfort problems, and about 13 percent have some specific complaint.

Table 11: Prevalence of comfort problems

		Overall (n=296)	General (n=209)	Low income (n=43)	New construction (n=44)
Home is too cold/drafty during the winter…					
Rarely/never		42% ± 6	42% ± 7	32% ± 16	52% ± 12
Sometimes	specific complaint	18% ± 3	19% ± 3	18% ± 15	13% ± 9
	no specific complaint	35% ± 7	36% ± 8	33% ± 12	35% ± 14
Most/all the time		5% ± 2	3% ± 2	17% ± 7	0%
Home is too hot/humid during the summer…					
Rarely/never		28% ± 7	26% ± 8	28% ± 8	42% ± 19
Sometimes		65% ± 6	67% ± 7	58% ± 12	54% ± 17
Most/all the time		8% ± 2	7% ± 3	14% ± 13	4% ± 6

Table 12: Summer comfort versus air conditioning type

	No air conditioning (n=77)	Room air conditioning (n=59)	Central air conditioning (n=152)
Home is too hot/humid during the summer…			
Rarely/never	24% ± 8	17% ± 10	33% ± 11
Sometimes	68% ± 9	72% ± 13	60% ± 10
Most/all the time	8% ± 5	11% ± 9	6% ± 4

Those respondents who told us that particular places in the house were too cold or drafty in the winter cited specific rooms or areas in the house with the greatest frequency (60 percent), followed by areas near doors or windows (28 percent), and in the basement (7 percent). Those respondents who told us that they found the house cold or drafty at certain times mentioned windy periods first (14 percent), followed by cold periods (5 percent).

Winter comfort problems do appear to be correlated with shell efficiency opportunities, but for our sample the differences are statistically significant only for the small proportion of households that experience substantial comfort problems (Figure 20). This group of homeowners (16 respondents) was much more likely to have high air leakage or have substantial uninsulated areas in the home. The two homes with the highest measured air leakage (in air changes per hour) fell into this group, and more than a third of these homes were in the highest 5 percent of measured air leakage for the sample. Moreover, half of the homes in this group had uninsulated walls. Low-income homeowners make up about 40 percent of this group, suggesting that many of these homeowners do not have the resources to remedy their comfort problems.

Respondents who believe that their houses are adequately- or well-insulated report that their homes are more comfortable in the winter than those who believe that their houses are not adequately insulated. In addition, respondents who plan to carry out major remodeling projects in their homes in the next two years report being less comfortable in the winter than do those who do not have remodeling plans. This finding offers further evidence of the importance of home comfort in respondents' decisions to make energy-saving changes to their dwellings.

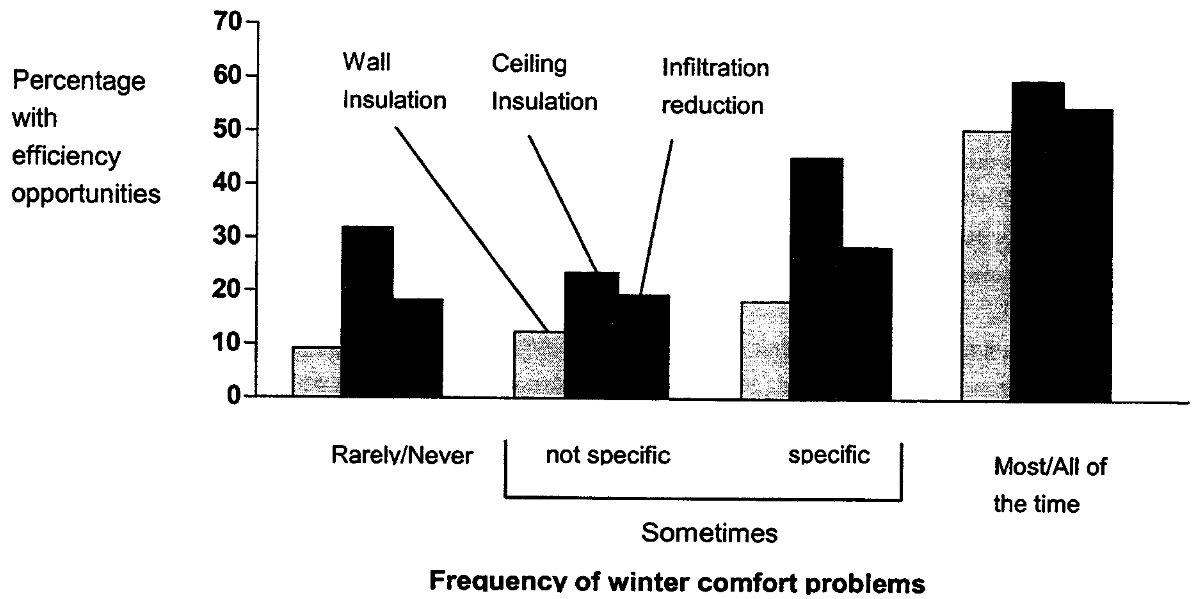
At the same time, not all comfort problems may be based in the structure of the home itself: there is a strong relationship between winter comfort and the level of agreement within the family about what is an appropriate winter thermostat setting. Families who are more frequently in agreement report that their homes are more comfortable than those who report disagreement about the most comfortable thermostat setting. This illustrates the problematic nature of trying to measure home comfort—it is inherently subjective. What is comfortable to one person may be chilly to another, or stifling to a third. Circumstances—such as reliance on a woodstove for heat—that may seem natural and comfortable to those who are used to them can seem inconvenient and uncomfortable to those who are not.

Summer Comfort

In a similar vein as our analysis of winter comfort, we created a scale for summer comfort based on what homeowners said about how often their homes were too hot or humid in the summer (see Appendix B). We divided the sample into three groups: (1) homeowners who said they rarely or never had problems being too hot or humid in the summer; (2) homeowners who reported occasional problems; and (3) homeowners who said their homes were too hot or humid most of the time. As Table 12 shows, the majority fall into the middle category. The correlation between winter and summer comfort is statistically significant, indicating that respondents who are more comfortable in the summer are also likely to be more comfortable in the winter.

Reported summer comfort does not appear to be a strong function of the presence or type of air conditioning in the home (Table 12). Homeowners in our sample with central air conditioning were somewhat less likely to report summer comfort problems, and those with room air conditioners were the most likely to report being too hot or humid, but the differences are not large, and the type of air conditioning present in the home is probably correlated with other structural factors that come into play (more new homes have central systems, and more low-income homes have room air conditioners).

Figure 20: Winter comfort versus shell opportunities



Low-income Housing

The preceding discussion of findings from the study notes a number of differences between low-income homeowners and others. We summarize these findings here.

Owner-occupied, low-income homes are 16 percent smaller on average than other homes, but they require more energy per square foot for heating. As a result, overall energy bills for low-income homeowners are about the same as for the general population. Of course, because these households are (by definition) low-income, energy costs represent a higher percent of income than other households. We estimate that the median low-income homeowner spends seven to ten percent of household income on energy costs, compared to two to three percent for all households. This difference in "energy burden" is reflected in responses to questions on our survey designed to measure the perceived need to conserve energy; low-income homeowners are much more likely to agree with statements such as "I have to conserve energy in my home because I can't afford to pay higher utility bills."

Low-income homes are about twice as likely as the general population to have underinsulated ceilings or high air leakage, and are somewhat more likely to have uninsulated walls. This is partly a consequence of the fact that low-income homeowners are more likely to be living in older homes that have a higher incidence of these building-shell defects. That these households are less likely to have the resources to address these deficiencies no doubt also plays a role.

The difference in measured air leakage between low-income homes and other homes is one of the more striking findings from this study. Though smaller on average, low-income homes leak about 20 percent more cubic feet per minute of air than the overall average. When expressed in terms of air changes per hour, low-income homes have 60 percent higher air leakage than other homes. Since winter comfort is affected by draftiness, it is no surprise that low-income homeowners are more likely to report persistent comfort problems with their homes.

At the same time, low-income homes in the scope of this study are not significantly more likely to have an energy efficiency opportunity with the heating system, water heater, refrigerator, or lighting. In contrast to energy defects in the building shell, which can be deferred indefinitely, heating systems, water heaters, and refrigerators all break down and must be replaced. Because of this, it appears that low-income homes tend to keep closer pace with the rest of the population in terms of the energy efficiency of mechanical systems and appliances such as refrigerators.

Overall, the median low-income home could save $132 per year on energy with an investment of about $700 in the measures that we defined. These savings are about 2.5 times higher than the median for all homes.

At the same time, we found that low-income homeowners perceive fewer opportunities to save energy than other homeowners. This may be because the main opportunities in low-income homes are the more expensive building shell measures that are out of reach financially for these homeowners

New Construction

As with low-income households, we summarize here results for new homes. While our strict definition of new construction applies only to homes built in the last five years, these findings appear to be applicable to most homes built in the last two decades.

Based on our sample of Wisconsin single-family homes, new homes use about the same amount of energy as older homes, with annual energy costs that average about $1400. Though new homes are 23 percent more efficient to heat per square foot, they are also larger by about the same percentage. Annual heating bills for new homes are thus about the same as for older homes. The experience of one of our respondents who lives in a house built in 1994 provides an illustration of this phenomenon: “We have found that we don’t pay any more for this house than we did for our little three bedroom ranch house three houses down, as far as energy. . . . That was barely 1,200 [square] feet; this is like 2,200.”

Because of state energy codes that date back to 1978, new homes are generally well insulated—though we would caution that our study did not include a detailed assessment of the quality of the insulation installation (see study limitations). In addition, though the state code does not have maximum air leakage requirements, new homes are generally tighter than older homes. It is noteworthy, though, that four of the 44 new homes in our sample (nine percent) had excessive air leakage by our definition.

Owners of new homes are about as likely as others to report occasional comfort issues with their homes during the winter, though slightly more owners of new homes in our sample reported having no problems with winter comfort, and none of the owners of new homes reported persistent winter comfort problems.

The two main energy efficiency opportunities for new homes appear to be water heater temperature reduction, and retrofitting lights with CFLs. The new homes in the sample had a somewhat higher than average prevalence of hot water temperatures that exceeded 135°F (29 percent), and also had slightly more opportunities for retrofitting incandescent lamps with CFLs (83 percent).

Conclusions

Most Wisconsin homeowners profess very favorable attitudes toward conserving energy and using it efficiently. We found that these attitudes do translate into energy-conserving behavior at the thermostat in a way that results in observable differences from home to home in heating energy use. Similarly, most homeowners tell us that they are careful to use their lights and appliances in ways that do not waste energy unnecessarily. The main motivation for these behaviors is frugality.

Yet frugality and attitudes in favor of conserving energy are not as powerful motivators when it comes to aspects of managing energy use that require a more substantial investment of time and money. People with favorable attitudes toward energy conservation and efficiency are just as likely as others to lack adequate wall or ceiling insulation. This is an important finding, since we estimate that a substantial proportion of the total energy savings opportunities to consumers in the state are in addressing shell measures in older homes. Wall insulation, ceiling insulation and air infiltration opportunities occur in about two-thirds of homes built prior to the 1960s, and account for more than half of the total energy cost savings that we identified. In general, the older the home, the more likely it is to be underinsulated or have high air leakage.

But while home appliances, furnaces and water heaters eventually break down and need to be replaced, shell defects can go unaddressed for decades. Moreover, these defects are largely hidden away inside walls or in attics. Though some homeowners with shell opportunities know about them and just haven't gotten around to dealing with them yet, the survey and interview data suggest that a majority of these households (perhaps two-thirds to three-quarters) are unaware of these opportunities. Perhaps half of these homeowners express interest in making improvements once they are pointed out.

On their own, though, people are more likely to point to windows and doors as their most significant heat loss problem, probably because these are the most noticeable. This all suggests that advertising and materials to promote shell retrofits should feature discussion of "hidden" opportunities in air leaks and missing insulation and how common these are in older homes.

The composition of our study sample suggests that people who have plans to remodel their homes are more interested than average in what can be done to save energy. To a lesser extent, the same appears to be true of people who have only recently moved into a home. It would be wise for programs to promote building shell improvements to identify channels to target these groups. A wall insulation job that would take considerable initiative on the part of a homeowner to arrange in isolation might be just a minor part of a large remodeling project.

Improving comfort is a motivating factor in adding insulation or reducing air leakage in homes. Homeowners with these opportunities are more likely to report specific winter comfort issues with their homes, and homeowners who have taken steps to improve insulation levels in the past report home comfort as an important driving force. But only a small minority of homeowners report that their homes are too cold or drafty most or all of the time, and many of these are low-income households that do not have the financial resources to address these problems. In addition, 30 percent of homeowners with major shell opportunities by our definition said they experience no winter comfort problems at all in their homes.

Home energy ratings can provide useful information to homeowners about shell opportunities, but we found that on average, the rating software used in Wisconsin overestimates the amount of heating energy used in homes, particularly homes that are inefficient. Consequently, savings estimates for insulating such homes will be overstated. We recommend an effort to adjust the rating procedures so that heating and cooling use estimates that are accurate on average. This might include simply creating new definitions for uninsulated areas that increase the effective R-value of these areas to R-5 or so. In any event, the ratings and estimates of heating energy use should be taken as rough approximations only. We provide some more detailed recommendations in this regard in Appendix B.

Low-income homeowners are much more likely than others to have shell opportunities, and have generally higher heating energy use per square foot. These households are also more likely to report comfort problems during the winter. At the same time, these homeowners are less likely to perceive energy saving opportunities in their homes. Though single-family homeowners make up a minority of low-income households (most are renters), these findings indicate a continued need for programs to address energy use in low-income homes.

Home lighting remains a largely untapped energy efficiency resource in Wisconsin. The saturation of compact fluorescent lighting remains low in Wisconsin homes, despite years of promotional efforts. Yet the pervasiveness of lighting that could be cost-effectively retrofitted with CFLs in Wisconsin homes suggests the need for continued efforts to promote these products. Future programs to increase the market share of CFLs in the state should in part project the message “These are not the CFLs you tried before.” This is needed to overcome the negative perceptions held by some of the one-third of homeowners who have already tried CFLs and found them to be wanting. Of course such a message would only compound existing negative perceptions of CFLs if it is not paired with continued efforts to make a variety of high-quality CFLs more widely available, and provide good application guidelines for consumers.

More than half of Wisconsin homeowners already have a high efficiency furnace, and most of the standard efficiency furnaces either use oil or are not old enough to warrant replacement. Moreover, market tracking data from other ECW studies indicate that most new furnace sales are high efficiency models, though these data also indicate that regional differences in market share exist. We recommend that this market continue to be monitored.

The percentage of homes that could replace an electric water heater with a fuel-fired one is small, but the savings are substantial and the payback attractive. Moreover, it appears that most of these homeowners do not convert when they replace their water heater. This suggests the opportunity for program efforts in this area. These efforts are most likely to be cost effective if natural gas use records can be used to target candidate households.

Promoting programmable thermostats does not appear to offer much potential for energy savings in Wisconsin. A third of homeowners already have a programmable thermostat, and the majority of homeowners with manual thermostats already practice setbacks. And most homeowners who do not already practice setbacks are not inclined to do so.

Finally, this would not be a true research report if it did not recommend more research. Since this study focused on the roughly 70 percent of Wisconsin households that are owner-occupied, additional investigation is needed to understand energy use in the 30 percent of households that are rental units. Understanding the energy-using characteristics of these homes is particularly important for understanding energy use in low-income households.

Study Limitations

We feel that this study provides a meaningful portrait of energy use in Wisconsin homes. Nonetheless, it is also important to recognize the limitations of the data:

- The study is limited in scope to single-family, owner occupied homes in the state. Though these make up the majority of Wisconsin households, nearly a third of households are outside the scope of the study. This is an especially important point when considering the low-income subgroup findings from the study: homeowners are a distinct minority of low-income households.

- The study sample appears to be reasonably representative of the population from which it was drawn, but it is not perfectly representative. In particular, the sample probably somewhat over-represents households that are interested in energy, and under-represents households that cannot make (or are not interested in making) the time for an energy audit, despite our generous incentives. We examined the study sample in detail in this regard (see Appendix A). Our conclusion is that these biases should be kept in mind when interpreting the results, but they do not threaten any of the fundamental findings.

- Some of the data in the study are based on auditor judgements, and some are self-reported by the participating homeowners. Auditors could not verify insulation levels in all cases (particularly walls and cathedral ceiling spaces), and heating system and water heater efficiency levels are based on the estimated age of the system in some cases (specifics about the proportion of various data elements that were based on estimates are provided in footnotes to the tables in the data book in Volume 2).

- Budget and on-site time constraints limited the kinds of data that we could gather. For example, we were not able to conduct measurements of duct leakage or assess distribution system imbalances, measure the combustion efficiency of heating systems, or make infrared scans for insulation voids. In general, while we were able to collect data in most of the important elements related to energy use in the study homes, we were limited in our ability to assess how these fit together as a system

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Appendix A — Study Design

Scope

The scope of this study includes single-family, owner-occupied households, which represents about two-thirds of Wisconsin households, as shown in Table A1. We estimate that 1.4 million Wisconsin households fall within the scope of the study.

Table A1: Distribution of Wisconsin households by type of structure and tenure

Type	Own	Rent	Total
SF detached	58.6%	6.7%	65.3%
SF attached	1.1%	1.4%	2.5%
Mobile Home/trailer	3.1%	0.6%	3.7%
2 unit	2.6%	7.7%	10.2%
3-4 unit	0.3%	3.7%	4.0%
5-9 unit	0.2%	4.0%	4.2%
10-19 unit	0.1%	3.3%	3.4%
20 to 49 unit	0.1%	3.2%	3.4%
50+ unit	0.1%	2.1%	2.2%
other	0.5%	0.6%	1.1%
Total	66.7%	33.3%	100.0%

within the study scope (shaded)	62.8%
not within the study scope (not shaded)	36.2%

Study Design

The study was conducted in two phases; a pilot phase to develop and refine the data collection instruments, and a subsequent full-scale effort to collect the bulk of the data.

Pilot Study

During the 1998/99 heating season, a 40 household pilot study was conducted to develop and refine the recruitment and data collection instruments and protocols. The sample for the pilot was allocated among three geographic areas:

Milwaukee metropolitan, Madison metropolitan, and rural Belleville in Dane county. For Milwaukee and Madison, a low-income segment was defined by identifying phone exchanges that overlapped census tracts with a high proportion of low-income households. Households outside the low-income segment in the City of Milwaukee and the City of Madison were also sampled. Finally, there was a Milwaukee County segment that excluded the City of Milwaukee.

The pilot was conducted in two phases. In the first phase, sampled households were recruited in February 1998 using a randomized incentive of $25 and $50. Twenty-one households were recruited and received site visits in this phase. Open-ended interviews were conducted with these households to use as the basis for designing a questionnaire for the second phase of the pilot. In the second phase, 19 households were recruited in May and June, 1998 using randomized incentives of $25 and $100. These households filled out a questionnaire that was developed between the two phases.

Based on the pilot results we:

1. decided to offer a cash incentive of $50 for the full-scale study, except for low-income or new construction households, which would be offered $100;

2. made some minor modifications to the on-site data collection instrument and protocol and the survey instrument;

3. abandoned the concept of targeting low-income households based on telephone exchanges; and,

4. sent the revised questionnaire to the 21 households in the first phase of the pilot (all but three were returned).

Full Scale Study

Recruitment and data collection for the full-scale version of the study occurred from January through June 1999, and was based on the stratified two-stage sampling plan (developed at the end of the pilot study), as described below.

First Stage

For the first stage of the sampling, the 72 counties in Wisconsin were ranked in descending order of the population of households within the scope of the study (based on 1990 census data), and grouped into eight strata as shown in Table A2. The first stratum contained the three largest counties in the state, representing the Milwaukee and Madison urban areas. The remaining strata were defined to contain roughly equal proportions of households within the scope of the study. Counties in the first two strata were sampled with certainty; for the remaining six strata, a simple random sample of two counties was drawn. One ad hoc substitution was made: in Stratum 5, Chippewa county was substituted for Sauk county to give the overall sample better representation in the northwestern part of the state.

Table A2: First stage sampling

Stratum	% of Eligible Households (1990 Census)	Counties (in descending order by population of eligible households)	Number of Counties	Number Sampled	Sampled Counties
1	27.65	Milwaukee, Waukesha, Dane	3	3	Milwaukee, Waukesha, Dane
2	13.49	Brown, Racine, Outagamie, Winnebago	4	4	Brown, Racine, Outagamie, Winnebago
3	8.28	Rock, Kenosha, Marathon	3	2	Rock, Kenosha
4	9.91	Sheboygan, Washington, Fond du Lac, La Crosse, Manitowoc	5	2	Washington, Manitowoc
5	10.94	Wood, Eau Claire, Dodge, Ozaukee, Walworth, Jefferson, Portage	7	2	Wood, Ozaukee
6	10.44	Chippewa, St. Croix, Waupaca, Sauk, Columbia, Grant, Marinette, Douglas, Barron, Shawano	10	2	Chippewa, Marinette
7	10.51	Polk, Oneida, Monroe, Oconto, Calumet, Clark, Dunn, Green, Pierce, Door, Lincoln, Vernon, Trempealeau, Juneau, Waushara	15	2	Calumet, Juneau
8	8.79	Langlade, Vilas, Iowa, Kewaunee, Green Lake, Taylor, Adams, Price, Richland, Jackson, Crawford, Ashland, Bayfield, Rusk, Burnett, Lafayette, Sawyer, Washburn, Marquette, Buffalo, Forest, Iron, Pepin, Florence, Menominee	25	2	Price, Crawford

Second Stage Sampling

The second stage of sampling comprised sampling households within the sampled counties via purchased random-digit dial telephone number lists. Second-stage sample targets for each county were established so that when combined with the 40 households from the pilot study, the sample would be roughly self-weighting across the strata. An overall sample size of 300 households (pilot plus full-scale) was established.

In addition, the full scale study targeted two subgroups for over-sampling: low income households and new construction. A low-income household was defined as being at or below 150% of the 1998 federal poverty guideline. A new construction household was defined as being built in 1994 or later. We established sample targets of 50 each for low-income and new construction households. Since each of these groups was thought to occur in about 10% of households within the study scope, these targets represented an oversample of about 20 households each.

To establish sampling targets for these subgroups across the county strata, we used data from the Center's 1997 Appliance Sales Tracking (AST) survey, for which demographic data including income and age of the home was collected on 2,383 households statewide that were within the scope of the study. (The nature of these data is discussed more fully later under "weighting.") The sample targets that resulted are shown in Table A3. The sample was allocated to individual counties within each stratum in proportion to relative population of each county.

Table A3: Second stage sampling targets

Stratum	General Population	Low Income	New Construction	Total
1	16 + 36 pilot = 52	5 + 2 pilot = 7	7 + 2 pilot = 9	68
2	28	9	8	45
3	16	4	4	24
4	22	4	7	33
5	24	6	5	35
6	21	5	4	30
7	21	9	10	40
8	16	6	3	25
Total	200	50	50	300

Recruiting

Recruiting was done with a computer aided telephone interviewing (CATI) system using a typical RDD protocol, which included evening and weekend calling, and a minimum of ten callbacks to numbers that were not answered or were busy. Recruiting was based on a script that was developed for the pilot study, and modified slightly for the full scale study. Table A4 shows the recruiting disposition from the full-scale study.

Table A4: Full-scale recruiting disposition

Within Study Scope?	Disposition	n	percent
no		1511	18.4%
	not a residence	744	9.1%
	not single-family	176	2.1%
	not owner-occupied	591	7.2%
unknown		4789	58.4%
	refused or terminated	2238	27.3%
	unable to contact	2483	30.3%
	language barrier	68	0.8%
yes		1892	23.1%
	terminated prior to recruitment	323	3.9%
	over-quota[a]	728	8.9%
	declined to participate	496	6.0%
	initially agreed but later cancelled	86	1.0%
	participated	259	3.2%
Total		8192	
recruitment script response rate[b]:			34.4%
recruitment rate[c]:			10.6%

[a]represents households that completed the recruitment script, but were not asked to participate because the sample quota was full.

[b]defined as recruitment script completions as a percent of sample points within the study scope (including proportional allocation of unknowns—55.6% in scope).

[c]defined as study participants as a percent of sample points within the scope of the study (including proportional allocation of unknowns). Assumes over-quota households would participate at same rate as other households (30.8%).

763 invalid telephone numbers, and 329 computer tone responses excluded from above.

Final Sample Size

Table A5 shows the final sample size for the study at the stratum level.

Table A5: Final study sample sizes by stratum.

Stratum	General Population	Low Income	New Construction	Total
1	56	3	8	67
2	32	9	6	47
3	16	4	5	25
4	23	6	6	35
5	25	1	4	30
6	19	8	4	31
7	24	6	9	39
8	17	6	2	25
Total	212	43	44	299

Case Weights

We developed case weights for each observation to make the final study sample as representative as possible of the overall eligible population. The weights represent the estimated number of households in the study population that each sampled household represents, and are the inverse of the probability of each house being sampled. The weights were based partly on the 1990 Census data, and partly on the Center's most recent Appliance Sales Tracking survey, which was conducted in July and August 1999. This large random-digit dial telephone survey collects demographic data on a sample of approximately 3,000 households in the course of identifying households that have recently purchased major appliances such as a refrigerator or water heater.

For the 1999 AST survey, we added some questions specifically intended to help assess the representativeness of this study sample (which we cover in more detail in the next section). We also made use of previous AST surveys to assess the stability of some of the variables over time. In all cases, the analysis was restricted to respondents who stated they: (a) owned their home; and, (b) lived in a single-family dwelling (attached or detached) or a mobile home or trailer. This reduced the available sample size to about 2,200 cases.

The case weights that we developed are the inverse of the product of three probabilities:

1. 1/(the probability of a county within a stratum being sampled), w_1
2. 1/(the probability of a household within a sampled county being sampled), w_2
3. 1/(the probability of a household in a specific subgroup (e.g., low-income, new construction) being sampled), w_3

The first probability is obtained from the study design, and is simply the number of counties sampled divided by the total number of counties in the stratum. This varies from 3/3 = 1 in Stratum 1 to 2/25 = 0.08 in Stratum 8.

The second probability is the number of study households in each sampled county divided by the total number of eligible households in the county, which we derived from the 1990 Census. These weights are shown in Table A6.

The third component of the weights adjusts for the over-sampling of low-income and new-construction households—and does a post hoc correction for one item (plans for remodeling) for which we observed a particular bias in the study. These weights were developed from the 1999 AST survey, as described below.

Table A6: Stage 2 sampling weights

Stratum	County	Population[a]	Study n	weight (w_2)
		a	b	(a/b)
1	Dane	75,017	24	3,125.71
	Milwaukee	162,427	28	5,800.96
	Waukesha	78,904	15	5,260.27
2	Brown	45,525	10	4,552.50
	Outagamie	35,078	13	2,698.31
	Racine	40,224	15	2,681.60
	Winnebago	33,560	9	3,728.89
3	Kenosha	30,382	12	2,531.83
	Rock	34,341	13	2,641.62
4	Manitowoc	20,927	12	1,743.92
	Washington	22,744	23	988.87
5	Ozaukee	18,374	19	967.05
	Wood	19,764	11	1,796.73
6	Chippewa	13,720	18	762.22
	Marinette	11,681	13	898.54
7	Calumet	8,946	24	372.75
	Juneau	6,134	15	408.93
8	Crawford	4,293	7	613.29
	Price	4,752	18	264.00

[a]source: 1990 Census

Low-Income

The difficulty with estimating the proportion of households that are low-income is that we need estimates that are specific to the study population of single-family owner-occupied households. This precludes using recent Census data. We therefore based the estimates on respondents who provided income information on the 1999 AST. Non-response on income questions is an issue for most surveys; indeed, in each AST round, a significant proportion of respondents either refused to give income information, or said they didn't know their annual income (Table A7).

Table A7: AST non-response on income

Survey Year	Percent without Income Information
1995	21.4%
1997	34.6%
1999 (income data alone)	33.4%
(income data + follow-up question)	22.1%

To mitigate this problem, in the 1999 survey we asked a follow-up question for those who refused to provide income data or said they didn't know. The follow-up question asked whether their income was above or below x dollars, where x was calculated as 150% of the 1998 Federal Poverty Guideline based on the prior response about the number of household members. Adding this question reduced the non-response on income by about a third.

For those who did report income data in 1999 AST (including households that were not in the scope of the study), the income figures track fairly closely with the Census Bureau's most recent Current Population Survey for Wisconsin (Table A8)—except for very low and very high incomes.

To classify respondents as low-income or not, we used the Federal Poverty Guidelines that were in effect for the previous year to establish whether respondents were at or below 150% of the guideline (Table A9).

Table A9: Federal poverty guidelines used for establishing low-income status.

	Federal Poverty Guideline	
Survey year	first person	each additional person
1995 (1994 guideline)	7,360	2,480
1997 (1996 guideline)	7,740	2,620
1999 (1998 guideline)	8,050	2,800

Because income was reported in categories, there were some cases in which it was ambiguous whether the household income was above or below the 150% threshold. We imputed these cases by giving each case a probability of being at or below the threshold that was proportional to where the threshold fell within the reported income category. For example, if a household that had a 150% threshold of $24,675 reported income in the category $20,000 to $29,999, we randomly assigned the poverty status of that household with a 4675/10000 = 0.4675 chance of being imputed as low-income. About 10% of cases with income data were imputed for the 1995 and 1997 data, and 1.5% for the 1999 data, owing to the follow-up question that was added to the 1999 survey.

There were also a small number of respondents (<1%) whose responses indicated they were both low-income and new construction. To keep the subgroups mutually exclusive, these were classified as new construction.

Table A10 shows the results for each of the last three AST's as well as the study.

Table A10: Proportion of low-income households for the 1995, 1997 and 1999 AST and study sample, by stratum.

stratum	1995 AST (n=1,729)	1997 AST (n=1,552)	1999 AST (n=1,712)	Study (unweighted) (n=299)
1	6.8%	5.7%	9.3%	4.5%
2	9.7%	11.9%	10.5%	19.1%
3	13.2%	11.0%	8.4%	16.0%
4	10.9%	6.6%	9.7%	17.1%
5	13.4%	10.1%	8.7%	3.3%
6	22.7%	13.0%	15.7%	25.8%
7	14.6%	21.1%	16.9%	15.4%
8	22.6%	18.0%	19.6%	24.0%
Overall	13.0%	10.8%	12.0%	14.4%

Although there are differences between the study sample and the AST's across the eight strata, we adopted the more tractable approach of applying a single weighting factor to downweight low-income households in the sample. The weighting factor was defined as the low-income proportion in the 1999 AST divided by the low-income proportion in the study, or

$$w_{low} = (205/1712)/(43/299) = 0.8326$$

New Construction

For the study and the 1999 AST, new construction was defined as any home built in 1994 or later. For the prior AST's, we defined new construction to be homes built any time within the five years prior to the survey, based on the response to the question "in approximately what year was this residence built?" There was about 10% non-response to the question in each round of the survey. The results are shown in Table A11.

Table A11: New construction proportion for the 1995, 1997 and 1999 AST and the study sample.

stratum	1995 AST n=1973	1997 AST n=2145	1999 AST n=1981	Study (unweighted) n=299
1	9.4%	5.9%	7.8%	11.9%
2	10.5%	10.3%	9.1%	12.8%
3	9.0%	8.4%	12.7%	20.0%
4	7.9%	11.5%	12.3%	17.1%
5	8.6%	8.2%	6.3%	13.3%
6	6.8%	7.4%	12.3%	12.9%
7	8.5%	17.4%	10.6%	23.1%
8	12.3%	9.0%	11.2%	8.0%
Overall	9.1%	9.2%	9.8%	14.7%

As with the low-income weight, we developed a single relative weighting factor for new construction households, derived from the 1999 AST:

$$w_{new} = (195/1981)/(44/299) = 0.6689$$

General Population

The 212 households in the study that are neither low-income or new construction represent what we refer to as the general population. Two weighting factors were applied to these. First, because of oversampling for low-income and new construction, these households are relatively under-represented in the study sample. We weighted these upwards by:

$$w_{gen} = (1 - 205/1712 - 195/1981)/(212/299) = 1.10266$$

Second, in assessing the representativeness of the study sample against information collected for the 1999 AST, we noticed a sizeable difference in responses to the question: "Do you plan to do any major remodeling or adding on to your home in the next two years?" As shown in Table A12, the difference is largest for the general population subgroup.

It is plausible that people who are planning to remodel their houses in the near future are more inclined to agree to an audit that might give them tips on how to improve the energy efficiency of their homes.

Table A12: Remodeling responses

Do you plan to do any major remodeling or adding on to your home in the next two years? (Percent responding "Yes")

	1999 AST n=1,278	Study (unweighted) n=299
Overall	16.5%	30.4%
general	20.6%	35.8%
low-income	10.3%	18.6%
new construction	11.5%	15.9%

We therefore developed remodeling-plans weights for general population households using the AST99 proportions. For those with remodeling plans

$$w_{rem1} = (242/1177)/(76/212) = 0.5735$$

and for those without remodeling plans

$$w_{rem2} = (935/1177)/(136/212) = 1.2383$$

Final Sample Weights

The final case weights are the product of the three weights

$$w_{overall} = w_{1*}\, w_{2*}\, w_3$$

where

$w_3 = w_{gen}*w_{rem1}$ for general population households with remodeling plans

$w_3 = w_{gen}*w_{rem2}$ for general population households without remodeling plans

$w_3 = w_{low}$ for low-income households

$w_3 = w_{new}$ for new construction households

The resulting weights for the full study sample of n=299 are shown in Table A13.

Because non-response to the questionnaire and differences between the pilot and the full-scale data collection created some systematic differences in the available study sample size, we also calculated weights that were appropriate for :

1. the pool of questionnaire respondents (n=296);

2. respondents to survey questions that were not included in the pilot questionnaire (n=277) — this excludes pilot households that completed the pilot version of the survey, but includes pilot households that later completed the revised survey; and,

3. the pool of households for data elements that were not collected in the pilot (n=259).

The weights for the first two groups above are only slightly different than the weights for the overall study sample. The weights for the third group are significantly different—because excluding pilot households eliminates one county entirely (Dane) and drastically reduces the number of sample points in Milwaukee county. However, there are very few data elements that were not collected as part of the pilot.

Table A13: Final study weights

Stratum	County	General Population (remodeling plans = yes)	General Population (remodeling plans = no)	Low-Income	New Construction
1	Dane	1951.08	4299.61	4830.07	2090.82
	Milwaukee	3620.99	7979.59		3880.33
	Waukesha	3283.48	7235.83		3518.65
2	Brown	2841.69	6262.25	3790.55	3045.22
	Outagamie	1684.30	3711.69	2246.70	1804.93
	Racine	1673.87	3688.71	2232.78	1793.75
	Winnebago	2327.59	5129.32	3104.79	2494.30
3	Kenosha	2370.57	5224.04	3162.13	2540.36
	Rock	2473.36	5450.56	3299.24	2650.51
4	Manitowoc	2721.40	5997.17	3630.10	2916.31
	Washington	1543.14	3400.63	2058.41	1653.67
5	Ozaukee	2112.74	4655.85	2818.19	2264.05
	Wood	3925.34	8650.29		4206.48
6	Chippewa	2378.91	5242.42	3173.25	2549.30
	Marinette	2804.36	6179.98	3740.76	
7	Calumet	1745.04	3845.56	2327.73	1870.03
	Juneau	1914.44	4218.85	2553.68	2051.55
8	Crawford	4785.20	10545.16	6383.01	5127.92
	Price	2059.88	4539.36	2747.68	2207.41

Sampling Error

To calculate sampling uncertainty, we used the SVY commands in Stata Version 5.0. These commands generally follow methods appropriate for two-stage sampling with unequal probability of selection, as outlined in standard sample design texts such as Cochran (1977). The SVY commands in Stata use variance estimators that only account for first-stage (i.e., county) sampling variance, and do not take into account the first-stage sampling fraction when applied to two-stage sample designs. Alternative estimators that account separately for first- and second-stage variance as well as the first-stage sampling fraction give comparable results.

Representativeness

The study was designed to yield a sample of households that are representative of the state's population of single-family, owner-occupied housing units. Tables A14-A24 provide a comparison between the (weighted) study sample and the 1999 AST on a number of demographic variables. Overall, the results show that the study sample is reasonably representative of the larger population, though some biases exist. In addition to the previously discussed bias in terms of remodeling plans, which we deemed should be corrected through post-hoc weighting, several other less substantial biases emerged from comparison with the 1999 AST phone survey results. In particular, we observed that the study sample somewhat:

1. over-represents households with more family members;

2. over-represents householders who have lived at their current residence for less than a year;

3. under-represents households who say they are never home during weekdays;

4. comparably represents the proportion of households that have programmable thermostats, but over-represents the fraction of these households that use the programming cababilities of the thermostats; and,

5. over-represents households that score favorably in terms of energy efficiency attitudes.

These differences should be taken into account in interpreting the results.

Table A14: Total annual household income

	1999 AST (n=1,474)	Study (n=281)	difference
<$5,000	0.9%	0.2%	-0.8%
$5,000-9,999	2.2%	2.4%	0.3%
$10,000-14,999	3.7%	3.9%	0.2%
$15,000-24,999	9.1%	10.4%	1.3%
$25,000-34,999	14.8%	17.0%	2.2%
$35,000-49,999	22.3%	23.9%	1.6%
$50,000-74,999	28.0%	24.1%	-3.9%
$75,000+	19.0%	18.1%	-0.9%

Table A15: Number of people in household (all ages)

	1999 AST (n=2,199)	Study (n=292)	difference
1	14.0%	10.2%	-3.8%
2	37.6%	33.9%	-3.6%
3	16.0%	16.3%	0.3%
4	19.4%	18.5%	-0.9%
5	8.5%	13.3%	4.8%
6	3.0%	5.0%	1.9%
7	0.9%	2.1%	1.2%
8+	0.6%	0.9%	0.2%
mean	2.87	3.18	0.31

Table A16: Number of children in household

	1999 AST (n=2,214)	Study (n=292)	difference
0	60.6%	52.4%	-8.2%
1	14.2%	13.0%	-1.3%
2	16.2%	19.4%	3.2%
3	6.2%	8.9%	2.7%
4	2.1%	4.5%	2.4%
5	0.3%	0.9%	0.5%
6+	0.3%	0.9%	0.7%
mean	0.78	1.06	0.28

Table A17: Number of seniors (age 65 or older) in household

	1999 AST (n=2,214)	Study (n=292)	difference
0	77.2%	78.5%	1.3%
1	12.9%	13.0%	0.1%
2	9.8%	8.5%	-1.3%
3+	0.1%	0.0%	-0.1%
mean	0.33	0.30	-0.03

Table A18: Respondent's highest education level

	1999 AST (n=2,150)	Study (n-295)
grade school[a]		3.6%
some high school	5.3%	3.5%
high school grad	36.4%	27.%$
some tech/junior	17.5%	17.5%
tech/junior grad	9.5%	9.8%
some college[a]		12.2%
bachelor's	21.8%	15.8%
advanced	9.5%	10.0%

[a]category not included in 1999 AST.

Table A19: About when was your home built?

	1999 AST (n=1,981)	Study (n=296)	difference
1995+	7.8%	8.0%	0.1%
1990-94	8.6%	11.2%	2.5%
1980-89	11.9%	11.2%	-0.7%
1970-79	18.1%	18.7%	0.7%
1960-69	13.6%	10.7%	-2.9%
1950-59	13.2%	10.3%	-2.9%
1940-49	6.5%	7.2%	0.7%
1930-39	3.7%	4.2%	0.5%
1929 or earlier	16.6%	18.5%	1.9%

Table A20: How long have you lived at this home?

	1999 AST (n=2,194)	Study (n=296)	difference
<1	2.6%	8.6%	6.0%
1-2	10.4%	9.2%	-1.3%
3-4	10.7%	11.1%	0.4%
5-10	25.8%	30.7%	4.9%
11+	50.5%	40.5%	-10.1%

Table A21: Remodeling Plans

	1999 AST	Study	difference
Do you plan to do any major remodeling or adding on to your home in the next two years?			
	(n=2,106)	(n=299)	
Yes	16.5%	20.1%	3.6%
No	83.5%	79.9%	-3.6%
Which of the following statements best describes your remodeling or addition plans?			
	(n=342)	(n=84)	
Just thinking about it	32.7%	35.0%	2.2%
Have definitive plans in place	41.2%	33.0%	-8.2%
Have talked to a contractor	7.6%	11.3%	3.7%
Have received bids for the work or purchased materials	18.4%	2.6%	-15.8%
Other[a]	0.0%	18.1%	18.1%

[a]unprompted in the 1999 AST survey

Table A22: How many hours per week is a member of this household at home between 8 a.m. and 5 p.m. on weekdays?

	1999 AST (n=1,217)	Study (n=265)	difference
0	14.8%	3.0%	-11.8%
1-9	11.2%	13.5%	2.3%
10-19	8.3%	13.0%	4.7%
20-39	17.9%	26.9%	9.0%
40+	47.8%	43.5%	-4.3%
mean	27.3	28.6	1.3

Table A23: Thermostat Type and Use of Programmable Features

Type	1999 AST (n=2,175)	Study (n=299)	Difference
manual	63.0%	66.0%	3.0%
programmable	36.2%	33.5%	-2.7%
none	0.8%	0.5%	-0.3%
Programmable Feature Used (if programmable)?			
	(n=772)	(n=96)	
Yes	73.7%	85.5%	11.8%
No	26.3%	14.5%	-11.8%

Table A24: Energy conservation attitude scale

	1999 AST (n=1,981)	Study (n=296)	difference
3 (pro)	27.0%	28.0%	1.1%
4	14.6%	24.0%	9.4%
5	17.1%	19.3%	2.2%
6	17.2%	11.5%	-5.7%
7	9.9%	6.1%	-3.8%
8	6.0%	7.6%	1.6%
9	5.7%	3.1%	-2.6%
10	1.4%	0.5%	-0.9%
11	0.9%	0.0%	-0.9%
12 (anti)	0.3%	0.0%	-0.3%
mean	5.24	4.81	-0.43

Scale comprises the sum of the scores of the following three questions, with response categories of strongly disagree (1 point), somewhat disagree (2 points), somewhat agree (3 points), strongly agree (4 points):

(a) I'm not interested in making energy-saving improvements to my home.

(b) Energy use in homes does not affect the environment very much. (asked as “Energy use in homes affects the environment very much,” on the 1999 AST; reverse coded)

(c) It's just not worth putting on more clothing in the winter to try to save a little energy.

Appendix B — Analysis Details

This appendix provides additional detail about how we analyzed the data for the study. In particular, the sections that follow cover:

- analysis of utility billing data,
- analysis of HERS modeling accuracy for space heating,
- definitions of energy efficiency opportunities, and how we estimated the savings and cost of these,
- the creation of attitude indices from questionnaire data,
- the creation of scales for winter and summer comfort,
- analysis of thermostat setting behavior.

Analysis of Utility Billing Data

Data Cleaning

We obtained usable natural gas histories for 199 of the 208 houses in the study with natural gas service, and electricity data for 270 of the 299 houses in the study. We did not attempt to collect data on other fuels. The length of the billing history obtained for each house varied by utility, from as little as 150 days to as much as 7.5 years. The median history was about 2 years, and 90% of the histories spanned between one and four years. Most of the usage histories were current to August 1999, when the initial data request was made, but some municipal and co-op electricity data (which was requested later) extended to December 1999.

The data were in the form of monthly usage with the read date, amount used, and a flag indicating whether the usage was based on an actual meter read or was a utility estimate. Overall, 15 percent of the monthly reads were estimated, and 85 percent were actuals. We consolidated the data to usage periods between actual meter readings. We also did some cleaning of the data to remove large outliers in the monthly data, correct apparent meter read errors, and eliminate early histories that were clearly different from the remainder of the history. Altogether these changes affected only about 1% of the data.

Weather Normalization

The weather has a significant impact on space heating and air conditioning in homes, and temperatures the last few years have been particularly anomalous. We used the Princeton Scorekeeping Method (PRISM) to perform two important functions: (1) separate weather-sensitive space heating and air conditioning use from the overall gas or electricity use; and, (2) adjust these uses to typical weather conditions.

Given a monthly usage history and a database of daily outdoor temperatures, the PRISM software that we used (Advanced Version 1.0) can statistically fit any of three models to the data:

1. heating-only model— Use per day = $\alpha + \beta_h h_h(\tau_h)$
2. cooling-only model— Use per day = $\alpha + \beta_c\ h_c\ (\tau_c)$
3. heating and cooling model — Use per day = $\alpha + \beta_h h_h(\tau_h) + h_c(\beta_c \tau_c)$

Where:

α = non-weather sensitive (or base) use per day

$\beta_{h,c}$ = use per heating or cooling degree day

$h_{h,c}$ = heating or cooling degree days per day from base temperature τ, which are calculated from daily average outdoor temperatures (T_{avg}) as:

$H_h = \max(\tau_h - T_{avg}, 0)$

$H_c = \max(T_{avg} - \tau_c, 0)$

and then averaged over the consumption period

$\tau_{h,c}$ = base temperature for calculating heating or cooling degree days

Model 1 (heating only) is appropriate for analyzing gas usage for houses with gas space heat. Model 2 (cooling only) would be appropriate for analyzing electricity usage for houses with air conditioning, but no electric space heat. And Model 3 is appropriate for analyzing houses with electric space heat and air conditioning. The α, β, and τ coefficients are fit individually to each house using a modified least-squares approach that allows the non-linear τ to be optimized.

In some cases, the τ parameter is poorly determined from the data, usually because there are too few data points. In these cases, we substituted fixed-τ models, with the τ's fixed at the median values (60F for heating, and 73F for cooling) based on houses that were run successfully under the standard PRISM models.

There were also cases where the heating and cooling coefficients ($\beta_{h,c}$) were negative. These generally represented cases where the model was inappropriately specified (e.g., a heating and cooling model for a household that did not use their air conditioning). In these cases, we switched to a different model.

Once the appropriate model is fit to the data, Weather normalized annual use for each component can be calculated as:

normalized annual base consumption (Base) = 365.25*α

normalized annual heating consumption (NAHC) = $\beta_h H_{oh}(\tau_h)$

normalized annual cooling consumption (NACC) = $\beta_c H_{oc}(\tau_c)$

and

normalized annual consumption (NAC) = Base + NAHC + NACC

where

$H_{oh,c}(\tau_{h,c})$ represent long-term average annual heating or cooling degree days to base temperature τ.

For houses without heating or cooling loads, we simply annualized the data as 365.25 times average use over the billing history, using a period as close as possible to an integer number of years of the history.

Table B1 shows the final model disposition of the usage histories.

Table B1: Disposition of usage histories

Model	Electricity	Natural Gas
Heating Only	8	191
Heating Only (fixed τ)	0	3
Cooling Only	133	0
Cooling Only (fixed τ)	21	0
Heating and Cooling	9	0
Annualized	99	5
Total	270	199

Weather Data

The 19 counties that were sampled for the study were assigned to one of eight weather zones that generally corresponded with the NOAA climate zones within the state. We obtained daily average temperature data for each zone. Long-term normals were based on the 20-year period from 1980 through 1999. Table B2 shows the assignment of counties to the weather zones, along with the 20-year average heating and cooling degree days (base 65).

Table B2: Weather zones applicable to each county

Weather Station	Annual Heating Degree Days (1980-1999)	Annual Cooling Degree Days (1980-1999)	Counties
Rhinelander	8905	304	Price
Rhinelander/Green Bay average	8260	386	Marinette
Green Bay	7762	479	Brown, Calumet, Manitowoc, Outagamie, Winnebago
Eau Claire	8280	453	Chippewa
Hancock	7621	569	Juneau, Wood
Lancaster	7427	611	Crawford
Madison	7313	612	Dane, Rock
Milwaukee	6861	680	Kenosha, Milwaukee, Ozaukee, Racine, Washington, Waukesha

Typical Results

The tables below shows the median results obtained from each model for each fuel.

Table B3: Median values for electricity (kWh)

	Heating Only (n=8)	Cooling Only (n=133)	Cooling Only (fixed τ) (n=21)	Heating and Cooling (n=9)	Annualized (n=99)
N	25	15	7	23	15
α	23.79	23.64	24.81	24.21	
c.v. α	17.5%	5.3%	7.8%	49.4%	
β_h	1.55			0.76	
c.v. β_h	29.9%			21.1%	
β_c		6.58	7.56	3.33	
c.v. β_c		75.1%	34.4%	152.6%	
τ_h	54.2			56.0	
c.v. τ_h	22.3%			38.6%	
τ_c		73.6	73.0	68.0	
c.v. τ_c		4.8%		9.3%	
NAC	16342	9489	10325	12634	8627
Base	8690	8633	9060	8843	8627
NAHC	6775	0	0	5488	0
NACC	0	878	1134	696	0
Model r^2	0.802	0.533	0.570	0.711	

Table B4: Median values for natural gas (therms)

	Heating Only (n=191)	Heating Only (fixed τ) (n=3)	Annualized (n=5)
N	23	28	21
α	0.58	1.18	
c.v. α	24.0%	12.7%	
β_h	0.13	0.12	
c.v. β_h	5.9%	10.7%	
τ_h	59.3	60.0	
c.v. τ_h	3.6%		
NAC	946	1204	326
Base	211	432	326
NAHC	745	772	0
NACC	0	0	0
Model r^2	0.984	0.777	

Imputation of Missing Energy Use data

We used the data for homes with billing data to impute energy use for cases that were missing data. This included imputing propane, oil, and wood use (because these data were not collected suppliers), as well as filling in missing natural gas and electricity data that we were not able to obtain.

Heating Use

We used a regression model to statistically adjust the REM/Rate estimates of heating use for homes that either heated with fuels other than just natural gas or electricity, or for which we lacked the gas or electric data. A more detailed comparison of billing data results and REM/Rate predictions of heating usage can be found in the next section of this appendix. The model we used here is:

h_int = r_int + dintrct +constant + ε

where

h_int = heating energy intensity from billing data estimate (BTU/sf/HDD)

r_int = heating energy intensity from REM/Rate prediction

dintrct = r_int * (thermostat setting used in REM/Rate analysis - avg. thermostat setting from survey)

ε = random error

The regression analysis was limited to 130 houses that heat with natural gas only, and had PRISM estimates of heating usage with uncertainty of less than ±25% (90% confidence interval). We also dropped one household with a severely undersized furnace that reported an average thermostat setting of 86F.

The results are:

```
  Source |       SS       df       MS              Number of obs =     130
---------+------------------------------           F(  2,   127) =   62.65
   Model |  399.749846     2  199.874923           Prob > F      =  0.0000
Residual |  405.159833   127   3.1902349           R-squared     =  0.4966
---------+------------------------------           Adj R-squared =  0.4887
   Total |  804.909679   129  6.23960992           Root MSE      =  1.7861

------------------------------------------------------------------------------
   h_int |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
   r_int |    .383386     .03766     10.180   0.000       .3088636    .4579084
 dintrct |  -.0233399   .0068166     -3.424   0.001      -.0368288    -.009851
   _cons |   3.636621   .3832807      9.488   0.000       2.878178    4.395065
------------------------------------------------------------------------------
```

The fitted model above was used to impute total heating energy use for 112 houses that heated with fuels other than natural gas or electricity, or for which we lacked utility billing data. We then apportioned out the total heating use according to the percentage of the total heating load that was estimated by the auditors for each fuel.

Air Conditioning

We did not have electricity data for eight homes with central air conditioning and 9 homes with room air conditioners. We imputed these using the median value for air conditioning use estimated by PRISM from homes for which we did have electricity data. We used 794.4 kWh and 394.4 kWh for central and room AC, respectively.

Fuel Use for Water Heaters, Ranges and Dryers

Forty-six homes had a water heater, range, oven or clothes dryer that used propane or fuel oil, and eight homes with natural gas appliances had insufficient utility data. We imputed these using a regression model of base use for 175 homes with natural gas data.

The model is

base = gasdhw + dhw_peop + rng_peop + dry_peop + dhwtemp2 + constant + ε

where

base = estimate of annual gas use other than for space heating, derived from the PRISM analysis (or from annualized data for homes without gas space heating)

gasdhw = 1 if a gas water heater is present; zero otherwise

dhw_peop = number of people in household if gas water heater present; zero otherwise

rng_peop = number of people in household if gas range present; zero otherwise

dry_peop = number of people in household if gas dryer present; zero otherwise

dhwtemp2 = (hot water temperature – 130)*gasdhw

ε = random error

We fit the model to 132 households with one or more of the above natural gas appliances, excluding those with solar water heaters, hot tubs or jacuzzis, or for which the standard error of the estimate of base use was more than 50 percent of the estimated value. The fitted results are:

```
  Source |       SS       df       MS              Number of obs =     132
---------+------------------------------           F(  5,   126) =   10.90
   Model |  569535.383     5  113907.077           Prob > F      =  0.0000
Residual |  1317039.99   126  10452.6983           R-squared     =  0.3019
---------+------------------------------           Adj R-squared =  0.2742
   Total |  1886575.37   131  14401.3387           Root MSE      =  102.24

------------------------------------------------------------------------------
    base |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  gasdhw |   142.5616   77.74389      1.834   0.069      -11.29126    296.4145
dhw_peop |   19.24823   6.617911      2.909   0.004        6.15158    32.34488
rng_peop |   11.37902   5.332742      2.134   0.035       .8256794    21.93236
dry_peop |   10.58528   5.532848      1.913   0.058      -.3640671    21.53462
dhwtemp2 |   2.610622    .876587      2.978   0.003       .8758821    4.345362
   _cons |   30.47295    74.0425      0.412   0.681       -116.055    177.0009
------------------------------------------------------------------------------
```

Electricity for Uses Other than Space Conditioning

Electricity data were missing for 29 homes. We imputed the non-space conditioning electricity for these using a regression model developed for homes that did have electricity data. The model is:

base = people + el_dhw + dhw_peop + el_rnge + el_dryer + n_refr + n_frz + lighting + constant + ε

where

people = the number of people in the home

el_dhw = 1 if electric water present; zero otherwise

dhw_peop = people*el_dhw

el_rnge = 1 if electric range or oven present; zero otherwise

el_dryer = 1 if electric dryer present; zero otherwise

n_refr = number of refrigerators in home

n_frz = number of stand-alone freezers in home

lighting = total annual kWh of lighting recorded in lighting survey

ε = random error

We fit this model to electricity data for 260 households that had estimates of base electricity use with a standard error less than 50 percent, and did not have a solar water heater. The results are:

```
Source |       SS       df       MS              Number of obs =     260
---------+------------------------------            F(  8,   251) =   23.09
   Model |  1.6518e+09     8   206473347            Prob > F      =  0.0000
Residual |  2.2441e+09   251  8940449.81            R-squared     =  0.4240
---------+------------------------------            Adj R-squared =  0.4056
   Total |  3.8958e+09   259  15041852.1            Root MSE      =  2990.1

------------------------------------------------------------------------------
    base |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  people |   858.3536   149.8145      5.729   0.000       563.2999    1153.407
  el_dhw |    1272.98   949.7086      1.340   0.181       -597.433    3143.393
dhw_peop |   649.0587    288.263      2.252   0.025       81.33618    1216.781
el_range |   923.9632   420.8057      2.196   0.029       95.20307    1752.723
el_dryer |     724.43   433.2021      1.672   0.096      -128.7443    1577.604
  n_refr |   1745.517   485.8785      3.592   0.000       788.5989    2702.436
   n_frz |   1029.691   353.1762      2.916   0.004       334.1249    1725.258
lighting |   1.080146   .3217368      3.357   0.001       .4464977    1.713793
   _cons |   1098.033   855.7708      1.283   0.201      -587.3733     2783.44
```

Energy Costs

We used published utility rates for natural gas and electricity use, and used 1998 statewide average prices for other fuels (Wisconsin Energy Bureau, 1999). For wood use for heating, we used the rate from the state Home Performance Program, based on wood prices in central Wisconsin.

Table B5: Fuel prices

	Mean	Minimum	Maximum
Electricity (cents/kWh)			
heating	6.48	3.60	7.75
cooling	6.51	3.60	8.01
base	6.49	3.60	7.75
service charge ($/month)	6.09	3.00	14.00
Natural gas (cents/therm)			
heating	54.0	39.4	60.8
base	51.6	39.4	60.8
service charge ($/month)	5.21	4.50	14.43
Propane ($\$/10^6$ Btu)	7.98		
Fuel oil ($\$/10^6$ Btu)	5.97		
Wood ($\$/10^6$ Btu)	3.86		

HERS Modeling Accuracy

The basic organizing framework for much of the physical data collected for the study was a standard Home Energy Rating System (HERS) rating conducted under the auspices of the Wisconsin Home Performance program. This protocol uses a software package called REM/Rate (version 8.46) developed by Architectural Energy Corporation (AEC) to model the energy performance of each house.

In this appendix we look at the accuracy of the software to predict heating energy use vis-a-vis annual heating energy estimates for each house derived from utility billing records. We focus on heating energy use, because: (1) it is the largest single end-use in most households; (2) it is less a function of lifestyle than most other end uses; and (3) actual heating energy use can be estimated readily from whole-house utility billing data. Though the software is mainly used to calculate an energy rating score for each house that is meant to be independent of occupant behavior (such as thermostat setting behavior), it is also used to estimate the savings and cost-effectiveness of energy efficiency improvements. For the latter analysis, the software calculates estimates of the actual heating energy use of each home: it is these estimates that we compare to utility billing data.

Factors that result in a difference between the REM/Rate predicted heating use and what we obtain from the billing data can be conceptually divided into two categories: random and systematic. Random factors are ones that vary from house to house. Most specification errors are random: an auditor assumes the wrong efficiency for a heating system, specifies a wall that is insulated as uninsulated, or errs in calculating the conditioned volume of the home. Measuring the magnitude of random error can tell us how confident we can be in the software predictions for any one house.

In contrast, systematic factors result in errors that occur consistently across many homes. These can result from specification errors that are common across all homes (for example, a software library definition for a common building component used by all raters is incorrect), or algorithmic or computational errors within the software itself. Measuring the systematic error tells us whether the software estimates of heating energy use are correct *on average*.

As described earlier in this appendix, we used the PRISM software to split recorded utility billing usage into heating and non-heating use (based on the correlation with heating degree days), and then adjust the heating use to long-term average weather conditions. As with any statistical procedure, the estimates that result are not absolutely certain, but have a statistical confidence interval associated with them. In addition to this house-to-house uncertainty in estimates of heating use, it is also known that PRISM tends to erroneously assign some seasonally variable non-heating use to heating (Fels et al. 1986). This means that the estimates of heating use tend to be slightly (perhaps five percent) overstated across the board.

Also of concern for this comparison is the definition of what constitutes a "normal" heating season. PRISM calculates weather normalized heating usage based on long-term averages of daily average temperatures (in the case of this study, the 20-year period from 1980 through 1999). REM/Rate, on the other hand is based on hourly Typical Meteorological Year (TMY) data, which is only available for a few major weather stations, and is interpolated for other locations in the state by AEC. AEC provided us with heating degree day information for the non-interpolated locations in Wisconsin. Comparing the two sets of data (Table B6) indicates that the REM/Rate predictions are based on weather norms with about five percent fewer heating degree days than those used in the PRISM analysis. Together with the tendency for PRISM to slightly overestimate actual heating use noted above, we might expect the REM/Rate predictions to be about 10 percent lower than the PRISM-derived figures.

Table B6: Comparison of PRISM and REM/Rate calculation of heating degree days

Station	PRISM HDD_{65}[a]	TMY HDD_{65}	Difference (percent)
Milwaukee	6861	6535	-4.8%
Madison	7313	6812	-6.8%
Green Bay	7762	7416	-4.4%
Eau Claire	8280	7703	-5.1%
Average[b]	7245	6872	-5.1%

[a]PRISM heating degree days based on period from 1980 through 1999

[b]average of 131 (of 147) cases in the analysis modeled using these stations

We started with 194 houses in the study that heat with natural gas, and for which we were able to obtain an estimate of annual heating usage from utility billing data. We dropped 23 cases that had other supplemental heating sources (such as woodstoves or baseboard electric). We also dropped 23 cases for which the estimate of heating usage was poorly determined from the billing data (90% confidence interval > 25%). The uncertainty in heating use for the homes that remained averages about ± 10 percent. Finally we dropped one unusual house that used gas to heat both the main residence and a separate rental unit that was not part of the study. This left a final analysis group of 147 households.

We compared the REM/Rate and the billing data estimates at two levels; total annual heating energy use (therms), and heating energy intensity (BTU/ft^2/heating degree day). For the latter measure, we excluded basements from the square footage of the houses, and normalized usage to the PRISM long-term heating degree days at the standard 65^{o}F reference temperature.

Table B7 summarizes the overall error statistics, and Figures B1 through B3 show the relationship between the two visually. The overall error statistics indicate that despite an a priori expectation that REM/Rate should come up with somewhat lower estimates of heating energy use, the REM/Rate predictions are higher than the PRISM results in more than three quarters of the cases. For the majority of houses, the difference is moderate (the median value is +22 percent), but the REM/Rate predictions of heating use are much higher for houses that are predicted by REM/Rate to have a high heating energy intensity. The 13% of the cases in the analysis with a predicted energy intensity of more than 15 BTU/ft^2/HDD are overestimated by REM/Rate by a median of 53% compared to the PRISM estimates.

In fact, the plots and the regression results point to a systematic difference between REM/Rate and the billing data that is a function of the predicted heating energy intensity. Almost all of the homes that are predicted by REM/Rate to have a high energy intensity (>15 Btu/ft^2/HDD) have substantially uninsulated walls or under-insulated ceilings. Because the calculated heat loss is a function of the inverse of the R-value of an area such as a wall, when the R-value becomes small (as in uninsulated wall sections), small differences in the assumed R-value can turn into large differences in estimated heating energy use. It is possible that the effective R-value of uninsulated areas is somewhat higher than assumed in the model, and this gives rise to predicted heating energy use that is much higher than observed.

Another factor that may be at play is that house specification errors probably tend to be somewhat one-sided—that is raters are more likely to mis-specify an insulated wall section as being uninsulated than they are to incorrectly specify an R-11 wall as, say R-19. This would lead to a general tendency to overestimate heating energy use on average.

Though not nearly as extreme as the overprediction of inefficient homes, the software predictions of heating energy intensity also appear to underestimate heating use for highly insulated homes. Here, the important issue may be insulation installation defects that degrade the effective R-value of the building shell. In either event, raters (or users of ratings) would do well to be suspicious of predicted heating energy intensity that is extreme in either direction, say less than 4 or more than 15 Btu/ft^2/HDD.

Table B7: Overall REM/Rate percent error statistics (n=147)

error range	-39% to +357%
mean error	+33%
median error	+22%
mean absolute error	40%
median absolute error	27%
% of houses with error less than or equal to…	
± 5%	10%
± 10%	19%
± 20%	39%
± 50%	76%
% of houses where…	
REM > billing	79%
REM < billing	21%
REM within 90% confidence interval for billing	22%

Error defined as [(REM – billing)/billing]*100

Figure B1: Observed versus predicted annual heating energy use

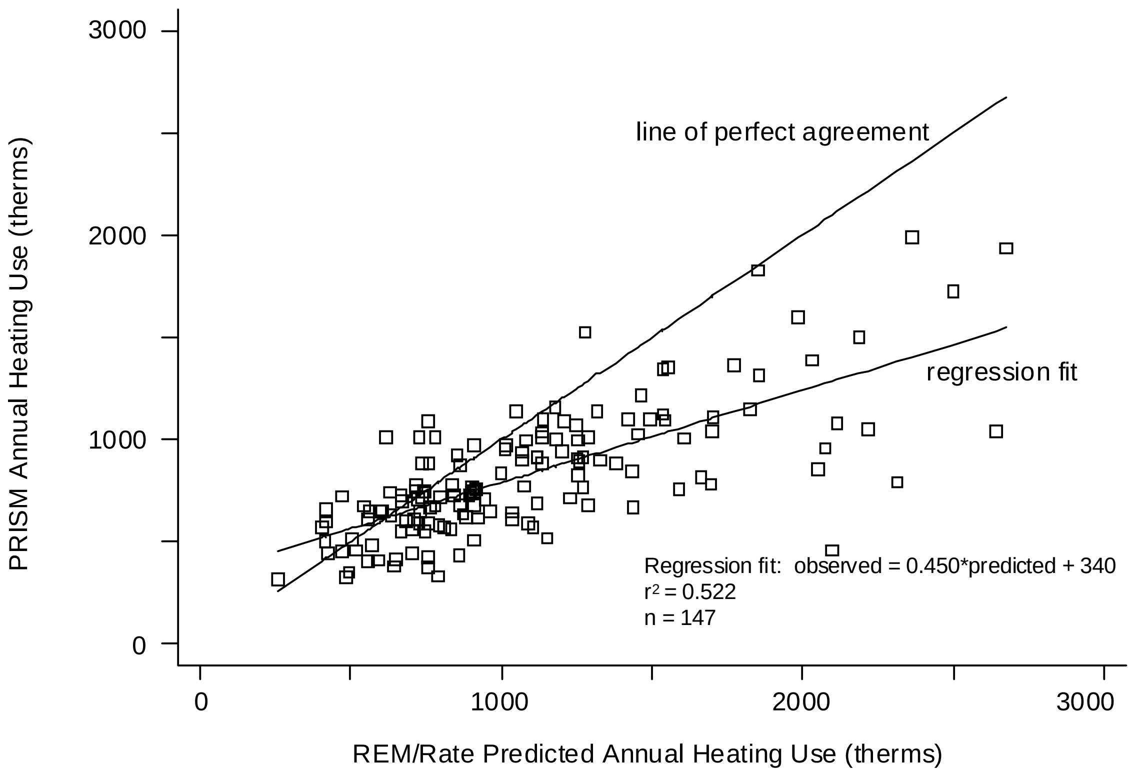


Figure B2: Observed versus predicted heating energy intensity

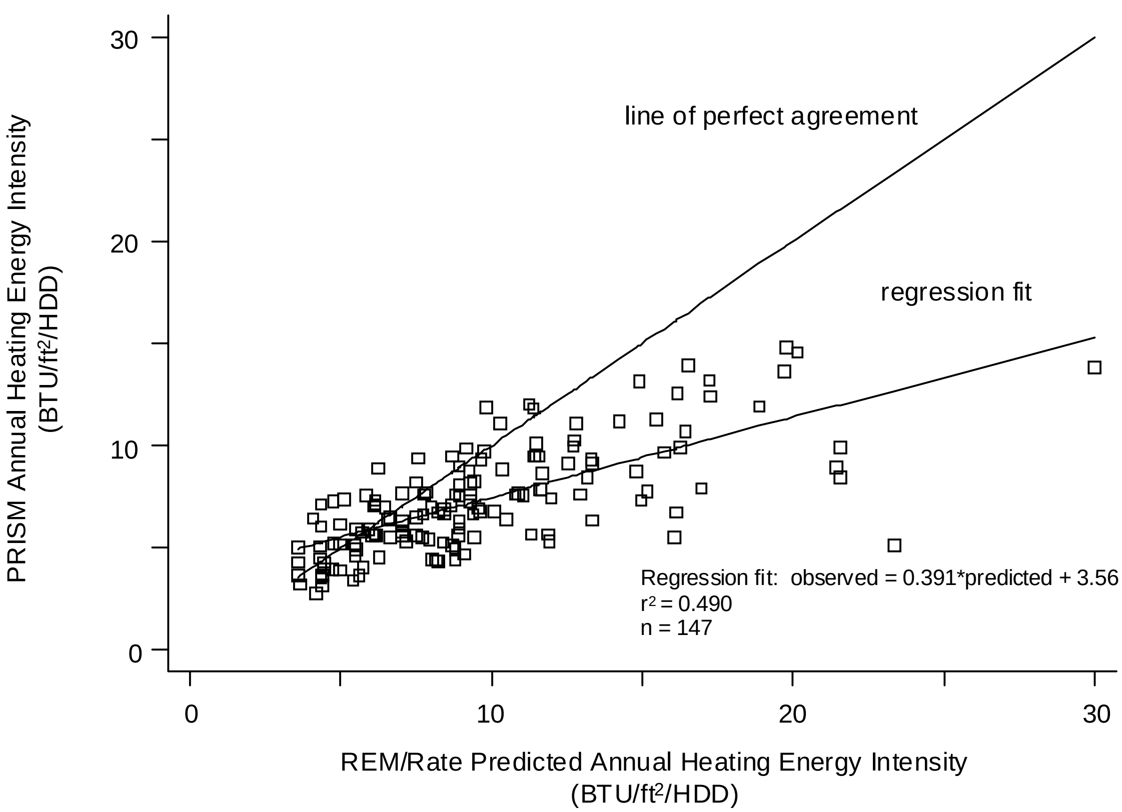
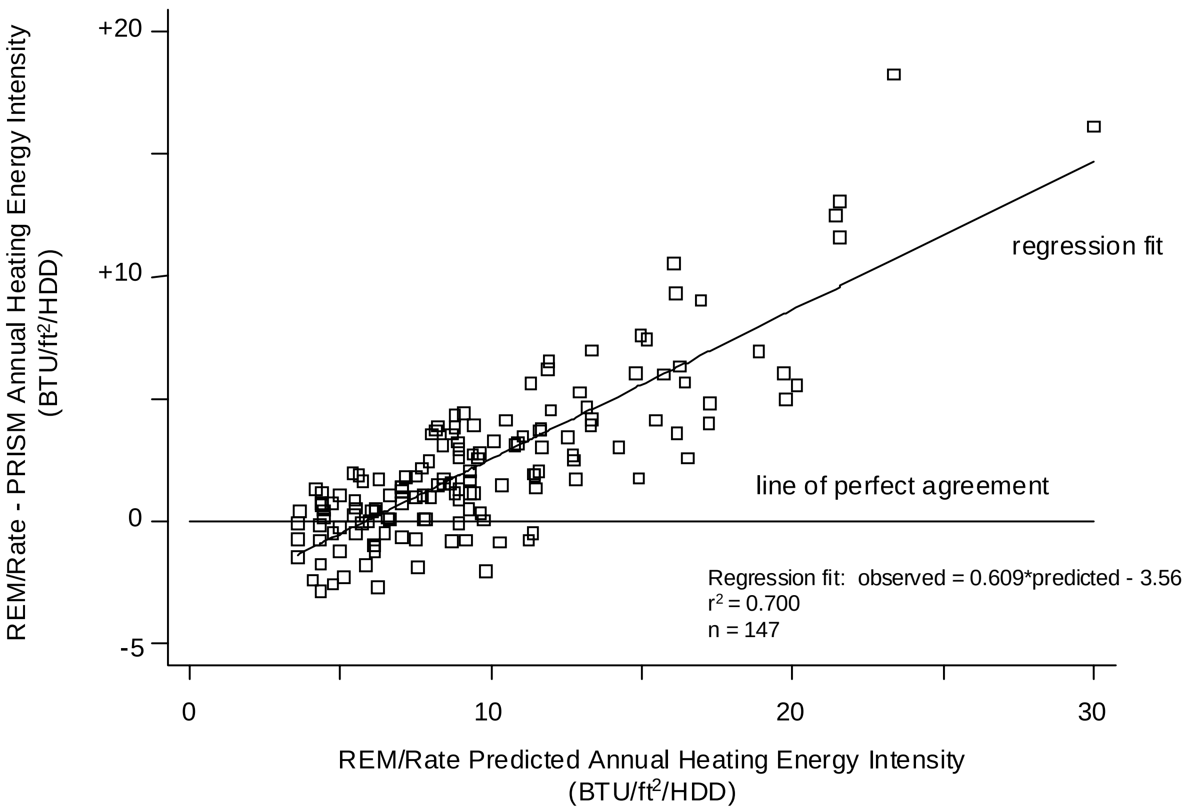


Figure B3: Difference in heating energy intensity versus predicted energy intensity



De-trending the REM/Rate predictions by applying the regression fit in Figure B2 improves the overall error statistics somewhat, as shown in Table B8, in that it removes the apparent linear bias that is a moderate factor for most houses and a major factor for houses that are predicted to be very energy intensive. After de-trending, it appears that one can be about 60 percent confident that REM/Rate's prediction will be within ± 20 percent, and 90 percent confident that it will be within ± 50 percent of the PRISM value.

This random, or house-to-house component to the difference between the two estimates has several possible origins. First, it must be remembered that the PRISM estimates of annual heating use have an average uncertainty of about ± 10 percent or so. This means that even if REM/Rate perfectly predicted heating energy usage in every case, we would still see some variation between the REM/Rate and PRISM estimates.

But the average difference between the two is larger than what the uncertainty in the PRISM estimates alone would indicate. This suggests that there are additional factors at work that create error in the predictions. These probably arise mostly from occasional errors in specifying the house (e.g., insulation levels, heating system efficiency, or even the geometry and size of the home) or from departures from what is assumed about how homeowners manage their heating energy use. (Geographic error may also play a minor role. If a house is located in a somewhat warmer or colder area than the weather station used for modeling its energy use, REM/Rate will somewhat under- or overestimate the house's heating usage.)

Table B8: REM/Rate percent error after de-trending (n=147)

error range	-38% to +149%
mean error	7%
median error	1%
mean absolute error	21%
median absolute error	17%
% of houses with error less than or equal to…	
± 5%	18%
± 10%	30%
± 20%	56%
± 50%	92%
% of houses where…	
REM > billing	54%
REM < billing	46%
REM within 90% confidence interval for billing	28%

Error defined as [(detrended REM – billing)/ billing]*100

We do not have any easy way to second-guess raters' estimates of insulation levels, but the homeowner questionnaire did allow us to look at differences that might arise due to assumptions about thermostat settings. REM/Rate uses a default heating setpoint of 68^{o}F, but raters can customize this parameter to any value between 60 and 75 ^{o}F. There is also a check box to indicate whether a programmable thermostat is present in the house. If a programmable thermostat is noted, the program assumes a 5 F^o setback for an eight hour period. We used this information to calculate the average thermostat setting that was used to model the house. Although raters for the study at one time or another used the full range of setpoints allowed by REM/Rate, in about three-quarters of the cases, the value was left at the default setting.

The survey data suggest that 68 ^{o}F is a reasonable value for many households (about two-thirds of homeowners report thermostat settings between 66 ^{o}F and 70 ^{o}F). However homeowners reported thermostat settings to us that ranged from 59 ^{o}F to 72 ^{o}F. And the difference between the average thermostat setpoint that was modeled in REM/Rate, and what homeowners reported to us ranged up to eight ^{o}F in either direction (though the two values were within about ± 4 F^o in 90% of the cases).

Moreover, the difference between the thermostat setpoint used in the REM/Rate analysis and what we calculated from the homeowner questionnaire is a statistically significant predictor of the difference between the REM/Rate prediction of heating energy use and the PRISM estimate from utility billing data (see Table B9). The coefficient, though not precisely determined, suggests that each F° of difference in thermostat setpoints creates about a 2.3 percent error in the REM/Rate prediction. If this value is accurate, then an eight F° error in modeling the thermostat setpoint for a home would create an 18 percent error in predicted heating energy use. Though most of the time the error would be much less than this value, the results indicate that taking care to determine homeowners' thermostat-setting preferences will increase the accuracy of the predictions.

Table B9: Model A

Dependent variable: Observed heating energy intensity (from billing data) BTU/ft^2/HDD	Model Results $r^2 = 0.489$ n = 130	
Independent variables:	coefficient	t-statistic
REM/Rate predicted heating energy intensity	0.383	10.18
REM/Rate predicted heating energy intensity * (survey – modeled thermostat setpoint)	-0.023	3.42
Constant	3.64	9.49

We also conducted some additional analysis to see the extent to which the difference between the REM/Rate predictions and observed heating energy use was a function of:

1. Systematic differences from rater to rater;
2. Geographic differences (i.e., county);
3. Modeling basements as conditioned versus unconditioned space;
4. Assumptions about unverified insulation levels; or,
5. The presence of wood fireplaces or electric space heaters.

Rater-to-Rater and Geographic Differences in Rating Accuracy

To look at whether individual raters tend to over- or under-estimate heating energy use, or whether houses in particular counties tend to be over- or under-estimated, we first remove the overall average bias effect by fitting the model in Table B9, and then analyzing the residuals (observed heating energy intensity – fitted). Note that this also removes the average effect of errors in specifying the thermostat setpoint—which does tend to vary from rater to rater—but for this analysis we prefer to focus on other possible rater-related modeling errors. We found that while there may be average differences across raters and counties, these tend to be small (on the order of 1 BTU/ft^2/HDD). The small number of cases for some raters and counties makes for wide confidence intervals, that make it difficult to note definite differences, however.

Basements as conditioned versus unconditioned space

Standard procedure for Wisconsin HERS ratings is to model basements as conditioned space, which for REM/Rate means that the basement is assumed to be at the same temperature as the rest of the house. But many Wisconsin basements are something between conditioned and unconditioned space. These basements are not used for living space, but the heating system and much of the ductwork is in the basement, so some heat is inevitably added to the basement.

We looked at how much the REM/Rate predictions of heating energy use changed when we modeled basements as unconditioned space in REM/Rate for a sample of a dozen houses in the study. These houses were drawn randomly from across the distribution of heating energy intensity. The results (Table B10) suggest that choosing to model basements as conditioned versus unconditioned space does not have a large effect on the predicted heating energy use for most homes. The average result is a slight downward revision of the heating energy estimates.

Table B10: REM/Rate predicted heating energy use (therms/year)

House ID	Basement modeled as conditioned	Basement modeled as unconditioned	Difference	Percent difference
03-0048	755	770	15	2.0%
25-0037	850	861	11	1.3%
28-0024	908	895	-13	-1.4%
30-0154	1436	1398	-38	-2.7%
30-0179	2075	2130	55	2.7%
30-0184	1135	984	-151	-13.3%
33-0087	729	762	33	4.6%
64-0006	725	786	61	8.4%
66-0026	570	504	-66	-11.5%
73-0028	1773	1684	-89	-5.0%
73-0048	1202	1142	-60	-5.0%
73-0054	778	793	15	1.9%
		average:	-19	-1.5%

Verification of Insulation Levels

Insulation levels in a home cannot always be observed directly by the rater. As part of the study, raters were asked to note whether the modeled insulation level for each defined wall, ceiling, or other area was based on a visual verification of the insulation level. To test whether assumptions about unverified insulation levels have an effect on the accuracy of the model, we calculated the percent of total above-grade wall and ceiling area that was visually verified for each house, and then looked for whether this affected the accuracy of the heating energy estimates. In the subgroup of houses here, about 75 percent of houses had all wall or ceiling areas recorded as verified, about 20 percent had none verified, and 5 percent had some verified and some unverified areas.

We found that houses with unverified insulation levels have—as one would expect—a somewhat larger range of modeling error, but there does not appear to be any average bias effect from these houses. Houses with unverified insulation are scattered throughout the distribution of predicted heating energy intensity.

Fireplaces and Electric Space Heaters

We also looked for whether the 20% houses in the analysis with a wood fireplace had an average prediction error that might be consistent with homeowners frequently relying on a wood fireplace for heat, and similarly for the 3% of houses that were recorded as having portable electric space heaters. Neither of these factors had a statistically significant impact on the relationship between observed and modeled heating energy use in our sample.

Heating Energy Use and Rating Score

Although for the purposes of this study we are mainly concerned with REM/Rate's ability to model heating energy use, an examination of the relationship between observed and predicted heating energy use and the rating score for each house provides some useful insights.

Figures B4 and B5 show plots of the REM/Rate predicted and observed heating energy intensity versus the HERS rating score. Although the HERS rating takes into account more than just space heating, Figure B4 demonstrates that it is a strong function of the predicted heating energy intensity. The relationship between observed heating energy intensity and the HERS score is much weaker, but it is comforting to see that houses with high observed heating energy intensities mostly score low and houses with low observed heating energy intensities gather high scores.

Outliers in this relationship tend to fall toward the side of low observed heating energy intensity combined with a low HERS rating. This reinforces the notion that rating errors tend to be toward the side of incorrectly specifying uninsulated building components and/or low efficiency heating systems. For example, the most severe outlier in Figure B5 is a house that was modeled as having uninsulated walls, R-19 ceilings areas (which were not visually verified), and a 60% AFUE furnace. Re-analyzing this house with R-11 walls, R-38 ceiling areas, and a 75% AFUE heating system reduces the estimated heating use by about 50%. Thus, it appears that while houses with high ratings are very likely to actually have low heating energy intensity, the reverse is not necessarily true.

The observed relationship between predicted and billing-data based heating energy use in Figure B2 can be algebraically combined with the relationship between the predicted heating energy use and the HERS score (Figure B4) to estimate the average change in HERS score from correcting the systematic error (Figure B6). As would be expected, the results indicate that the ratings for low-scoring homes should be increased substantially on average, and those for high-scoring homes (>83) should be decreased slightly. Overall, the adjustment tends to pull in the tails of the rating distribution, so that there is less differentiation across homes. This may not be a desirable outcome if the goal of the ratings is to allow homeowners to distinguish between efficient and inefficient homes. On the other hand, it could be argued that the unadjusted rating scores falsely label inefficient homes as being worse than they really are. Additional research into how homeowners interpret the rating scores would be needed to adequately address this issue.

Figure B4: Predicted heating energy intensity versus HERS score

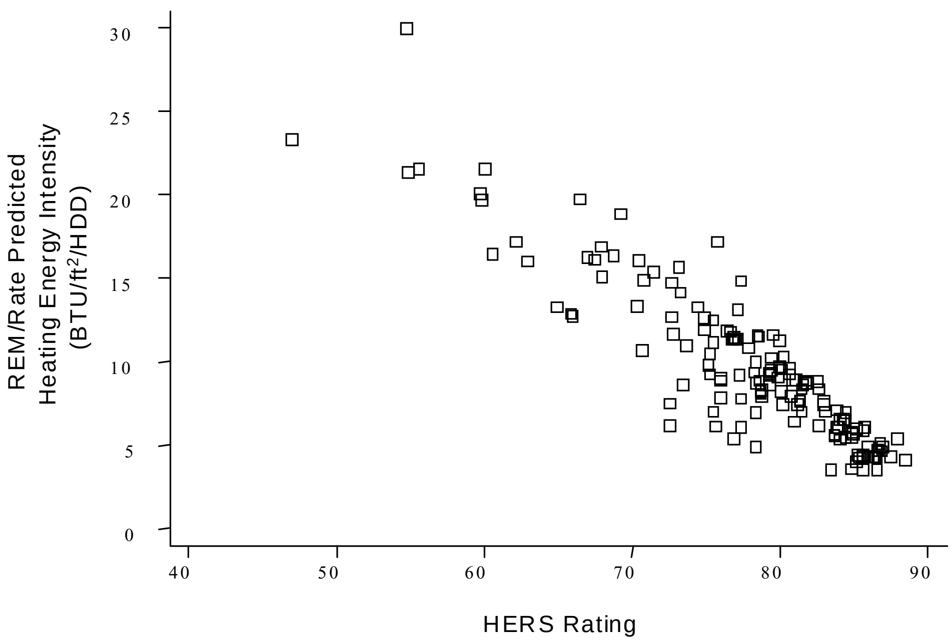


Figure B5: Observed heating energy intensity versus HERS score

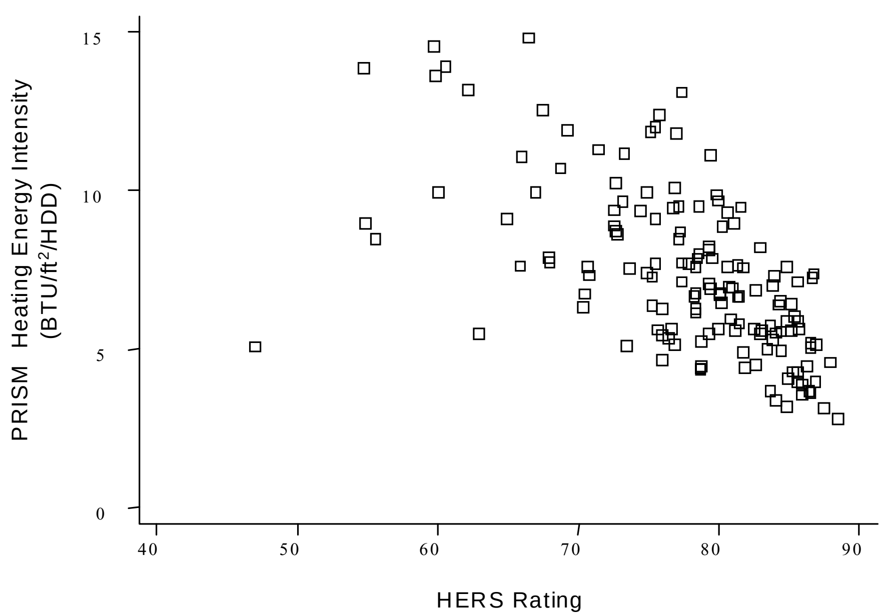
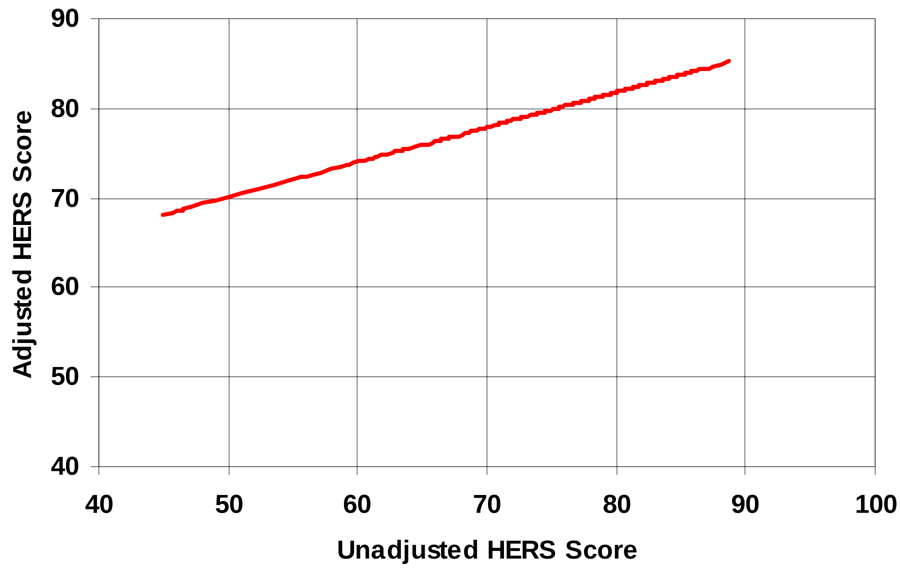


Figure B6: Adjusted versus unadjusted HERS score



Energy Efficiency Opportunity Definitions and Calculation Methods

The table below provides more detail about how we defined the energy efficiency opportunities that we analyzed, and documents how we estimated the energy savings and cost for each.

Table B11: Definition of energy efficiency opportunities

Measure	Estimate or Algorithm	Sources and assumptions
Wall Insulation		
definition of opportunity	≥25% of net wall area with uninsulated cavities	
savings	heating: 0.02 MMBtu per square foot insulated cooling: 15%*fraction of wall area uninsulated*estimated cooling use	*Ohio Wx evaluation (Blasnik, 1999)*: 183 ccf/year or 0.19 ccf/ft^2 (11.7% of total gas use); 211 ccf/year 0.22 ccf/ft^2 (13.5% of total gas use) — including infiltration benefit from dense-pack cellulose *Iowa Wx evaluation (WECC, 1994)*: 172 ccf/year (15.6% of heating gas use) Wisconsin Wx audit estimate average: 158 ccf/year

Measure	**Estimate or Algorithm**	**Sources and assumptions**
cost	\$0.96 per square foot for masonry walls \$0.825 per square foot all other siding types	Wisconsin Home Performance program assumptions for insulation blown from interior (masonry) and exterior (other siding types)
Ceiling Insulation		
definition of opportunity	≥25% of ceiling area one or more of: attic insulated to R-11 or less attic insulated to >R-12 to <R-25 in home w/ wall insulation or infiltration reduction opportunities cathedral w/ uninsulated cavities	
savings	heating: annual MMBtu/sf = $((1/R_{init})-(1/R_{fin}))*24*HDD/(0.8*1e6)$ where R_{init} = initial section R-value (R-5 minimum) R_{fin} = final section R-value (R-38 for attic space; R-19 for 2X6 cathedral; R-11 for 2X4 cathedral) HDD = annual heating degree days (to PRISM reference temperature, or 60F if no PRISM value) cooling: 10%*fraction of ceiling area to be insulated*estimated cooling use	*Ohio Wx evaluation:* 148 ccf/yr (10.2% of total gas use) *Iowa Wx evaluation:* 65 ccf/yr (5.9% of total gas use) Wisconsin Wx audit estimate average: 108 ccf/yr
cost	\$0.5 per square foot for attic areas with existing insulation of R-11 or less \$0.28 per square foot for attic areas with existing insulation >R-12 to <R-25 \$0.85 per square foot for uninsulated cathedral areas	Wisconsin Home Performance program assumptions for insulation blown from exterior
Rim/Bandjoist Insulation		
definition of opportunity	≥25% of rim/band joist area uninsulated	
savings	heating: MMBtu per square foot of rim/band joist area cooling: negligible	estimate
cost	\$0.40 per square foot insulated	Wisconsin Home Performance program assumptions

Measure	Estimate or Algorithm	Sources and assumptions
Frame Floor Insulation		
definition of opportunity	≥500 sf of frame floor insulated to < R-11	
savings	heating: annual MMBtu/sf = $((1/R_{init})-(1/R_{fin}))*24*HDD/(0.8*1e6)$ where R_{init} = initial section R-value (R-5 minimum) R_{fin} = final section R-value (R-3 per inch * joist height) HDD = annual heating degree days (to PRISM reference temperature, or 60F if no PRISM value) cooling: 10%*fraction of floor area to be insulated*estimated cooling use	estimate
cost	$0.45 per square foot insulated	Wisconsin Home Performance program assumptions for adding batt insulation
Infiltration Reduction		
definition of opportunity	blower-door measured air leakage > 10 air changes per hour @ 50 Pa	
savings	heating: .8 MMBTU per 100 CFM50 reduction where CFM50 reduction = $= 0.6*CFM50_{pre} - 750$ $CFM50_{pre}$ is measured leakage cooling: 10%*(CFM50 reduction/1500) *estimated cooling use	Analysis of pre- and post-treatment blower door readings for homes treated under the Iowa Weatherization program
cost	$100 + $10 per 100 CFM50 reduction	estimate adapted from Wisconsin Home Performance program assumptions
Furnace Replacement		
definition of opportunity	non-condensing furnace >15 years old, supplying at least 50% of total heat for home; if oil, must have natural gas or propane in home	
savings	HEATCONS*PLOAD*(1-0.8/0.9) Where HEATCONS = estimated home heating	estimate, assuming upgrade from 80% AFUE to 90% AFUE

Measure	Estimate or Algorithm	Sources and assumptions
	usage PLOAD = % of total heating load served by furnace to be replaced	
cost	$500 incremental between standard efficiency and condensing	estimate
Water Heater Temperature Reduction		
definition of opportunity	hot water temperature > 135F	
savings	fuel fired: 1 therm per year per degree setback to 125F electric: 18 kWh per year per degree setback to 125F	estimate based on: gas base use regression model (see Appendix B) results (2.6 therms/year/F) Iowa Wx program estimates (avg. 33 therms/yr, 400 kWh/yr) Wisconsin Wx program estimates (avg. 8 therms/yr)
cost	$0	
Water Heater Wrap		
definition of opportunity	unwrapped pre-1987 water heater	
savings	fuel-fired: 1.5 MMBtu/year electric: 250 kWh/year	Iowa Weatherization program estimate
cost	$20	Iowa Wx program data
Low Flow Showerhead		
definition of opportunity	flow rate of existing showerhead > 3.5 gpm	
savings	fuel-fired: 30 therms/year electric: 550 kWh/year	estimate based on: Iowa weatherization program estimate (avg. 40 therms/yr, 738 kWh/yr) Wisconsin weatherization program audit estimates (avg. 28 therms/yr)
cost	$6	Iowa and Wisconsin weatherization program data
Water Heater Fuel Switch		
definition of opportunity	electric water heater older than 10 years in house w/ natural gas or propane	
savings	3250 kWh per year electricity	based on average estimated DHW

Measure	Estimate or Algorithm	Sources and assumptions
	increase of 200 therms per year for gas or propane	use from statistical analysis of natural gas and electricity data
cost	$600	estimate
Refrigerator/Freezer Replacement		
definition of opportunity	refrigerator: ≥ 5 kWh/day, >10 years old freezer: ≥ 4 kWh/day, >10 years old	
savings	refrigerator: annual kWh savings = existing refrigerator annual kWh – 750 freezer: annual kWh savings = existing refrigerator annual kWh – 550 (annual kWh of existing units extrapolated from short-term metering data)	estimate
cost	refrigerator: $700 freezer: $350	estimate
Compact Fluorescent Lighting		
definition of opporutnity	incandescent bulb in the 40-100 Watt range, used 2 hrs/day or more	
savings	annual savings per CFL = existing wattage/3/1000*reported hours of use/day * 365	National Lighting Product Information Program Specifier Report on Screwbase CFLs recommends guideline of replacing incandescent bulbs with CFLs of 1/3 the wattage.
cost	$12 for CFL ≤ 15 Watts $17 for CFL > 15 Watts subtract $5 for avoided incandescent bulbs for life of CFL (10 @ $0.50 each)	estimate

Attitudinal Indices

Measuring Attitudes and Behavior

The relationship between attitudes and behavior has long been problematic. From at least the 1940s social psychological research has shown at best only a weak connection between the two (Wicker 1969). Studies have shown that the more specific both the attitude and its object, the stronger the correlation between attitude and behavior (Heberlein 1981). Some authors have suggested that energy conservation behavior is a specific enough attitude object that we should expect to see strong correlations between energy conservation behavior and attitudes about energy conservation (Van der Pligt 1996). On the one hand, certain aspects of energy consumption lend themselves to the study of conservation behaviors. It is possible to find out from respondents at what temperatures they set their thermostats during different times of the day in order to determine the degree to which they save energy by setting the temperature back at night, for example, or to inventory the types of light bulbs used in a sample of dwellings to measure the frequency of use of compact fluorescent bulbs and the amount of energy saved by their use in each household. On the other hand, energy is invisible, and people do not tend to think of themselves as using energy when they perform mundane routines with household appliances, drive to the store, or turn up the air conditioning (Shove 1997). In short, the existing literature on the relationship between energy attitudes and energy-conserving behavior has left open the possibility that we might be able to identify households who are more likely to conserve energy by measuring the respondents' attitudes and behavior, but suggests that it will not be an easy task.

Creation of the Attitudinal Indices

In an effort to find a link between attitudes toward energy use and energy-related behaviors, we devised a series of indices of attitudes and self-reported behavior based on the questionnaire. To do this, we searched the literature to find examples of successful constructs with which to measure energy attitudes. Of those studies which used constructs rather than individual questions, many focused on attitudes toward issues that were no longer of relevance to current Wisconsin homeowners, such as oil embargoes, energy security, and energy crises. Two studies, however, offered useful questions that had been tested in the field and yielded statistically significant results (Peters 1990; Samuelson & Biek 1991). We combined these questions (edited as necessary in order to simplify the language or to be relevant to respondents living in the snowbelt) with the more successful questions (i.e., questions with responses that were not highly skewed in one direction) included in the pilot study to create the following seven original constructs (see Table B12 for a listing of questions included in each construct):

1. resistance to turning down thermostat;
2. energy conservation-mindedness;
3. link between health and energy use;
4. perception of one's home's energy efficiency;
5. perceived ability to make energy-saving changes;
6. frugality;
7. energy bills as a financial hardship.

Table B12: Original seven constructs

Willingness to turn down thermostat:
"I would be very uncomfortable in the winter if I turned the thermostat setting down three degrees when people are at home and awake." (from Peters 1990) "While others might tolerate turning down the thermostat in the winter, my own need for being warm is high." (from Samuelson & Biek 1991, adjusted for snowbelt)
Energy conservation-orientation:
"It's just not worth putting on more clothing in the winter to try to save a little energy." (originally from S&B, with very slight wording change for readability) "A large amount of energy is wasted in America by individuals who overcool (or overheat) their homes." (from Samuelson & Biek 1991; very similar to question in Peters 1990) "I would only conserve energy if I could not afford to pay for it." (from Samuelson & Biek 1991) "It's my right to use as much energy as I want, as long as I pay for it." "I am not interested in making my home more energy efficient." "I am not interested in making energy-saving improvements to my home." "I always try not to use more electricity than I really need."
Link between health and energy use:
"My family's health would suffer if our home were not heated to its present temperature." (from Peters 1990) "I would probably get more colds and illnesses if I turned down the thermostat in the winter." (from Peters 1990) "Outdoor air is much better for my family's health than indoor air." "It is essential to my family's health to use air conditioning to stay cool in the summer." (from Samuelson & Biek 1991, with very slight wording change for readability)
Perception of one's home's energy efficiency:
"My home is very energy efficient." "There's nothing more I can do to cut back on my home's energy use."
Perceived ability to make energy-saving changes:
"My life is too busy to deal with energy-saving improvements in my home." "I only use electricity when it's really needed; there's no way I could cut down." "I have a great deal of control over how energy is used in this home."
Frugality:
"I am willing to keep the house a little chilly in order to lower my energy bills." "I have to conserve electricity in my home because I can't afford to pay higher utility bills."
Energy bills as a financial hardship:
"My energy bills are about as low as they can get." "My annual energy bills don't amount to much compared to my other expenses." "Paying the energy bills is a financial hardship for our family."

We conducted a factor analysis on the attitudinal data in order to measure the reliability of our constructs and to determine if there were other ways to group the variables that would better measure the attitudes in which we were interested. Because few of the attitudinal questions asked in the pilot questionnaire survived in the full-scale questionnaire, only the 277 households that completed the full-scale version of the questionnaire were included in the analysis. However, this number is more than adequate for performing a factor analysis (Hair et al.1995).

After dropping from the analysis those attitudinal variables that did not have significant correlations with any of the other attitudinal variables and those with unacceptably low measures of sampling adequacy, we performed the factor analysis using an orthogonal (varimax) rotation with the remaining variables (Table B13). Five attitudinal components emerged from the final factor analysis; four of these had significant eigenvalues, held together theoretically, and had high reliability as measured by Cronbach's alpha scores.

The four attitudinal indices, including the questions that comprise them and their respective Cronbach's alphas, are listed below. Note that cases that had missing answers to any of the attitudinal questions in a particular index were coded as missing for that index.

1. *Energy conservation-orientation*. Cases with low scores for this index are less inclined to exhibit favorable attitudes toward energy conservation; cases with high scores, more inclined.

   - "I am not interested in making energy-saving improvements to my home."
   - "It's just not worth putting on more clothing in the winter to try to save a little energy."
   - "I would only conserve energy if I could not afford to pay for it."
   - "I am not interested in making my home more efficient."

   Standardized Cronbach's alpha=.6616

2. Perception of household's ability to make energy-saving changes. Cases with low scores for this index perceive fewer opportunities to save energy at home than do cases with high scores.
   - "I only use electricity when it's really needed; there's no way I could cut down."
   - "There's nothing more I can do to cut back on my home's energy use."
   - "My energy bills are about as low as they can get."

   Standardized Cronbach's alpha=.6824

3. *Willingness to turn down thermostat*. Cases with low scores for this index see more barriers to turning down their thermostats, and can be expect to be resistant to doing this; cases with higher scores see fewer barriers and can be expected to be more willing to turn down their thermostats.

   - "My family's health would suffer if our home were not heated to its present temperature."
   - "I would be very uncomfortable in the winter if I turned the thermostat setting down three degrees when people are at home and awake."
   - "I would probably get more colds and illnesses if I turned down the thermostat in the winter."

   Standardized Cronbach's alpha=.6581

4. *Perception of household's energy bills as a financial hardship*. Cases with high scores for this index perceive their energy bills as more of a financial hardship than do cases with low scores.

   - "I have to conserve energy in my home because I can't afford to pay higher utility bills."
   - "Paying the energy bills is a financial hardship for our family."

   Standardized Cronbach's alpha=.6648

Table B13: Rotated component matrix

	Component				
	1	2	3	4	5
Q55b. Not interested in making energy-saving improvements	.739	3.314E-02	-4.086E-02	.251	-3.397E-02
Q55c. Large amt energy wasted by overcooling/overheating	1.088E-02	-.148	-9.047E-02	.119	.725
Q55d. Not worth putting on more clothing to save energy	.583	.118	.263	-9.366E-02	-.309
Q55e. Only conserve if couldn't afford to pay	.632	4.714E-02	.289	-6.751E-02	-1.566E-02
Q55f. Always try not to use more than really need	-9.958E-02	.211	.245	6.490E-02	.604
Q55g. Family's health would suffer	.152	6.557E-02	.742	.185	3.709E-04
Q55l. Very uncomfortable if turned down thermostat	-1.205E-02	3.819E-02	.772	-.229	5.209E-02
Q55ov2. Have to conserve energy/can't afford higher bills	-4.924E-02	6.189E-02	.126	.785	4.404E-02
Q55p. Probably get more colds & illnesses	.121	.127	.691	.223	-.150
Q55t. Great deal of control over energy use in this home	-4.389E-03	.345	-5.361E-02	-.296	.514
Q55u. Only use electricity when really needed	9.542E-02	.700	.114	.316	3.196E-03
Q55v. Paying energy bills a financial hardship	8.899E-02	2.532E-02	-1.276E-02	.839	-3.667E-02
Q55w. Not interested in making home more energy efficient	.729	.159	-6.535E-02	-3.308E-02	-8.715E-02
Q55xv2. Nothing more I can do to cut back	.228	.792	7.963E-02	9.682E-02	-2.234E-02
Q55y. Too busy to deal with energy-saving improvements	.264	9.057E-02	.145	9.204E-02	-.587
Q55z. Bills as low as can get	2.753E-02	.763	6.366E-02	-.194	3.909E-02

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 6 iterations.

n=120

Results

Attitudinal Constructs and Demographic Variables

Table B14 shows relationships between several demographic indicators and the attitudinal constructs. Age, sex, and education were measured for the person in the household who was primarily responsible for filling out the questionnaire.

Table B14: Means of attitudinal constructs by selected demographic items

	n	Conservation-Orientation		Perception of Ability to Make Energy-Saving Changes		Perception of Energy Bills as Financial Hardship		Willingness to Turn Down Thermostat	
Scale Range		4 to 16		3 to 12		2 to 8		3 to 12	
Sex of primary respondent									
a. Male	140	13.8		8.4		4.2		6.9	
b. Female	132	14.2		8.8		4.4		6.9	
Age of primary respondent									
a. 18 to 29	14	14.2		9.6	f***	4.5		8.7	
b. 30 to 39	73	14.0		9	f***	4.1		7.9	
c. 40 to 49	75	14.3		8.9	f***	4.3		8.6	f*
d. 50 to 59	44	14.0		8.5	f***	4.3		8.2	
e. 60 to 69	32	14.1		8.4	f***	4.5		8.4	
f. 70 and over	37	12.8	c*	6.9	a-e***	4.3		7.0	c*
Education of primary respondent3									
a. Up to high school graduate	97	13.7	c*	8.2	c*	4.6	c*	8.1	
b. Some college, but no degree	112	13.6	c*	8.5		4.3		8.2	
c. BA or higher	67	14.6	a,b*	9.1	a*	3.9	a*	7.9	
Subgroup status									
a. Low Income	43	13.4		7.8		5.6	b,c***	7.6	
b. New Construction	42	13.9		8.8		3.8	a***	8.4	
c. General Population	192	14.0		8.6		4.4	a***	8.1	
Annual income									
a. Less than $10k	9	14.4		8.5		6.2	f-1***	6.4	
b. $10k -14.9k	13	13.1		7.8		5.8		9.3	

	n	Conservation-Orientation	Perception of Ability to Make Energy-Saving Changes		Perception of Energy Bills as Financial Hardship		Willingness to Turn Down Thermostat
Scale Range		4 to 16	3 to 12		2 to 8		3 to 12
c. $15k-19.9k	15	14.0	7.1	h,i**	4.7		7.5
d. $20k - 24.9k	16	12.5	7.3	h,i**	4.5		7
e. $25k - 29.9k	12	13.0	8		4.4		8.2
f. $30k - 34.9k	27	13.5	8.6		4.8	a***	8.1
g. $35k - 49.9k	59	14.2	8.5		4.4	a***	8.2
h. $50k - 74.9k	66	14.5	9.1	c,d**	3.7	a***	8.1
i. $75k and up	46	14.1	9.1	c,d**	3.4	a***	8.5
Years lived in house							
a. Less than 1 year	26	13.7	9.3		4.0		8.7
b. 1 to 2 years	28	14.6	9.1		4.9		7.6
c. 3 to 4 years	41	13.5	8.5		4.6		7.6
d. 5 to 10 years	72	14.0	8.7		3.9		8.5
e. More than 10 years	110	13.8	8.2		4.4		7.9

Notes:

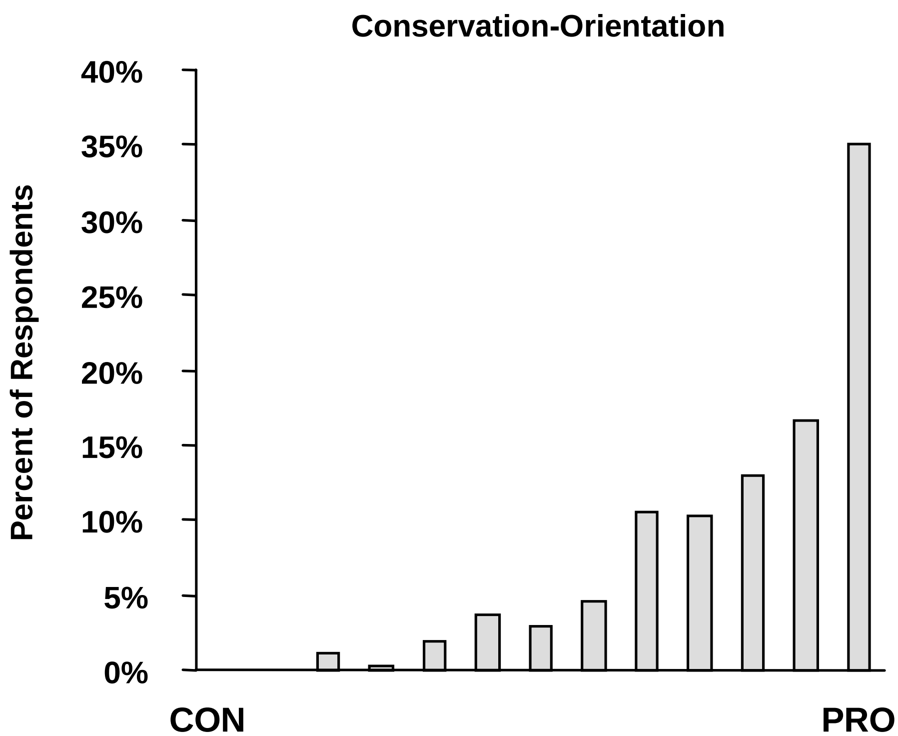
* p<.05; ** p<.005; *** p<.000 for 2-way t-test of difference of means

Overall n for the study is 299; N for completed questionnaires is 296. However, due to missing responses and slight variations between the pilot and full-scale versions of the questionnaire, n varies slightly from question to question. Because the four attitudinal constructs could not be calculated for all cases due to missing values, n for a particular construct may vary slightly from the reported n.

“Primary respondent” refers to the person who filled out the questionnaire.

Conservation-orientation. Education appears to be directly associated with conservation-orientation, with those respondents with higher levels of education showing higher levels of conservation-orientation than those with less education. The relationship between conservation-orientation and income is unclear; there is a statistically significant correlation between these two variables, which suggests that those respondents with higher incomes are more favorably oriented toward energy conservation. However, the fact that there is no relationship between conservation-orientation and whether respondents fall into the low income subgroup contradicts this. While the distribution of scores on the conservation-orientation construct indicates that our sample is highly favorably oriented toward energy conservation (Figure B7), the fact that we have a range of scores from highly conservation-oriented to not at all conservation-oriented allows us to make inferences from this variable.

Figure B7: Distribution of conservation-orientation score



Perception of the household's ability to make energy-saving changes. Age appears to be inversely related to perception of the household's ability to make energy-saving changes, with older respondents perceiving less opportunity to make energy-saving changes. Education appears to be related to perception of the household's ability to make energy-saving changes, with more educated respondents seeing more room to make these changes. This could be because those who are better educated are more aware of opportunities—especially technical ones—to increase their energy efficiency. However, the high correlation between education and income (r^2=.455) suggests that this relationship may be influenced by the fact that more highly educated respondents may also be able to consider spending more money to save energy, and so perceive as within their reach opportunities that lower income respondents would not be able to consider.

Perception of the household's energy bills as a financial hardship. Households that fall into the low income category report seeing their energy bills as a financial hardship significantly more frequently than those households that are neither low income nor living in new construction. Households living in new construction report the lowest scores for this construct, indicating that they are significantly less likely than both the other two groups to perceive paying their energy bills as a financial hardship.

Willingness to turn down the thermostat. There is no relationship between this construct and any of the demographic variables.

Energy Conservation-orientation and Self-Reported Energy-Saving Behavior

The negative and statistically significant correlation (r=-.2002, p=.002) between conservation-orientation and the average winter thermostat setting (calculated from the self-reported temperature settings asked on the questionnaire, with the daytime setting when no one is home weighted by the number of hours someone is at home between 8 a.m.

and 5 p.m. on weekdays) indicates that respondents who are more conservation-oriented report keeping their thermostats set lower on average than their less conservation-oriented counterparts.

Table B15 shows relationships between the attitudinal constructs and a series of individual variables, some of which are measures of energy-saving behavior. The mean conservation-orientation scores of respondents giving various different answers to the individual measures of energy-saving behavior vary little. Thus, respondents who have installed compact fluorescent lights, who do not have air conditioning or (if they do have air conditioning) who take their units out of the window during the winter, who believe that their houses are well-insulated, or who wash at least half of their laundry loads in cold water score no higher on the conservation-orientation index than do those who report not practicing these energy-saving behaviors. Those households with air conditioning who report not using it actually have lower conservation-orientation scores than those who report using it sparingly. However, households with programmable thermostats have slighter higher conservation-orientation scores than those with manual thermostats (with means of 14.4 versus 13.8, respectively; $p<.05$). According to our data, then, being attitudinally inclined toward energy conservation translates into action only at the thermostat.

Other Attitudinal Constructs and Self-Reported Behavior

A number of predictable relationships to be found between the other attitudinal constructs and the rest of the self-reported data are shown in Table B15. Respondents who report already having installed compact fluorescent lights see fewer opportunities for their households to make energy-saving changes, as do those who do not have air conditioning. Not surprisingly, respondents who see their energy bills as more of a financial hardship are less likely to report having installed compact fluorescent lights, tend to report having lower levels of insulation in their homes, and are less likely to have air conditioning. The results in Table B16 indicate that respondents whose attitude scores suggest that they would be less willing to turn down their thermostats in the winter do indeed report higher average winter thermostat settings than the rest of the sample. Some of the attitudinal constructs are relatively highly correlated with each other, also in predictable ways. Specifically, respondents who are more conservation- oriented also see their households as having more opportunity or ability to make energy-saving changes, and show greater willingness to turn down their thermostats in the winter. Those respondents who see greater opportunity for making energy-saving changes in their households also show greater willingness to turn down their thermostats, as do those who see paying the energy bills as more of a financial hardship. These statistically significant relationships are exactly what we would expect given the attitudes that these constructs are meant to measure. The results offer support that these constructs appear to be successfully measuring the respective attitudes.

Table B15: Means of attitudinal constructs by selected independent variables

	n	Conservation-Mindedness		Perception of Ability to Make Energy-Saving Changes		Perception of Energy Bills as Financial Hardship		Willingness to Turn Down Thermostat
Have you installed any compact fluorescent lights?								
a. Yes	87	14.1		7.9	b**	3.9	c**	8.2
b. No	183	14.0		8.9	a**	4.4	c**	8.1
c. Don't know	6	12.8		8.5		6.1	a,b**	7
If you have a window air conditioning unit(s), what do you do with it in the winter?								
a. Take the unit out of the window	47	13.9		8.9		4.6		7.5
b. Leave it in with a cover on	10	13.9		8		3.7		6.4
c. Leave it in with no cover	3	11.4		7.1		3.6		5.7
Overall, how well is your home insulated?								
a. No insulation	6	13.8		8.7		5.4		8.9
b. Poorly insulated	22	13.8		8.9		4.5		7.6
c. Adequately insulated	105	14.1		8.8		4.4		8.2
d. Well insulated	109	13.7		8.2		3.9	e**	7.8
e. Don't know	34	14.0		9		5.1	d**	8.6
Do you have air conditioning in your home?								
a. Yes	199	14.0		8.7	b*	4.1	b*	8.1
b. No	78	13.8		8.1	a*	4.7	a*	8
How familiar are you with your household's monthly energy bills?								
a. Not very familiar	23	12.9	c*	7.9		3.6	b*	7.3
b. Somewhat familiar	74	13.9		8.7		4.6	a*	8.1
c. Very familiar	178	14.1	a*	8.6		4.2		8.2

	n	Conservation-Mindedness	Perception of Ability to Make Energy-Saving Changes		Perception of Energy Bills as Financial Hardship	Willingness to Turn Down Thermostat
Which of these statements best describes the way you used your air conditioner(s) last summer?						
a. Not used at all	4	7.7	8.9	b-e**	4.4	7.7
b. Turned on only a few days or nights when really needed	94	8.0	8.6	a**	4.4	8
c. Turned on a few times each week	30	8.9	9.5	a**	4	8.9
d. Turned on just about all summer	20	7.5	8	a**	3.9	7.5
e. Let the thermostat control how much it ran	42	8.0	8.5	a**	3.9	8
Does at least half of laundry loads using only cold water:						
a. Yes	45	14.1	9		4.4	8.1
b. No	207	14.0	8.5		4.2	8.1

Notes:

* p<.05; ** p<.005 for 2-way t-test of difference in means

Overall n for the study is 299; n for completed questionnaires is 296. However, due to missing responses and slight variations between the pilot and full-scale versions of the questionnaire, n varies slightly from question to question. Because the four attitudinal constructs could not be calculated for all cases due to missing values, n for a particular construct may vary slightly from the reported n.

Conservation-orientation and Audit Data

To determine whether there is any relationship between conservation-orientation and the presence or absence of actual energy-saving measures as recorded by the auditors, we ran a series of logistic regression models using binary variables for the presence or absence of the energy saving opportunities defined earlier as the independent variables and conservation-orientation and perceived ability to make energy-saving changes as the dependent variables. The results (Table B17) indicate that households with high scores on the conservation-orientation index, while they are more likely than the rest of the sample to report lower average thermostat settings, are no more likely to make energy-saving investments in their houses (with the single exception of reducing infiltration) or to report practicing other energy-saving behaviors. They also show that households who perceive more opportunities to save energy in their house are no more likely to make energy-saving changes than are other households, except for an increased likelihood of opportunities for CFL retrofits, and a decreased likelihood for refrigerator replacement.

Table B16: Correlations among attitudinal constructs and average winter thermostat setting

		Conservation-orientation	Ability to make energy-saving changes	Energy bills as a financial hardship	Willingness to turn down thermostat	Average winter thermostat setting
Conservation-orientation	Pearson Correlation	1.0000				
(lower score, less conservation-oriented)	Sig. (2-tailed)	.				
	N	273				
Ability to make energy-saving changes	Pearson Correlation	0.2868 ***	1.0000			
(lower score, less perceived ability to make energy-saving changes)	N	241	245			
Energy bills as a financial hardship	Pearson Correlation	-0.0868	-0.0547	1.0000		
(lower score, energy bills seen as less of a financial hardship)	N	241	244	244		
Willingness to turn down thermostat	Pearson Correlation	0.2343 ***	0.2279 ***	-0.1258	1.0000	
(lower score, less willing to turn down thermostat in winter)	N	272	244	243	276	
Average winter thermostat setting	Pearson Correlation	-0.2002 **	0.0035	0.1289	-0.2576 ***	1.0000
	N	234	204	204	235	236

* p<.05, ** p<.005, *** p<.0005

Table B17: Logistic regression of energy efficiency opportunities on attitude indices

	Odds ratio	Std. error	z	P>|z|
Independent variable: index of conservation orientation				
Dependent variable				
wall insulation	1.032	0.085	0.379	0.705
ceiling insulation	0.965	0.063	-0.546	0.585
frame floor insulation	0.798	0.097	-1.858	0.063
rim joist insulation	1.018	0.068	0.272	0.786
infiltration reduction	0.814	0.051	-3.308	0.001
furnace replacement	1.287	0.181	1.799	0.072
water heater fuel switch	0.890	0.098	-1.055	0.291
water heater temperature reduction	0.939	0.057	-1.037	0.300
water heater wrap	1.015	0.075	0.198	0.843
low-flow showerhead	0.864	0.146	-0.866	0.387
refrigerator replacement	0.938	0.084	-0.710	0.478
compact fluorescent	0.972	0.061	-0.452	0.651
Independent variable: index of perceived ability to reduce energy use				
Dependent variable				
wall insulation	1.066	0.109	0.631	0.528
ceiling insulation	1.047	0.088	0.542	0.588
frame floor insulation	0.692	0.116	-2.188	0.029
rim joist insulation	1.028	0.086	0.331	0.740
infiltration reduction	0.986	0.082	-0.166	0.868
furnace replacement	1.217	0.160	1.498	0.134
water heater fuel switch	0.850	0.133	-1.040	0.298
water heater temperature reduction	1.091	0.088	1.084	0.278
water heater wrap	0.972	0.086	-0.321	0.748
low-flow showerhead	0.741	0.209	-1.061	0.288
refrigerator replacement	0.786	0.092	-2.061	0.039
compact fluorescent	1.261	0.099	2.967	0.003

Index of Winter Comfort

Winter

The winter cold and draftiness index was created in two parts. First, answers to questions 42a ("How often do you or other members of your household find your home too cold during the winter?") and 42c ("How often do you or other members of your household find your too drafty during the winter?") from the questionnaire were combined to create a scale from 1 (Never too cold/drafty) to 3 (Always too cold/drafty), as follows, for the full-scale and pilot cases:

Table B18: Initial winter comfort—full-scale study

		Q42c—Too Drafty				
		Never	Sometimes	Most times	Always	Missing
Q42a — Too Cold	Never	1	2	3	3	(missing)
	Rarely	1	2	3	3	(missing)
	Sometimes	2	2	3	3	(missing)
	Most times	3	3	3	3	3
	Always	3	3	3	3	3
	Missing	(missing)	(missing)	3	3	(missing)

Table B19: Initial winter comfort—pilot study

		Q42c—Too Drafty				
		Rarely or Never	Sometimes	Most times	Always	Missing
Q42a — Too Cold	Rarely or Never	1	2	3	3	(missing)
	Sometimes	2	2	3	3	(missing)
	Most times	3	3	3	3	3
	Always	3	3	3	3	3
	Missing	(missing)	(missing)	3	3	(missing)

Unweighted frequencies for this intermediate scaling are:

Table B20: Winter comfort frequencies, intermediate scaling

Index	n	Percent
1	120	40.5
2	156	52.2
3	16	5.4
(missing)	7	2.3
Total	299	100.0

To further differentiate the middle category, 2, the index was then split into four categories based on the responses to the open-ended question 41, “Are there specific places in your home where—or times when—you or members of your household often feel too cold or feel uncomfortable drafts?”[1]

Table B21: Frequencies of responses to question 41

Initial index	Q41, Places or times where it's cold or there are uncomfortable drafts	Final index
1	n/a	1
2	Nothing listed	2
2	Time or place listed	3
3	n/a	4

1 Note that there were no candidates for recoding that reported the basement for q41 but did not use it as a living space.

The final index for winter cold and draftiness runs from 1 (Never too cold/drafty) to 4 (Always too cold/drafty). Unweighted frequencies for the final index are listed below.

Table B22: Winter comfort frequencies, final scaling

Index	n	Percent
1	120	40.1
2	48	16.0
3	108	36.1
4	16	5.3
Missing	7	2.3
Total	299	100.0

Summer

The summer heat and humidity index was created by combining answers to questions 49a ("How often do you or other members of your household find your home too hot during the summer?") and 50a ("How often do you or other members of your household find your home too humid during the summer?") from the questionnaire. Answers were scaled as follows:

Table B23: Summer comfort scale—full-scale study

		Q50a —Too Humid					
		Never	Rarely	Sometimes	Most times	Always	Missing
Q49a — Too Hot	Never	1	1	2	3	3	(missing)
	Rarely	1	1	2	3	3	(missing)
	Sometimes	2	2	2	3	3	(missing)
	Most times	3	3	3	3	3	3
	Always	3	3	3	3	3	3
	Missing	(missing)	(missing)	(missing)	3	3	(missing)

Table B24: Summer heat and humidity—pilot study

		Q50a—Too Humid				
		Rarely or Never	Sometimes	Most times	Always	Missing
Q49a — Too Hot	Rarely or Never	1	2	3	3	(missing)
	Sometimes	2	2	3	3	(missing)
	Most times	3	3	3	3	3
	Always	3	3	3	3	3
	Missing	(missing)	(missing)	3	3	(missing)

The unweighted frequencies for this scale are as follows:

Table B25: Summer comfort index frequenices

Index	n	Percent
1	81	27.1
2	185	61.9
3	22	7.3
Missing	11	3.7
Total	299	100.0

The tables that follow are crosstabulations of the comfort indices with select items from the questionnaire and physical data.

Table B26: Means of self-reported winter comfort by selected variables

	n	Winter Comfort (mean)	
Year home was built			
a. 1995 or later	24	1.91	
b. 1990 to 1994	32	1.54	i*
c. 1980 to 1989	33	1.99	
d. 1970 to 1979	55	2.01	
e. 1960 to 1969	31	2.06	

		n	Winter Comfort (mean)	
f.	1950 to 1959	31	1.83	
g.	1940 to 1949	20	2.36	
h.	1930 to 1939	13	2.40	
i.	1929 or earlier	49	2.28	b*
	Total	288	2.02	
Years lived in home				
a.	Less than 1 year	25	2.12	
b.	1 to 2 years	27	2.39	
c.	3 to 4 years	33	2.15	
d.	5 to 10 years	87	2.01	
e.	More than 10 years	119	1.90	
	Total	291	2.03	
How well is your home insulated?				
a.	No insulation	8	2.25	
b.	Poorly insulated	18	2.56	d***
c.	Adequately insulated	110	2.19	b***
d.	Well insulated	114	1.69	b,c,e***
e.	Don't know	39	2.30	d***
	Total	289	2.03	
Agreement about temperature setting among family members (excludes single-member households)				
a.	Rarely or never agreed	26	2.55	c,d***
b.	Sometimes agreed	29	2.56	c,d***
c.	Usually agreed	161	1.95	a,b***
d.	Always agreed	51	1.78	a,b***
	Total	267	2.04	
Ability to make home more comfortable when it is cold				
a.	Never	0	0.00	
b.	Some of the time	14	2.57	d***
c.	Most of the time	89	2.50	d***
d.	Always	164	1.72	b,c***

		n	Winter Comfort (mean)	
	Total	267	2.02	
Ability to make home more comfortable when it is drafty				
a.	Never	5	2.53	
b.	Some of the time	19	2.76	d***
c.	Most of the time	70	2.58	d***
d.	Always	110	1.82	b,c***
	Total	204	2.19	
Q8a. Plan on major remodeling				
	No	230	1.93	***
	Yes	60	2.42	
	Total	291	2.03	

* p<.05; ** p<.005; ***p<.001

Table B27. Means of self-reported summer comfort by selected variables

		n	Summer Comfort (mean)	
Presence of air conditioning				
	Air conditioning (central or window)	211	1.79	
	No air conditioning	77	1.83	
	Total	288	1.80	
Room versus central air conditioning				
	Room AC only	57	1.97	**
	CAC	154	1.72	
	Total	211	1.79	
How did you use your air conditioning last summer?				
a.	Not used at all	5	2.00	
b.	Turned on only a few days or nights	102	1.88	e**
c.	Turned on a few times each week	34	1.90	e**
d.	Turned on just about all summer	23	1.78	
e.	Let thermostat control how much it ran	40	1.50	b,c**
	Total	205	1.80	
Dehumidifier use				
a.	It is rarely used	19	1.87	
b.	It is used for a part of the summer	45	1.70	
c.	It is used all summer long	119	1.77	
	Total	183	1.77	
Ability to make home more comfortable when it is hot				
a.	Rarely or never	3	2.31	
b.	Some of the time	49	2.02	d***
c.	Most of the time	136	1.86	d***
d.	Always	92	1.64	b,c***
	Total	280	1.82	

* p<.05; ** p<.005; ***p<.001

Table B28: Correlations among winter comfort and self-reported thermostat setting behaviors

		Continuous measure of night setback		Continuous measure of setback when no one home		Continuous measure of vacation setback		Average self-reported winter thermostat setting	Winter comfort index
Continuous measure of night setback	Pearson Correlation	1							
	N	284							
Continuous measure of setback when no one home	Pearson Correlation	0.628	**	1					
	N	266		273					
Continuous measure of vacation setback	Pearson Correlation	0.374	**	0.385	**	1			
	N	198		201		204			
Average self-reported winter thermostat setting	Pearson Correlation	-0.251	**	-0.236	**	0.179	*	1	
	N	262		254		187		262	
Winter comfort index	Pearson Correlation	0.015		0.036		0.092		0.068	1
	N	278		271		202		260	291

* p<.05, ** p<.005

Table B29: Means of winter comfort by mitigating behaviors

		n	Winter Comfort (mean)	
Q42e. Turn up thermostat				
a.	Never	47	1.80	
b.	Some of the time	136	2.10	
c.	Most of the time	54	2.23	d*
d.	Always	30	1.64	c*
	Total	267	2.03	
Q42f. Start fire in fireplace				
a.	Never	169	1.96	
b.	Some of the time	56	2.08	
c.	Most of the time	18	2.10	
d.	Always	13	2.18	
	Total	257	2.01	
Q42g. Turn on portable heater				
a.	Never	205	1.97	
b.	Some of the time	44	2.37	
c.	Most of the time	6	2.20	
d.	Always	1	1.00	
	Total	256	2.04	
Q42h. Turn on oven				
a.	Never	250	2.02	
b.	Some of the time	11	2.28	
c.	Most of the time	0	0.00	
d.	Always	0	0.00	
	Total	261	2.03	
Q42i. More to more comfortable part of house				
a.	Never	130	1.69	b,c***
b.	Some of the time	96	2.36	a***

		n	Winter Comfort (mean)	
c.	Most of the time	31	2.43	a***
d.	Always	3	2.41	
	Total	261	2.03	
Q42j. Put on more clothing/blanket				
a.	Never	28	1.30	b,c***
b.	Some of the time	104	1.97	a***
c.	Most of the time	98	2.24	a***
d.	Always	36	2.19	
	Total	266	2.03	

* p<.05; ** p<.005; ***p<.001

Table B30: Means of summer comfort by mitigating behaviors

		n	Summer Comfort (mean)
Q49c. Turn on the CAC (includes only households with CAC)			
a.	Rarely or never	60	1.95
b.	Some of the time	43	1.75
c.	Most of the time	61	1.76
d.	Always	37	1.65
	Total	201	1.79
Q49d. Turn CAC to cooler setting (includes only households with CAC)			
a.	Rarely or never	90	1.81
b.	Some of the time	77	1.82
c.	Most of the time	19	1.75
d.	Always	11	1.58
	Total	198	1.79
Q49e. Turn on room AC			

		n	Summer Comfort (mean)	
(includes only households with room AC)				
a.	Rarely or never	3	2.24	
b.	Some of the time	14	1.95	
c.	Most of the time	23	1.95	
d.	Always	16	2.03	
	Total	56	1.99	
Q49f. Turn room AC to cooler setting (includes only households with room AC)				
a.	Rarely or never	10	2.00	
b.	Some of the time	24	1.85	
c.	Most of the time	16	2.07	
d.	Always	5	2.19	
	Total	55	1.97	
Q49g. Turn on fans				
a.	Rarely or never	31	1.60	
b.	Some of the time	85	1.76	
c.	Most of the time	91	1.86	
d.	Always	73	1.87	
	Total	279	1.80	
Q49h. Open windows or doors				
a.	Rarely or never	40	1.66	
b.	Some of the time	79	1.81	
c.	Most of the time	84	1.79	
d.	Always	75	1.87	
	Total	277	1.80	
Q49i. Wear lighter clothing				
a.	Rarely or never	19	1.35	b,c,d***
b.	Some of the time	44	1.74	a***
c.	Most of the time	104	1.79	a***
d.	Always	113	1.92	a***

		n	Summer Comfort (mean)	
	Total	281	1.81	
Q49j. Move to a more comfortable part of house				
a.	Rarely or never	97	1.63	b,c**
b.	Some of the time	96	1.90	a**
c.	Most of the time	56	1.92	a**
d.	Always	29	1.87	
	Total	278	1.81	
Q49k. Close shades/blinds				
a.	Rarely or never	37	1.64	
b.	Some of the time	71	1.79	
c.	Most of the time	80	1.83	
d.	Always	95	1.84	
	Total	283	1.80	

* p<.05; ** p<.005; ***p<.001

Table B31: Correlations between comfort and attitudinal indices

		Index of winter cold and draftiness	Index of summer heat and humidity	Conservation-orientation	Ability to make energy-saving changes	Energy bills as a financial hardship	Willingness to turn down thermostat
Index of winter cold and draftiness (lower score, less cold & draftiness)	r	1.0000					
	n	291					
Index of summer heat and humidity (lower score, less heat & humidity)	r	0.2284***	1.0000				
	n	284	288				
Conservation-orientation (lower score, less conservation-oriented)	r	0.0694	0.0688	1.0000			
	n	270	267	273			
Ability to make energy-saving changes (lower score, less perceived ability to make energy-saving changes)	r	0.2424***	0.0905	0.2868***	1.0000		
	n	241	239	241	245		
Energy bills as a financial hardship (lower score, energy bills seen as less of a financial hardship)	r	-0.2010**	-0.0801	0.0868	0.0547	1.0000	
	n	240	238	241	244	244	
Willingness to turn down thermostat (lower score, less willing to turn down thermostat in winter)	r	-0.0153	0.0014	0.2343***	0.2279***	0.1258	1.0000
	n	272	268	272	244	243	276

r = Pearson correlation

* p<.05, ** p<.005, *** p<.0005

Table B32: Means of winter comfort by energy-saving opportunities from audit

	n	Mean
More than 25% of ceiling area is uninsulated		
No	183	1.94
Yes	107	2.31*
Total	291	2.03
More than 25% of wall area is uninsulated		
No	247	1.95
Yes	44	2.50**
Total	291	2.03
Rim joists substantially uninsulated		
No	226	1.99
Yes	65	2.15
Total	291	2.03
Candidate for water heater fuel switch		
No	268	2.04
Yes	21	1.86
Total	288	2.03
Water heater temperature is set too high		
No	219	2.04
Yes	68	1.95
Total	287	2.02
Candidate for water heater wrap		
No	220	2.07
Yes	68	1.91
Total	288	2.03
Infiltration over 0.5 estimated natural air exchanges/hour		
No	213	1.94
Yes	67	2.33*
Total	280	2.03

* p<.05; ** p<.005

Table B33: Means of summer comfort by energy-saving opportunities from audit

	n	Mean
More than 25% of ceiling area is uninsulated		
No	220	1.80
Yes	68	1.79
Total	288	1.80
More than 25% of wall area is uninsulated		
No	243	1.79
Yes	46	1.83
Total	288	1.79
Rim joists substantially uninsulated		
No	223	1.75
Yes	66	1.98*
Total	288	1.80
Candidate for water heater fuel switch		
No	266	1.80
Yes	21	1.85
Total	286	1.80
Water heater temperature is set too high		
No	220	1.84
Yes	65	1.69
Total	285	1.80
Candidate for water heater wrap		
No	220	1.78
Yes	66	1.86
Total	286	1.80
Infiltration over 0.5 estimated natural air exchanges/hour		
No	209	1.82
Yes	68	1.77
Total	277	1.81

* p<.05; ** p<.005

Analysis of Thermostat Setting Behavior

Conservation-orientation and Thermostat Use

As the only energy-conserving behavior that can be predicted by conservation-orientation is having a programmable thermostat and reporting a lower average winter thermostat setting, it is worth delving deeper into the relationship between conservation-orientation and behaviors associated with thermostat use. Here, we bring in to the analysis both physical data and data gathered in the structured interviews. The combination of questionnaire, physical, and qualitative data yields important insights about thermostat use and conservation-orientation that each type of data viewed alone cannot provide.

Thermostat type and self-reported thermostat setting Table B34 shows the distribution of types of thermostats in the sample.[2]

Table B34: Thermostat distribution and use

	n	Overall	Manual thermostat	Programmable thermostat
		(percent)		
Type of thermostat used†	297	100.0	66.6	33.4
Percent of those with programmable thermostats who report using its automatic features	99		n/a	82.8
Mean reported temperature during . . .		(degrees F)		
Sleeping hours	281	66.5	66.9	65.7*
When someone is awake at home	287	68.9	68.7	69.4*
When no one was home during the day	268	66.2	66.4	65.8
When the household was away on vacation	198	61.1	61.2	60.9
Self-reported thermostat setpoint (weighted for weekday hours house is occupied; excluding vacation settings)	249	67.8	67.8	67.7
		(hours)		
Mean hours someone is at home weekdays between 8 a.m. and 5 p.m.	261	28.6	28.9	28.1

† Two households without thermostats are not included in the percentages reported on this table.

* p<.05 for difference in means between manual and programmable thermostats

Two-thirds of households in the sample use manual thermostats to regulate their heating systems, and one-third use programmable thermostats. From questions posed as part of ECW's AST surveys in 1995, 1997, and 1999, it appears that the saturation of programmable thermostats is rising in Wisconsin at an average rate of about 2.5 percent

[2] The thermostat types reported in the text and tables were verified by the auditors when they collected the physical data.

per year, from 25 percent in 1995 to 30 percent in 1997 to 36 percent in 1999. We asked respondents to tell us at what temperatures they kept their home during sleeping hours, when someone was at home during the day, and when no one was at home during the day. This information was used to calculate both day and night setbacks and an average self-reported winter thermostat setting (weighted for the hours respondents told us someone was at home during weekdays between 8 a.m. and 5 p.m.), to which we will refer as the "self-reported thermostat setpoint." The self-reported thermostat setpoint ranged from 59°F to 74°F, with a mean of 68°F. While both households with manual and with programmable thermostats reported setting back their thermostats at night and during the day when no one is home, we found that their setback practices varied. Table B35 shows that households with programmable thermostats are much less likely to keep their thermostats at a constant temperature, and report steeper setbacks both at night and during the day when no one is home, than do households with manual thermostats. At the same time, households with programmable thermostats report slightly higher settings during the day when someone is home, which we estimate to be the case well over half the time on average. This appears to largely offset the setbacks during other periods of the day, so that the self-reported setpoint is nearly the same between the two groups. If these self-reported data are accurate (an issue we will examine later), it implies that the mere presence of a programmable thermostat in a home has a minimal effect on heating energy use on average.

Table B35: Crosstabulation of day and night setback practices by thermostat type

	Overall	Manual thermostat	Programmable thermostat
Night setback practices (n=278):*			
Set up	4.3	5.9	1.1
No change	38.8	49.7	17.2
Setback 1-4 degrees	30.6	22.2	47.3
Setback 5+ degrees	26.3	22.2	34.4
Column totals	100.0	100.0	100.0
Day setback practices (n=269):*			
Set up	0.7	0.5	1.2
No change	44.6	53.0	26.7
Setback 1-4 degrees	26.8	20.8	39.5
Setback 5+ degrees	27.9	25.7	32.6
Column totals	100.0	100.0	100.0

* Chi-square tests for both cross-tabulations are significant at $p<.001$.

Thermostat Type, Behavior, Conservation-Orientation, and Actual Energy Use: Regression Models

While the self-reported data on thermostat settings suggest little difference in the average winter thermostat setpoint between households with manual or programmable thermostats, it is possible that these data are not accurate, or that setbacks reported by households with programmable thermostats occur more regularly than those reported by households with manual thermostats.

To explore these issues from another angle, we looked at actual heating energy use as a function of thermostat type, reported thermostat settings, and homeowner attitudes about conserving energy. Our analysis is restricted to 147 gas-heated homes for which we had good ability to isolate heating usage from monthly gas usage data.

We fit several regression models to the data, using heating energy intensity (Btu/ft2/heating degree day) as the dependent variable in order to remove the confounding effects of house size and climate.

We also included two independent variables in the models to help control for differences across houses in insulation levels and air leakage: (1) an insulation control variable, calculated as the total shell conductivity (U-value times area) divided by the house's total conditioned area; and (2) an infiltration variable based on a blower door measurement of air leakage (ft3/minute at 50 Pascals) divided by the house's total conditioned area. We would note, however, that because these are observational data, there may be other unobserved factors that affect heating and may affect the results.

Model 1 (Table B36) shows the results of regressing heating energy intensity on a binary variable for the presence of a programmable thermostat. The magnitude of the programmable thermostat coefficient suggests that homes with programmable thermostats use about 2.5 percent less energy for heating than homes with manual thermostats (0.197 divided by the average heating energy intensity of 6.98 Btu/ft2/heating degree day), but the result is not statistically significant. The 90-percent confidence interval associated with this estimate suggests that homes with programmable thermostats have somewhere between ten percent lower and five percent higher heating energy intensity than homes with manual thermostats.

Table B36: Regression coefficients for regression of heating energy intensity on selected independent variables

	Dependent Variable: Heating Energy Intensity (Btu./square foot/HDD)			
	Model 1	Model 2	Model 3	Model 4
	Coefficients (t-values)	Coefficients (t-values)	Coefficients (t-values)	Coefficients (t-values)
Independent Variables				
Thermostat type	-0.197 (-0.681)	--	--	--
Self-reported thermostat setpoint	--	0.180* (2.755)	--	0.226** (3.206)
Conservation-orientation	--	--	-0.047 (-0.669)	0.032 (0.452)
Insulation	6.911** (5.950)	6.507** (5.011)	7.592** (5.641)	6.462** (4.872)
Infiltration	1.242** (5.263)	1.236** (4.874)	1.196** (4.376)	1.262** (4.799)
Intercept	2.783	-9.316	3.114	-12.953
Adjusted R^2	0.510	0.516	0.491	0.532
n	144	122	111	111

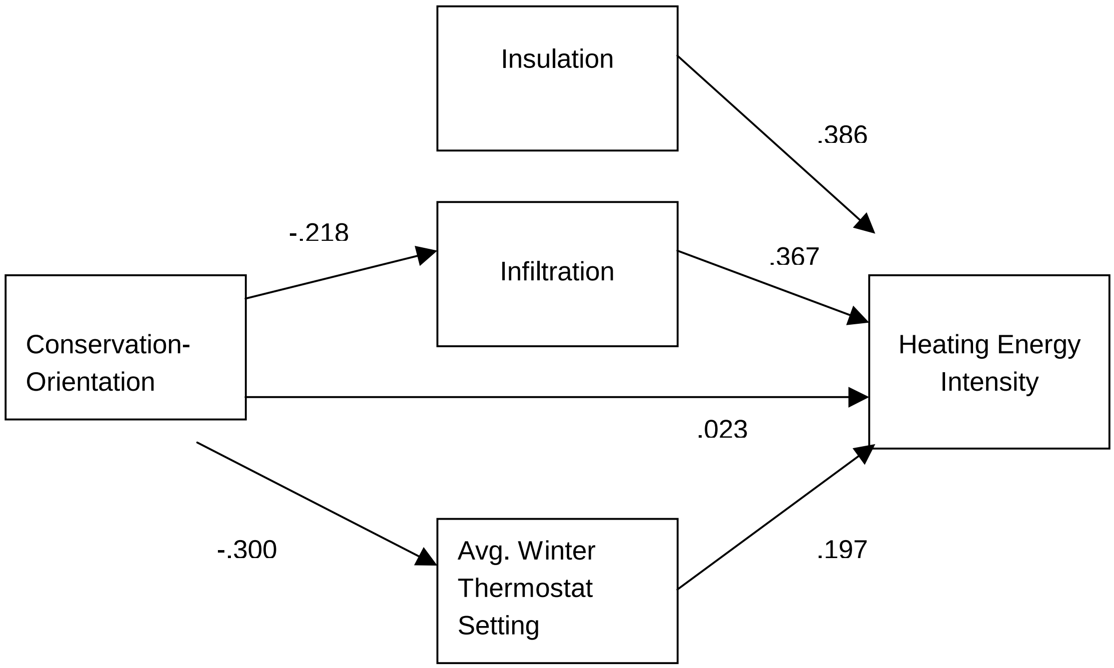
* p<.05, ** p<.005

In contrast, there is a statistically significant relationship between our calculated self-reported thermostat setpoint and heating energy intensity (Model 2). This model suggests that after controlling for differences across houses in insulation and infiltration, for every degree change in the self-reported thermostat setpoint the homeowner can expect to save about 0.24 Btu/ft2/heating degree day. This means that an average homeowner from our sample can expect to save a little over 3 percent from his or her heating bill with every degree of reduction in their average winter thermostat setting. A widely used rule of thumb is that each degree of reduction in the thermostat setpoint results in a 3 percent reduction in heating energy use (DOE 1980)—nearly the same as the percent reduction we calculated for our sample. Thus, for the subgroup of houses in our sample that are heated with natural gas, the self-reported thermostat-setting data appears to be a good indicator of actual behavior, assuming that the goal is to compare the thermostat-setting behaviors of households rather than to gather an accurate report of their actual thermostat settings.

Model 3 shows that conservation-orientation on its own does not have any statistically significant predictive power with respect to heating energy intensity. Given that the self-reported thermostat setpoint is significantly correlated with household heating energy intensity, Model 4 suggests that, via the mechanism of respondents' thermostat-setting behavior, conservation-orientation may nonetheless have an effect on heating energy intensity.

To test this conclusion, we subjected Model 4 to the decomposition of total effects into direct and indirect parts via a path analytic model. Figure B8 shows the postulated relationships among the variables in the model. As this path-analytic model demonstrates, conservation-orientation has a substantial direct effect on the average self-reported winter thermostat setting, and a more modest direct effect on infiltration (the degree of draftiness of the dwelling). Infiltration in turn has a substantial direct effect on heating energy intensity, while average self-reported winter thermostat setting has a more modest, but still statistically significant, direct effect on heating energy intensity. Conservation-orientation also has a very minor direct effect on heating energy intensity. The correlations between conservation-orientation and both average self-reported winter thermostat setting and infiltration are fairly sizable, suggesting that the total effect of conservation-orientation on heating energy intensity is not spurious. In addition to postulating that more conservation-oriented respondents set their thermostats at lower average temperatures than do those who are less conservation-oriented, indirectly affecting heating energy intensity, this model suggests that more conservation-oriented respondents also tend to live in less drafty houses, thus again indirectly affecting heating energy intensity. However, unlike the average winter thermostat setting (which is purely a behavioral indicator), it is impossible to tell from the data how much of a house's infiltration rate is a direct result of the current homeowner's behavior, and how much is a physical factor that is beyond the control of the homeowner. The major causal factors in the model are insulation and infiltration. While there indeed appear to be relationships between conservation-orientation and energy-saving behaviors that are tied in with actual heating energy consumption in this model, at a multivariate level, these mostly physical factors overwhelm the attitude-behavior relationships.

Figure B8. Path Analytic Model of Heating Energy Intensity



Thermostat Type: Insights from the Structured Interviews

The structured interviews are useful for better understanding thermostat use and the prospects for energy savings from the installation of programmable thermostats. It was clear from the interviews that even after going through the home energy audit and filling out the questionnaire (which described the different kinds of thermostats about which we asked), at least four of the thirty cases interviewed did not know what a programmable thermostat was, and others had not been aware that such thermostats existed before the study.

It is interesting to examine how interviewees with manual thermostats responded to the audit recommendations and savings estimates (based on an 8 hour setback of 5^oF) for programmable thermostats. Fourteen cases both had a manual thermostat and were not interested in switching to the programmable variety. Of the seven households with manual thermostats that set their thermostats back manually during the winter, six felt that there would be no point to installing a programmable thermostat for their households, and several expressed disbelief in the annual savings estimated by the audit. Of the seven households with a manual thermostat who indicated during the interview that they kept their home temperature constant, six told us that they would not adopt a setback pattern if they were to acquire a programmable thermostat, and none was interested in acquiring one. The following are the reasons given for not wanting a programmable thermostat:

They did not believe the savings estimate provided by the HERS audit.

The payback or the increased convenience were not worth the cost.

Setting the thermostat would be a "hassle." For example, there would be no point since there was almost always someone at home during the day, and they were not interested in setting the temperature back at night; they were "technologically impaired" and would be unable or unwilling to program the thermostat; or costs might actually go up because their schedules varied so much that programming the thermostat might become impractical, and so their temperature setting would end up being constant whereas currently they were setting back manually.

Most of their heating comes from a wood stove instead of the furnace.

They had heard of a programmable thermostat that "went berserk" and overheated a house.

Of the two cases that indicated an interest during the interview in obtaining a programmable thermostat, one did not expect it to change the household's temperature setting habits, but wanted it for convenience, and the other planned to use it to begin setting back the thermostat at night and so felt it would reap cost and energy savings. Of those households that already had programmable thermostats, three were positive about it and felt it saved them money, while two were unhappy with it and had stopped using the thermostat's programmable features. One of these latter cases had lost the instructions, and no one in the household was able to reset the thermostat when the power went out, so they ended up keeping the temperature constant. The other case had been unhappy with the default settings on the thermostat, but had been unable to figure out how to change the settings despite having the instructions, and so used the override function when they wanted to change the temperature setting. These two incidents suggest that programmable thermostats may be too complicated to operate.

The analyses of the self-reported thermostat-setting data and of the interview data indicate that the impact of programmable thermostats on heating energy use in Wisconsin is modest at best. The habits, attitudes, and beliefs expressed in the interviews and the lack of significant difference between the self-reported thermostat setpoints reported by those with programmable and those with manual thermostats suggest very little difference in heating energy use for these two groups.

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