What's Really out There in Snowbelt Homes? A Characterization Study of Wisconsin Housing

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ABSTRACT

This paper reports the findings of a study of a statistically representative sample of 299 single-family, owner-occupied homes in Wisconsin. On-site audit data, homeowner surveys, and utility billing data were collected to characterize energy-related aspects of owner-occupied housing in the state. The study shows that the average Wisconsin homeowner pays about $1300 annually in energy costs. Low-income homes are smaller but more energy intensive to heat. New homes are more energy efficient but also larger; both of these subgroups pay about the same total for annual energy costs. About 40 percent of homes in Wisconsin have a major cost-effective energy efficiency opportunity such as wall insulation, infiltration reduction or an older inefficient furnace. Building shell opportunities tend to be concentrated in older homes, and are also associated with homeowners who state that they have plans to remodel in the near future and homeowners who report winter comfort problems. Attitudes in favor of energy efficiency are a good predictor of lower average thermostat settings, but are not otherwise correlated for the most part with the presence or absence of energy efficiency opportunities.

Introduction

Background

Wisconsin homes use about one-third of the total non-transportation energy in the state (Wisconsin Energy Bureau 1999). Although a number of government and utility programs have aimed to increase the efficiency with which energy is consumed in Wisconsin homes over the last two decades, hard data on the energy-related characteristics of these homes are surprisingly scattered and difficult to come by. The Wisconsin Energy Bureau publishes annual energy statistics that track aggregate use for natural gas and electricity from which general trends in residential energy use can be discerned—but not the underlying causes of these trends. Utilities in the state conduct extensive appliance saturation surveys and load research studies, but these data are largely proprietary.

At the national level, the Energy Information Administration conducts the Residential Energy Consumption Survey about every three years, which collects data on a statistically representative sample of U.S. households (EIA, 2000). However, this information has two drawbacks from the perspective of state-level planning: (1) the smallest geographic unit for which the data are available is the census region, and (2) the information is limited to that which can be gleaned from householder (or renter) self-reports and fuel supplier data.

Moreover, 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 program planning and evaluation.

Partly in anticipation of this need, and partly in pursuit of other research objectives, the Energy Center of Wisconsin (ECW) initiated a residential characterization study in 1998. The main goal of the study was to collect detailed energy-related data for a statistically representative sample of Wisconsin homes, with a focus on collecting on-site physical data that cannot be gathered via mail or telephone surveys.

To keep the design tractable, the study was limited to single-family, owner-occupied housing, which we estimate to constitute about 70 percent of Wisconsin's two million households, based on Census data and other ECW survey data.

After a pilot study to test the instruments and recruiting and data collection protocols in the first half of 1998, the full-scale study was implemented in 1999, with a final sample size (pilot and full-scale) of 299 households. This paper reviews the major findings of this study; a more detailed report is available from the Energy Center of Wisconsin (Pigg & Nevius 2000).

Study Design

Based on the results of the 1998 pilot study (n=40), the Residential Characterization Study was designed as a two-stage probability sample, intended to be representative of the state as a whole. The first stage sampling was at the county level. We divided the 72 counties in the state into eight strata based on population, and then sampled 19 counties across the strata. Counties in the most populous strata were sampled with certainty, while two counties per stratum were sampled in the lower strata.

In the second stage of sampling, individual households were sampled based on purchased samples of telephone numbers within each county and using a typical random-digit dialing (RDD) protocol. The sample sizes for each county were constructed so that the overall sample would be close to self-weighting. However, we did endeavor to oversample two subgroups of homes: low-income households (at or below 150 percent of the 1998 federal poverty guideline), and newly constructed homes (built in 1994 or later). A cash incentive of $50 was offered for homeowners who agreed to participate (low-income and new construction homes were offered $100). The RDD recruiting had a 34 percent response rate in terms of completing the recruitment script with eligible sampled households, and about one of every three households contacted were willing to participate.

The final sample size for the study (pilot and full-scale) was 299. Of these, 43 were low-income and 44 were new construction. Table 1 summarizes the basic housing type and demographic characteristics of the sample. It is important to note that the scope of the study limits the low-income subgroup to single-family homeowners, though rental households make up the majority of low-income 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 the Center's biennial Appliance Sales Tracking (AST) survey series (ECW, 1999). This allowed us to assess the representativeness of the final study sample in relation to this larger sample. The results show that the study

Table 1. Basic Structural and Demographic Statistics for the Study Sample

	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				
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)

sample is, in most respects, a reasonably representative sample of single-family owner-occupied households in the state. The most notable bias was that the study sample had about twice the average incidence of households who said they had plans to remodel their homes in the next two years. We downweighted these households to correct this bias. Other slight biases include slight over-representation of households with more family members, households who have lived at their current residence for less than a year, and households with favorable attitudes toward energy efficiency and conservation—and a slight under-representation of homeowners who say they are never home during weekdays.

Data Collection and Analysis

Three types of data were collected on each household: (1) an on-site audit of the home was conducted to collect data on the structure and appliances; (2) homeowners were asked to complete a 32-page survey; and (3) natural gas and electricity monthly usage histories were obtained.

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 two to three 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 homeowner survey solicited information on basic household demographics, appliance use, comfort, attitudes toward energy use—including energy efficiency and conservation—and maintenance practices for heating and cooling equipment. All but three homeowners completed the questionnaire, which was typically filled out while the rater was in the home. In addition, 30 households were sampled for later in-depth interviews.

Natural gas usage histories were obtained for 199 of the 206 households with natural gas service, and electricity histories were obtained for 270 of 299 households. Budget and time constraints precluded obtaining data on other fuels. The utility billing data were statistically analyzed using the Princeton Scorekeeping Method (PRISM) to disaggregate space heating and cooling usage based on the correlation with heating and cooling degree days (Fels, 1986; Fels et al. 1995). In general, the space heating estimates are fairly reliable, since these make up a substantial fraction of overall usage and are highly correlated with the weather. Estimates of air conditioning use are less certain due to Wisconsin's short cooling season, and the fact that individual household use of air conditioning equipment is idiosyncratic.

The software used for the HERS program (REM/Rate, version 8.46) provided estimates of heating and cooling usage for all houses in the study. We used these estimates as the basis for estimating space heating consumption for fuels other than natural gas and electricity and also in a few cases where we were not able to obtain the utility billing history. The estimates were statistically adjusted to correct for an observed bias, based on analysis of predicted and observed heating usage for a subgroup of 147 houses that heated with natural gas only. The analysis indicated that the software tends to overpredict heating energy consumption (median: 22 percent), but the error is a function of the predicted heating energy intensity (Btu/square foot/heating degree day). Heating energy consumption for inefficient homes (i.e., largely uninsulated, leaky, or with inefficient heating systems) is overpredicted by much

more, and the software tends to somewhat underpredict heating energy use in newer, well-insulated homes.

All analysis was conducted using case weights that were developed to true the study up to the population proportions for each stratum. Statistical confidence intervals take into account the two-stage sample design (confidence intervals reported in this paper are at a 90 percent confidence level).

RESULTS

Energy Use and Costs

We estimate annual household energy costs to average $1290 ± 60 in Wisconsin, with 90 percent of homeowners paying between about $700 and $2100 per year (Table 2). On average space heating costs make up about 40 percent of the total energy cost for Wisconsin households.

Annual heating use and costs for low-income homeowners and owners of new homes are not significantly different from the overall population—but heating energy intensity does vary across these groups. Low-income homes are 16 percent smaller but have 11 percent higher average heating energy intensity. New homes are 23 percent more energy efficient in their heating use per square foot, but are also 20 percent larger on average. Generally lower heating energy intensity can be seen in homes built during the 1980s and 1990s, and undoubtedly are the result of energy codes first adopted in the state in 1978.

Energy Efficiency Opportunities in Wisconsin Homes

We defined a dozen common energy efficiency measures and looked at the prevalence of these opportunities in the homes in the sample (Table 3). We screened these measures minimally for cost-effectiveness by excluding measures that we calculated to have a simple payback of more than ten years. Overall the results indicate that major energy efficiency opportunities exist in about 40 percent of homes, and minor opportunities exist in nearly all homes. Low-income homes have a higher than average incidence of major opportunities, and (not surprisingly) new construction homes have a very low incidence.

Insulation. Auditors gauged insulation levels during the audit of each home. Insulation levels were usually based on visual inspection of wall cavities or ceiling areas, but in about a quarter of the cases visual verification was not possible; these were based on auditor judgement or information from the homeowner.

The two main areas of interest are above-grade walls and ceilings. The data for walls indicate that 14 ± 7 percent of Wisconsin homes have walls that are substantially uninsulated, which we define to be uninsulated stud cavities for more than 25 percent of the total wall area. For homes with insulation, the most prevalent condition is 2x4 stud-frame construction with R-11 in the cavities; however, a significant minority of homes are constructed of 2x6 framing with R-19 in the cavities. The latter tend to be newer homes: about three-quarters of the homes in our new construction subgroup used 2x6 framing.

Ceiling insulation is a bit more complicated. Ceilings in a home can be any combination of flat attic areas or sloped cathedral areas. Attic joists may be open to the attic area or floored and used for storage, thereby limiting the amount of insulation a homeowner

may be willing to install. Similarly, cathedral areas are often closed rafter cavities, but may also be built of truss members that allow more insulation.

Table 2. Average Annual Energy Use and Cost

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 ($)	117 ± 5	117 ± 5	120 ± 10	120 ± 5
Total annual energy cost ($)	1290 ± 60	1290 ± 70	1260 ± 100	1290 ± 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

Table 3. Prevalence of Energy Efficiency Opportunities in Wisconsin Homes

Percent of Wisconsin homes with opportunities for…	Overall (n=299)	Low-income (n=43)	New construction (n=44)
Wall insulation	14% ± 7	20% ± 12	0%
Ceiling insulation	21% ± 11	40% ± 19	2% ± 4
Floor insulation	3% ± 2	11% ± 11	2% ± 2
Rim/band joist insulation	21% ± 7	33% ± 13	4% ± 5
Infiltration reduction	20% ± 8	48% ± 11	9% ± 7
Furnace replacement	9% ± 3	7% ± 9	0%
Any heating/cooling measure	*48%* ± 11	*74%* ± 17	*14%* ± 8
Water heater fuel switch	4% ± 2	4% ± 5	2% ± 4
Water heater temperature reduction	23% ± 6	32% ± 12	29% ± 14
Water heater wrap	21% ± 5	15% ± 10	0%
Low-flow showerhead	2% ± 2	3% ± 3	0%
Any water heating measure	*42%* ± 5	*52%* ± 18	*31%* ± 13
Refrigerator replacement	10% ± 2	8% ± 9	2% ± 4
Compact fluorescent lights	76% ± 6	69% ± 15	83% ± 11
Any measure	*91%* ± 3	*94%* ± 6	*87%* ± 10

(See text for definitions of measures.)

Eighty three percent of the aggregate ceiling area in our sample is attic space and 17 percent is cathedral space. Sixty-two percent of homes have only attic areas, 5 percent have only cathedral areas, and 33 percent are a mixture. For attic areas, we found that floored attics are not a significant obstacle to adding insulation: only about six percent of the aggregate attic area is floored. Although very few homes have completely uninsulated ceiling areas, about 20 percent are insulated to less than R-19 and about half are insulated to less than R-30. We considered a home to have ceiling insulation opportunities if more than 25 percent of the ceiling area was any combination of: (a) attic space insulated to R-11 or less; (b) attic space insulated to more than R-11 but less than R-25 in a home that also had wall insulation or infiltration reduction opportunities; or, (c) cathedral space with uninsulated cavities.

Comparing the audit-based estimates of insulation level to what homeowners reported on the questionnaire reveals that most homeowners living in homes that we would classify as inadequately insulated (22 percent), either believe their homes to be adequately insulated or say they do not know how well insulated their homes are (Table 4).

Table 4. Homeowner Perceptions Versus Auditor Assessment for Insulation

Homeowner Questionnaire: "Overall, how well is your home insulated?"	Audit Assessment: Walls and ceilings adequately insulated?[a] **Yes** (78% of homes)	**No** (22% of homes)
No Insulation	2%	6%
Poorly Insulated	3%	21%
Adequately Insulated	37%	41%
Well Insulated	46%	14%
Don't know	12%	18%
Total	100%	100%

[a]Criteria for "adequate" insulation: walls insulated to R-11 or higher; ceilings insulated to R-19 or higher

Infiltration. Blower door tests to measures air leakage were conducted on all but 11 of the 299 homes. We take one-twentieth of the air flow at 50 Pascals of pressure difference as an estimate of the amount of infiltration that occurs naturally in the home. These measurements are commonly converted to air changes per hour using the conditioned volume of the home. The median natural air changes per hour for the homes tested for the study was 0.3. If we consider houses with natural air changes per hour greater than 0.5 to be leaky, then the data indicate that about 21 ±7 percent of Wisconsin homes have air sealing opportunities. The small group of houses with very high leakage rates are notable in that these homeowners were much more likely to report significant comfort problems on the questionnaire.

Heating Systems. Most (85 percent) of the heating systems in Wisconsin homes are forced air furnaces (fueled mainly by natural gas or propane), and most of the remainder are hydronic boilers. Our sample indicates that about half of all homes in the state with furnaces currently have a high-efficiency condensing unit installed. This is not surprising, given that utility and government energy efficiency programs have promoted high-efficiency furnaces in the state for more than a decade, and these efforts have been heralded as an early example of market transformation (Prahl & Pigg 1997). Tracking studies of the furnace market in the state indicate that about four percent of households purchase a new furnace each year, and about three-quarters of these sales are high-efficiency models (ECW, 1999). Many of the standard efficiency units in the sample are less than 15 years old and therefore unlikely to be replaced in the near term, and some are furnaces that only supply a small proportion of the home's heat. If we limit the definition of an opportunity for furnace replacement to units that are more than 15 years old, supply at least half the home's heating needs, and, if oil-fired, are in homes that have natural gas or propane available, fewer than 10 percent of homes present an opportunity for furnace replacement.

Water Heating. Seventy-one percent of the water heaters in the study are fired by natural gas or propane, and nearly all the others (28 ± 5 percent) are electric. Though a majority (58 percent) of homes with electric water heaters have natural gas or propane available in the home, many of these water heaters are relatively new (less than ten years), or are in homes served by municipal utilities that have low electricity rates that make it unattractive to switch to propane. We therefore estimate that about 15 percent of homes with electric water heaters (four percent of all homes) are near-term candidates for switching water heater fuels.

As part of the site audit, shower flow rates and hot water temperatures were measured. The results show that very few homes are good candidates for low-flow showerheads, with more than 95 percent of households measuring three gallons per minute or less. On the other hand, the water temperature data suggest that average water heater setpoints are higher than typically recommended. Hot water temperatures averaged 129 ± 1 ^{o}F, and about a quarter of homes were measured to have hot water temperatures greater than 135^{o}F, up to a maximum of 175^{o}F. These high temperatures represent both an energy efficiency opportunity and a safety hazard, particularly in households with small children (20 percent of households have a child under the age of six in the home). Some of these households may have increased their hot water temperature to stretch the amount of hot water available (by mixing a smaller proportion of hotter water); we found an inverse correlation between the gallons of hot water storage capacity per person in the home and the likelihood of having a high hot water setpoint. We also found that homes with electric waters heaters are much less likely (12 percent) to have a hot water setting of 135 ^{o}F or more than homes with fuel-fired water heaters (28 percent).

Refrigerators and Freezers. Just under a quarter of Wisconsin homes (22 ± 6 percent) have more than one refrigerator, and 60 ± 6 percent have a 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.[1] The results show that the average refrigerator draws about 200 Watts and uses about 1000 ± 50 kWh per year. The average stand-alone freezer draws about the same wattage, but runs slightly less, using 800 ± 90 kWh per year.

Although the brevity of the metering period leaves some uncertainty in the data, the metering data suggest that about 10 percent of Wisconsin homes have a refrigerator or freezer more than 10 years old that would be a good candidate for replacement because of high energy use (more than 5 kWh/day for a refrigerator or 4 kWh/day for a freezer).

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 for recording luminaires. An average of 3.5 luminaires per house were recorded, though this ranged from zero to 15. The dominant locations for these luminaires were kitchens (29 percent), living rooms (22 percent), recreation rooms (11 percent), and outdoors (7 percent). Ceiling fixtures make up about half of the recorded sample, and table and floor lamps make up over a third.

Seventy-seven percent of the recorded luminaries have incandescent lamps, with standard wattages of 60, 75 and 100 Watts constituting two-thirds of these. Twelve percent of the luminaires were fluorescent; these are mostly kitchen and basement ceiling fixtures. Only five percent of all fixtures are compact fluorescent lights (CFLs), and these occur in 13 percent of homes. Half of the CFLs are in ceiling fixtures in various locations in the house, and another third are in table lamps, mainly in living rooms. The mean self-reported burn time for the CFLs was 4.8 hours per day, compared to 5.0 hours for all luminaires. We estimate that about three-quarters of homes have one or more incandescent bulbs between 40 and 100 Watts in locations that could be cost-effectively retrofitted with a CFL.

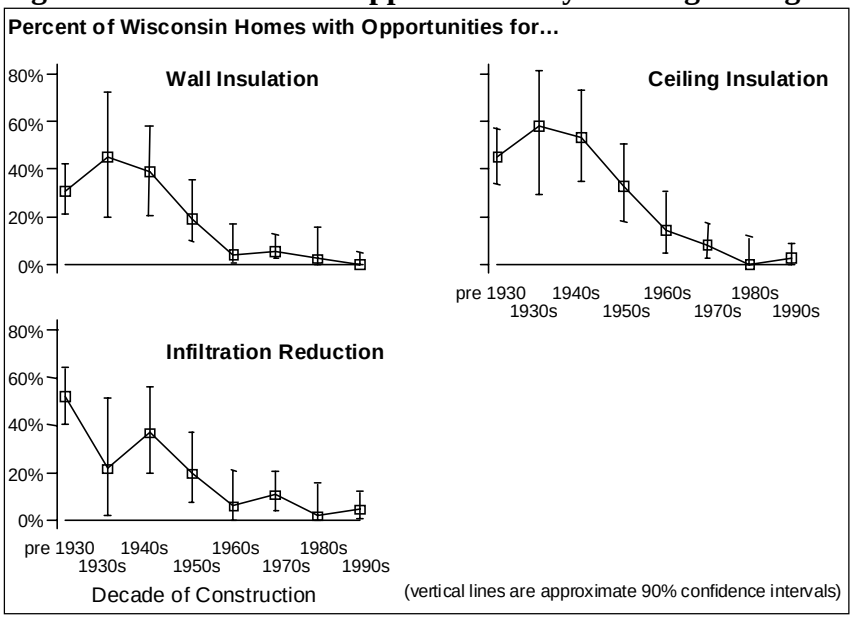
[1] A total of 452 units were metered. We discarded energy use measurements that were based on less than 90 minutes of data, which occurred in about 14 percent of the cases.

We next look at how some of these measures break out by several factors of interest.

Housing Vintage. As might be expected, major shell opportunities are much more prevalent in older homes than in new ones (Figure 1). Our data show that opportunities for adding wall insulation are concentrated in homes built before 1960, and opportunities for adding ceiling insulation are concentrated in homes built before 1970. The likelihood of excessive air leakage similarly rises with home age.

The same is not true of other measures. Other than the obvious fact that new homes are unlikely to be candidates for replacing a furnace, water heater or refrigerator, we found no correlation between home age and measures that have to do with mechanical systems or appliances in the home.

Figure 1. Shell Measure Opportunities by Housing Vintage



Comfort. An entire section of our questionnaire was devoted to home comfort issues. We focus here on what people had to say about their homes being too cold or drafty in the winter. The sample can be roughly divided into three groups: homeowners who reported that they rarely or never experience problems with their homes being cold or drafty (43 percent); homeowners who report sometimes having problems with their homes being cold or drafty (52 percent); and homeowners who report that these problems occur most or all of the time (5 percent).

While it does appear that comfort problems are generally associated with a lack of insulation or high air leakage, the differences are statistically significant in our sample only for the small proportion of households that report significant problems with winter comfort. These homes are much more likely to have uninsulated walls or high measured air leakage.

Attitudes Toward Energy. From attitude data collected in the homeowner survey, we constructed an index of "conservation-orientation" to measure the degree to which households view energy conservation and energy efficiency favorably. A more detailed description of this index and how it relates to thermostat setting behavior can be found in

Nevius and Pigg, 2000. We found that homeowner attitudes that are favorable toward energy conservation and efficiency are associated with lower reported thermostat settings, which in turn are associated with lower average heating energy intensity. It appears that having attitudes that are favorable toward conservation does translate into action at the thermostat.

On the other hand, we found no correlation between our index of conservation-orientation and other energy efficiency opportunities in Wisconsin homes, with one exception—infiltration. The study sample does show a tendency for homes occupied by people who score favorably on our index of conservation-orientation to be somewhat less leaky than homes occupied by people who have low scores on this index. But we do not have a direct explanation for this finding, since high conservation-orientation scores are not associated with a higher self-reported incidence of caulking and weatherstripping in our sample.

Remodeling Plans. One interesting aspect of the recruiting for the study was the finding that our sample was biased in favor of households that had plans to do major remodeling of their homes in the next two years. This suggests that households with remodeling plans are more interested in energy efficiency, since it appears that these households were more eager to participate in our study.

Analysis of energy efficiency opportunities with respect to remodeling plans suggests that households with remodeling plans are somewhat better-than-average candidates for shell improvements such as wall insulation and leakage reduction, though not for other measures. What drives these differences is largely the fact that households with remodeling plans are more likely to be owners of older homes (pre 1980s). If we restrict the analysis to homes that were built before 1980, households in our sample that have remodeling plans are more likely to be candidates for shell measures, but the differences are not statistically significant.

Conclusions

Overall, this study demonstrates that energy efficiency opportunities exist in a significant proportion of Wisconsin homes. However, these opportunities are not distributed uniformly throughout the population. Opportunities for shell measures (insulation and infiltration reduction) are concentrated in older homes. The older the home, the higher the probability that it is inadequately insulated or air sealed. It is problematic from the perspective of trying to implement energy efficiency programs that the majority of homes that we found to be inadequately insulated are owned by people who either do not know this, or feel that their homes are already adequately insulated. Efforts to promote insulation retrofits should be designed with this finding in mind.

We found that opportunities for energy-related shell improvements are positively correlated with homeowners' plans to remodel or add onto homes in Wisconsin. Moreover, the fact that our (unweighted) study sample had about twice the average incidence of homeowners with remodeling plans suggests that homeowners who do have remodeling plans are more interested than average in finding out how efficient their homes are. All of this suggests that program efforts to promote shell improvements would do well to target the home remodeling market.

Although the low-income subgroup of the sample is small, all evidence points towards these homes being less energy efficient on average than the overall population,

mainly due to a higher incidence of underinsulated walls and ceilings and higher air leakage. Although total energy bills are about the same for these households (because their homes are smaller on average), energy bills represent a much higher percent of income for low-income homeowners. These findings indicate a clear need for continued efforts to address energy efficiency in low-income households in the state.

The extent to which these findings can be generalized to other areas is difficult to know. We found our study sample to be comparable to the 1997 RECS single-family sample in most aspects that do not vary strongly with climate. It is probable that the lighting, refrigeration and perhaps water heating findings could be generalized to other demographically similar areas. Our findings for shell opportunities is probably limited to other cold-climate states. And it is likely that the furnace situation in Wisconsin is unique.

Finally, this study focused on the 70 percent of Wisconsin households that own a single-family home. Thirty percent of Wisconsin households—and a majority of low-income households—are rental units. The question of what is really out there in these rental homes remains, and we hope to be able to provide the answers in the near future.

References

[ECW] Energy Center of Wisconsin. 2000. "Appliance Sales Tracking: 1999 Residential Survey." Madison, Wis.: Energy Center of Wisconsin.

[EIA] Energy Information Agency. 1999. "A look at Residential Energy Consumption in 1997." DOE/EIA-0632(97). Washington, D.C.: Energy Information Agency.

Fels, M. 1986. "Measuring Energy Savings: The Scorekeeping Approach." *Energy and Buildings* 9: 1-2.

Fels, M., K. Kissock, M. A. Marean, and C. Reynolds. 1995. *PRISM (Advanced Version 1.0) Users' Guide.* Princeton, N.J.: Princeton University, Center for Energy and Environmental Studies.

Nevius, M. and S. Pigg. 2000. "Programmable Thermostats that Go Berserk? Taking a Social Perspective on Space Heating in Wisconsin." In *Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Prahl, R. and S. Pigg. 1997. "Do the Market Effects of Utility Energy Efficiency Programs Last? Evidence from Wisconsin." In *Proceedings of the 1997 International Energy Program Evaluation Conference*, 523-531. Chicago, Ill.

Pigg, S. and M. Nevius. 2000. "Energy and Housing in Wisconsin: a Study of Single-Family Owner-Occupied Homes." Madison, Wis.: Energy Center of Wisconsin (forthcoming).

Wisconsin Energy Bureau. 1999. *Wisconsin Energy Statistics*. Madison, Wis.: Wisconsin Energy Bureau.