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Effect of Lifestyle on Energy Use Estimations and Predicted Savings

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OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04; Microfiche A01

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EFFECT OF LIFESTYLE ON ENERGY USE ESTIMATIONS AND PREDICTED SAVINGS

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Date Published - March 1988

Building Energy Retrofit Research Program

for the
Office of Buildings and Community Systems
Building Services Division
U.S. Department of Energy

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
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MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

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ABSTRACT

Audit predictions of energy-conservation savings are usually much higher than the savings actually achieved. Speculation about possible causes for this discrepancy has often centered around residents' life-style, specifically their indoor temperature management. Detailed indoor temperature data and extensive demographic information were available for 300 homes in Hood River, Oregon. These data were analyzed to examine the effect of demographic variables on indoor temperature and energy use. Changes in indoor temperature before and after retrofit were also examined. The effects of these variables were very small. Some small improvements to auditing procedures can be suggested based on this analysis. However, the major conclusion is that while some take-back of energy savings is occurring, it is very small in magnitude and can not explain the large differences between predicted and achieved energy savings.

EXECUTIVE SUMMARY

Most conservation programs rely on audit predictions of energy savings attributable to conservation measures. However, in program after program, these predictions have proven to be very different from (usually much larger than) the savings actually achieved. The causes of these discrepancies are uncertain, but residents' varying lifestyles are often discussed.

Lifestyle variations can affect the difference in predicted and achieved savings in two ways. First, they can introduce errors in the basic energy consumption calculations. Second, homeowners can change their lifestyle after the installation of a conservation measure, taking back some of the conserved energy in the form of improved comfort. This report examines both questions. Can lifestyle variables account for differences in energy use, and if so, can they be incorporated in energy consumption calculations to improve their accuracy? Can they explain how people are changing their behavior, and which customers are most likely to change their behavior?

This investigation was funded by the Single-Family Retrofit Research Program of the DOE Office of Buildings and Community Systems. The data source used for this examination was part of the Hood River Conservation Project (HRCP). One part of the HRCP evaluation included monitoring about 314 homes on a 15-min basis over a 2-year period. The data collected included electric space-heating energy use, indoor temperature, total electrical use, and either water-heater energy use or wood stove heat output. Extensive survey information describing each household is also available for these 314 homes as well as detailed weather data from three local weather stations.

The available data resources were screened to select the variables of interest and to limit the analysis to electrically heated homes. Most of the analysis relied on multiple regression analysis. Pre-retrofit data was examined to find relationships that might be useful in basic energy use calculations. This examination included indoor temperatures, space-heating energy use, water-heating energy use, and other base energy uses. Changes in behavior following retrofit were evaluated

and the indoor temperatures of wood-heated and electrically heated homes were compared.

The major conclusion is that while some takeback is occuring, it is very small in magnitude and can not explain the large differences between predicted and achieved energy savings due to conservation retrofits. The results of this study can be used to make minor adjustments and improvements to audit procedures but will not eliminate the large savings discrepancies noted.

The only lifestyle variable found to have a major effect on energy use was the close relationship between number of occupants and water-heater energy use. This relationship should be incorporated into audit predictions of hot water use and energy savings. The unreliability of self-reported indoor temperatures was confirmed. These temperatures were overwhelmingly lower than the measured temperatures and should not be used in any estimation procedures. Also, the presence or absence of clock thermostats should not be used to infer the use of nighttime setback behavior. The explanatory power of other lifestyle variables, although statistically significant, was too weak to be useful in predicting energy use. However, consideration of education levels and heating-system type may be helpful in selecting the appropriate degree-day base temperature for individual homes.

Nighttime temperatures were raised slightly following retrofit but the difference was very small. About 2/3 of the households did not change their indoor temperature by more than 2°F. Among the total sample, almost as many customers chose colder temperatures as warmer temperatures. About 34% of the variation in takeback behavior can be explained by pre-retrofit temperatures, house size, portable heater use, education levels, and pre-retrofit energy use. The effects of these variables are large enough to incorporate into audit predictions as some sort of correction factor. However, the magnitude of this takeback correction is so small that it would not significantly improve the accuracy of the audit predictions.

1. INTRODUCTION

Most conservation programs rely on audit predictions of energy savings attributable to conservation measures to judge the economic worth of the conservation measures and as marketing tools to promote their installation. However, in program after program, these predictions have proven to be very different from the savings actually achieved. In a Minnesota program for gas-heated homes, the average savings were only two-thirds of the predicted amount.[1] This same relationship was also found for a large conservation program in the Northwest.[2] In both of these studies, there was substantial variation across households in actual energy savings and in the ratio of actual-to-predicted savings. In the Minnesota program, the actual natural gas saving was within ±50% of the audit estimate in only 45% of the homes studied. In the Northwest program, more than 10% of the homes actually increased their energy use while actual savings were more than double the audit estimates in another 10% of the homes. The causes of these variations are uncertain, but residents' varying lifestyles are often considered to be a factor.

Lifestyle variations can affect the difference in predicted and achieved savings in two ways. First, they can introduce errors in the basic energy consumption calculations. For example, homeowners who keep windows open during the winter for fresh air will use much more energy than would be predicted assuming the windows were closed. On the other hand, homeowners who use night setback or who close off portions of the house during cold weather will use much less energy than would be estimated. Second, homeowners can change their lifestyle after the installation of a conservation measure, taking back some of the conserved energy in the form of improved comfort, or possibly increasing energy savings. This report examines both questions. Can lifestyle variables account for differences in energy use, and if so, can they be incorporated in energy consumption calculations to improve their accuracy? Can they explain how people change their behavior following retrofit, and which customers are most likely to change their behavior?

This investigation was funded by the Single-Family Retrofit Research Program of the Department of Energy (DOE) Office of Buildings and

Community Systems. The mission of this Retrofit Research Program is to determine the energy savings that can be achieved through various retrofit measures and to improve the understanding of how retrofits actually perform in occupied buildings. The data source used for this examination was part of the Hood River Conservation Project (HRCP), a $21 million project funded by the Bonneville Power Administration, Pacific Power and Light (PP&L), and other participants. The HRCP involved retrofitting about 3000 homes in Hood River, Oregon in an effort to define the maximum electrical conservation potential achievable in a short time in a small geographical area. One part of the HRCP evaluation included monitoring about 314 homes on a 15 min basis over a 2-year period. The data collected included electric space-heating energy use, indoor temperature, total electrical use, and either water-heater energy use or wood stove heat output. The magnitude of this data base is staggering with almost 90 million data points. Extensive survey information describing each household is also available for these 314 homes as well as detailed weather data from three local weather stations.

The available data resources were screened (see Sect. 2) to select the variables of interest and to limit the majority of the analysis to electrically heated homes. Most of the analysis relied on multiple regression analysis and the approach is described in Sect. 3. Pre-retrofit data were examined to find relationships that might be useful in basic energy use calculations. This examination included indoor temperatures, space-heating energy use, water-heating energy use, and other base energy uses and is covered in Sect. 4. Changes in behavior following retrofit were evaluated and are discussed in Sect. 5. The indoor temperatures of wood-heated and electrically heated homes are compared in Sect. 6. Overall results and conclusions from the study are found in Sect. 7.

2. DATA PREPARATION

2.1 Monitored Data

A special group of 314 homes was chosen to represent a cross-section of the electrically heated portion of the Hood River residential community. As such, it was made up of 249 single-family dwellings (79%), 55 mobile homes (18%), and ten multifamily or duplex homes (3%). About 26% of the homes used one or more portable heaters. Baseboard heating systems were used in 61% of the houses while the remainder were equipped with central heating systems (a few heat pumps, but mostly central resistance furnaces). Although all of the homes were nominally electrically heated, 39% claimed to use wood or prestologs as their main source of heat. There are only 82 homes that claimed to use electricity as their only source of heat (and since a few of these had wood stove monitors, even this number is high). Of these 82 homes, only 46 were single-family dwellings.

The conservation retrofits applied to the monitored homes included ceiling, floor, and wall insulation, caulking and weatherstripping, storm windows and doors, pipe and duct insulation, water-heater insulation, low-flow showerheads, and clock thermostats. The retrofits varied from home to home based on the economics of the savings projections made during the audit. These retrofits were made without any charge to the homeowners. Air to air heat exchangers were put in many homes to avoid indoor air pollution problems. These heat exchangers provide forced ventilation to make up for the loss of fresh air caused by the improved tightness of the homes.

In the monitored homes, total electrical consumption, space-heating electricity use, water-heating electricity use (in about 200 homes), wood stove heat output (in about 100 homes), and indoor temperature were measured at 15 minute intervals. Each temperature monitor was placed in a frequently occupied room such as a den or living room and was positioned near an inside wall. The equipment used to measure the indoor temperature was calibrated and was accurate to within 2.5%, or about 2°F. The electrical energy use meters were accurate to about

3%. Data reflecting the energy use and indoor temperature were transmitted over the house wiring system to a four-channel recorder once every 15 min. Project personnel collected the data tapes every two weeks. These data tapes were then processed and screened by the PP&L staff. Data were collected for one full year before and one full year after the homes were retrofit with conservation measures (Spring of 1984 to Spring of 1986).

As received, the monitored data were arranged in records containing both energy consumption data and data quality flags. These data quality flags were assigned by the PP&L staff based on a number of automatic data checks. Questionable data, such as a long period with no consumption, were checked out in the field. If these data reflected the true usage (for example a vacation period) they were retained. If they were caused by an equipment malfunction, they were coded as bad data values. Whenever these flags indicated the data were beyond the acceptable bounds, the data value was set to missing and was not used in the analysis. The overall quality of the data was quite high and less than 6% of the data values for any channel, such as space heat or indoor temperature, were set to missing during the winter months.

2.2 Survey Data

The end-use monitored homes were surveyed in 1984. These customers knew they had been selected for the research portion of the project and were generally very cooperative. These data included physical descriptions of the dwelling and appliance stock, demographic information such as age, income, and education of residents, and attitude information such as feelings about the energy shortage. The survey data were carefully reviewed by ORNL and variables judged most likely to affect the customers' energy use and indoor temperature management were selected.

Several physically descriptive variables were included for two reasons. First, some of these variables, such as house size, may be correlated with demographic variables, such as income. By including both physical and demographic variables that may or may not be correlated in the model, it is possible to use statistical tests to determine the effect of each variable independently, as if all the other variables were held constant. The results of these tests indicate if variable correlations are too strong to define such independent relationships. Second, some of the physical variables, such as the presence of portable heaters, wood stoves, or clock thermostats, reflect a conscious life-style choice made by the customers.

The physically descriptive variables selected for analysis included house size, heating-system type, portable heater presence, dishwasher presence, clock thermostat, house age, which retrofit measures were installed (and their cost and projected savings), and dwelling type (single family vs mobile home). The demographic variables selected included number of residents, age of residents, household income, and educational levels of residents. Lifestyle choices were reflected in variables that described closing off rooms, wood stove use, self-reported nighttime temperatures, and whether the house was occupied during the daytime.

The surveys included both attitude and knowledge questions related to energy use. The attitude questions ranged from thoughts on environmental pollution, unemployment, and crime to whether or not they believed there were any actual scarcity problems with various energy resources. The knowledge questions tested the residents' understanding of the relationships between temperature selection and energy consumption and between energy consumption and utility bills. Early inspection of these questions showed no relationships between the responses to these questions and whether or not the customer used high or low amounts of energy or to the indoor temperatures. Another review of these data[3] revealed that an attitude of "yes, I have a right to use as much energy as I can afford" was a significant determinant of indoor temperature. This same paper also identified the service area, either the Hood River Co-op (with lower rates) or PP&L (with higher rates), as a significant factor affecting indoor temperature. Both of these variables were therefore included in this analysis as well.

2.3 Spectral Analysis

Spectral analysis is a method of identifying cyclical patterns of energy use. Previous application of this method indicated that it might produce information useful in differentiating customers into groups with similar energy use behavior.[4] This method was applied to the data base and the resulting group identities were used as another explanatory variable in the regression analysis to discover whether these energy use patterns were related to takeback behavior. A more detailed discussion of this spectral analysis is included in Appendix A.

3. ANALYSIS METHODOLOGY

The analysis efforts were organized into 3 categories: (1) examination of pre-retrofit data to analyze the effect of lifestyle variables on indoor temperatures and electricity use, (2) comparison of pre- and post- retrofit data to identify which customers were more likely to change their indoor temperature, and (3) a comparison of wood-burning homes to electrically heated homes.

Statistical regression analyses of these data sets were performed to examine the influence of the selected variables on energy use or indoor temperature. The regression results can reveal three important pieces of information: first, whether or not the tested variable is significant in explaining differences between households, second, the relationship between the tested variable and either indoor temperature or energy use, and third, how much of the measured differences among households can be explained by the tested variables.

All of the independent variables tested are listed in Table 1. In a regression analysis, variables can be treated as continuous values when the numerical value bears a meaningful relationship to the variable, such as income, where a person earning $40,000 earns twice as much money as a person earning $20,000. Other variables represent classes and must be treated differently. For example, you could not say that a mobile home was a "2" and a single family home was a "1" and achieve any meaningful results because a mobile home has no true numerical relationship to a single family home. Such class-type variables are better tested in a yes/no fashion. The usual way to investigate the influence of such class variables is to assign them the value of "0" for no and "1" for yes. When treated in this manner, the magnitude of the coefficient from the regression analysis reflects the magnitude of the effect of the class variable. For example, if the presence of a pet was indicated by a "0" for homes without pets and a "1" for homes with pets, and the resulting coefficient in an indoor temperature regression was -3.2, then homes with pets would tend to be about 3.2°F cooler than homes without pets.

Table 1. Independent variables

Variable name	Definition
ATTITUDE	= 0 if the survey respondent agrees that "People have a right to use as much energy as they want and can pay for", otherwise = 1
BABY	= 1 if any babies ($\leq$ 2 years old) live in the house, otherwise = 0
BASEBOARD	= 1 if baseboard heating system, otherwise = 0
CENTRAL	= 1 if central resistance furnace, otherwise = 0
CLOSEOFF	= 1 if 1 or more rooms are closed off and unheated, otherwise = 0
DISHWASH	= 1 if house has an automatic dishwasher, otherwise = 0
HEATPUMP	= 1 if heat pump, otherwise = 0
HIEDUCAT	= 1 if householder # 1 had at least some college education, otherwise = 0
HIINCOM	= 1 if the household combined pre-tax income is greater than $40,000, otherwise, = 0
HOME9TO5	= 1 if the house is occupied during the day, otherwise = 0
HOUSEAGE	age of the house, in years
INCOM	self-reported household income, $'s
LOEDUCAT	= 1 if householder # 1 had never gone past elementary school, otherwise = 0
LOINCOM	= 1 if the combined pre-tax income is less than $14,000, otherwise = 0
MAJOR2	= 1 if both floor and ceiling insulation were installed and no other major measures were installed, otherwise = 0
MEASURES	number of conservation measures applied to the house
MOBIL	= 1 if mobile home, otherwise = 0
MULTI	= 1 if multi-family housing, otherwise = 0
PEOPLE	= # of people who live in the house
PORTHEAT	= 1 if 1 or more portable heaters are in the household, otherwise = 0
PPL	= 1 if serviced by PP&L, = 0 if serviced by Hood River Co-op

Table 1 (continued)

Variable name	Definition
SELFTEMP	self-reported nighttime thermostat temperature
SENIOR	= 1 if any senior citizens live in the house, otherwise = 0
SMALLFAM	= 1 if less than 3 people in the household, otherwise = 0
SPECTRHI	= 1 if in the spectral group #3, otherwise = 0 (see Appendix A)
SPECTRLO	= 1 if in the spectral group #2, otherwise = 0 (see Appendix A)
SQFT	house area, ft^2
TEEN	= 1 if any teenagers live in the house, otherwise = 0
THERTYPE	= 1 if a clock thermostat, or a thermostat with a timer is in the household, otherwise = 0
TOTCOST	total cost of measures applied to the house
TOTSAVE	total estimated (predicted) savings
YOUTH	= 1 if any children under 13 years old live in the house, otherwise = 0

Continuous variables can also be treated as class variables if a step, or threshold, relationship is suspected. This approach can detect behavioral differences between groups of customers determined not by their relative amount of some value, such as education or income, but by their position relative to some threshold level, such as finishing high school or earning an income above the poverty level. In these cases the differences among customers may not be directly related to the absolute magnitude of the variable but to whether or not some minimum, or threshold, level has been obtained. When transforming a continuous variable into a class variable, it is important not to create two auto-correlated class variables. If a variable is divided into two regions, high and low, then only one yes/no indicator can be used for the regression analysis. If two such indicators were used, one each for high and low, then the two indicators would be 100% correlated and the regression results would indicate that the model was flawed. Therefore, if both high and low indicator tests are desired, the variable must be divided into three regions; high, medium, and low; then two yes/no indicators can be created without colinearity problems.

In many of the models the effect of income was tested both as a numerically continuous variable and by using "high-income" and "low-income" class variables. Education, family size, and house size were treated similarly. To avoid multicolinearity problems, the class and continuous forms of these variables were tested separately, and the most significant relationship was retained.

The dependent variables used for the regression analysis were indoor temperature, space-heating energy use, total household energy use, and water-heating energy use. For each regression analysis, one value of the dependent variable was chosen to represent the household. This was done to eliminate the complications of a panel analysis where the variables for each customer vary due to factors outside the area of interest, such as hourly variations in water use due to bath or washing schedules. The dependent variables were chosen to represent both average values (for example, the average indoor temperature over the winter season) and values at selected points in time (for example, the household 5:00 a.m. temperature averaged over all weekdays in the winter season).

Graphical examinations of energy use trends within groups chosen to represent differing lifestyle characteristics were made. These were often used to select independent variables for the regression analysis and to focus in on specific time periods when the differences between households would be most pronounced.

4. ANALYSIS OF PRE-RETROFIT DATA

The pre-retrofit analyses were based on data collected during the December, 1984 through February, 1985 period. (This winter period was chosen to avoid milder weather when the indoor temperature influences due to solar gain and natural ventilation would be greater.) Using these data, an average winter weekday profile (a set of 96 observations representing the indoor temperature and energy use for each 15-min period during the day) was produced for each customer. When values at a particular time are compared, they therefore represent the customer's temperature or energy use at that time of day averaged over the entire winter period. The evaluation of pre-retrofit data was limited to 187 homes heated mainly with electricity, as reported by the homeowner (the wood-heated homes are examined in Sect. 6). Homes with supplemental wood heat were included because a previous analysis of this data base showed that both the space-heating and total energy use in these homes was about the same as in homes heated exclusively with electricity.[5]

4.1 Indoor Temperature

The magnitude of the indoor temperature variations among the households was very small and the tested variables explained from 6 to 12% of these differences. These temperature variations were examined at 4:00 a.m. (usually the coldest time), 7:00 a.m. (immediately following any morning temperature set-up), and 4:00 p.m. (the warmest time of the day), as well as the overall average temperature per household. The variables tested in these models included the presence of senior citizens or children, income (as both continuous and high- and low-level tests), number of residents, heating system type (central resistance furnace or baseboard), high and low education levels, the energy use attitude question, dwelling type, the use of portable heaters, and whether they were in the PP&L area. Table 2 summarizes the effect of these variables on indoor temperatures and Table 3 provides a closer examination of the statistically significant variables.

Table 2. Variables used for multivariable regression analysis of indoor temperatures

Demographic variables	Physically descriptive variables
Statistically Significant[a]	
senior citizens	central furnace
number of residents	portable heaters
education	
Not Statistically Significant[a]	
Attitude	baseboard heat
income	dishwasher
teenagers	dwelling type
children under 12	utility rates

[a]At the 90% confidence level or better.

Table 3. Regression analysis results for indoor temperatures

Dependent variable	Adjusted R^2 (%)	Significant[a] variable	Coefficient (standard error)
Average indoor temperature	6	intercept	69.7 (1.0)
		central furnace	-1.4 (0.7)
		high education	-1.4 (0.7)
4:00 a.m. indoor temperature	12	intercept	67.0 (1.3)
		senior citizen	-3.0 (1.0)
		number of people[b]	0.6 (0.3)
		central furnace	-2.4 (0.8)
7:00 a.m. indoor temperature	7	intercept	67.0 (1.2)
		number of people	0.7 (0.3)
		low education	3.6 (1.6)
4:00 p.m. indoor temperature	7	intercept	71.8 (0.8)
		high education	-1.7 (0.7)
		portable heater[c]	1.4 (0.8)

[a]Statistically significant at the 95% confidence level unless otherwise noted.

[b]Statistically significant at the 94% confidence level.

[c]Statistically significant at the 93% confidence level.

At 4:00 a.m., a reduced version (in which many of the variables shown to be statistically insignificant were removed) of this model accounted for 12% (adjusted R^2) of the variations between households. At this time, homes with senior citizens tended to be about 3°F cooler than other homes (see Fig. 1). Homes with central heating systems were also about 2.4°F cooler than other homes. The temperature was proportional to the number of residents, rising about 0.6°F for each person above a base level of 67°F. At 7:00 a.m., homes where the primary resident had never gone past elementary school were about 3.6°F warmer and the temperature was again proportional to the number of residents, rising about 0.7°F for each person. At 4:00 p.m., homes where the primary resident had at least some college education were about 1.7°F cooler than other homes and homes with portable heaters were about 1.4°F warmer.

Only two variables were significant in explaining differences in the overall average temperature, a high education level and the use of a central resistance furnace. Homes with a college-educated resident had average temperatures about 1.4°F cooler than other homes. Homes with a

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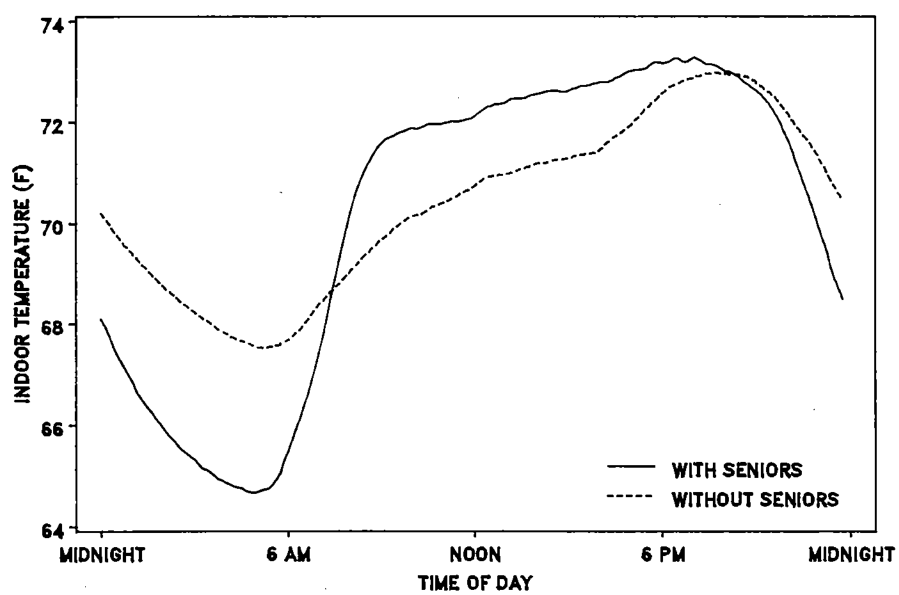

Fig. 1. Indoor temperature profiles for homes with and without senior citizens, average winter 1984/1985.

central resistance furnace were also about 1.4°F cooler than homes with baseboard heat or heat pumps.

During the survey, customers were asked to report their nighttime temperature settings. We compared these self-reported temperatures to the average monitored indoor temperatures between 11:00 p.m. and 6:00 a.m. As Fig. 2 clearly shows, people overwhelmingly under-estimated their nighttime temperatures. This reinforces the unreliability of self-reported temperature information as input to energy savings estimation procedures.

The indoor temperature and space heating profiles for 36 customers with clock thermostats were compared to those for 143 customers with ordinary thermostats. As Figs. 3 and 4 show, there are no significant differences in the temperature magnitudes or in the shapes of the curves between homes with and without clock thermostats. The space heating profiles are also similar in shape and magnitude, with only slightly higher morning peaks for the clock-thermostat homes and no significant nighttime savings. These slight differences in the group averages can

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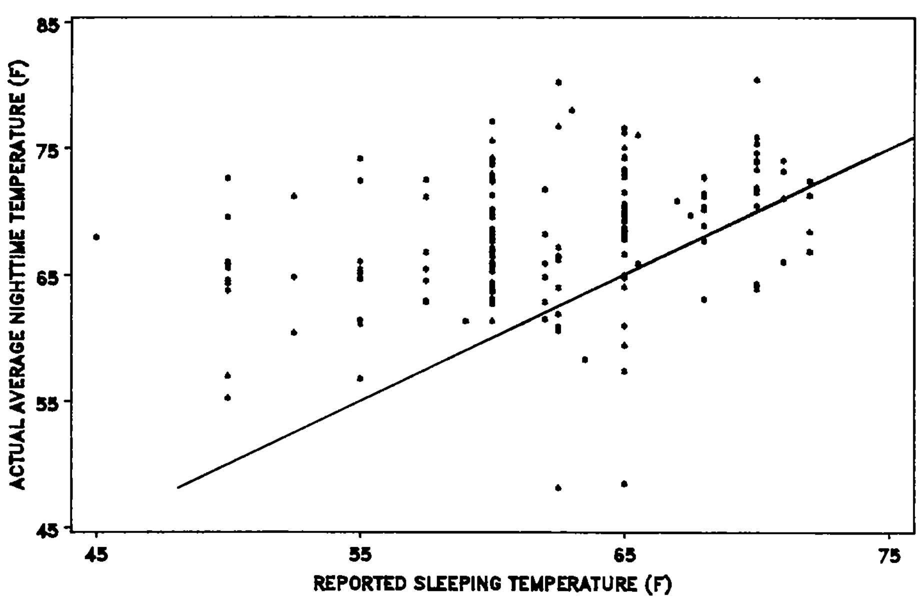

Fig. 2. Measured average nighttime temperature vs. reported sleeping temperature, winter 1984/1985 (the straight line marks the point at which the reported and measured temperatures would be equal).

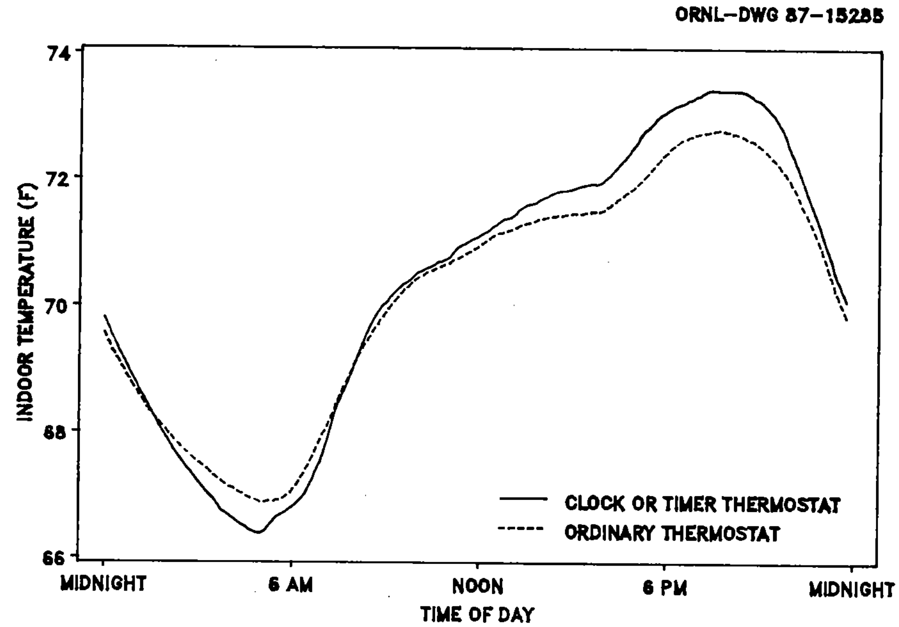

Fig. 3. Average winter indoor temperature profiles for homes with and without clock thermostats, 1984/1985.

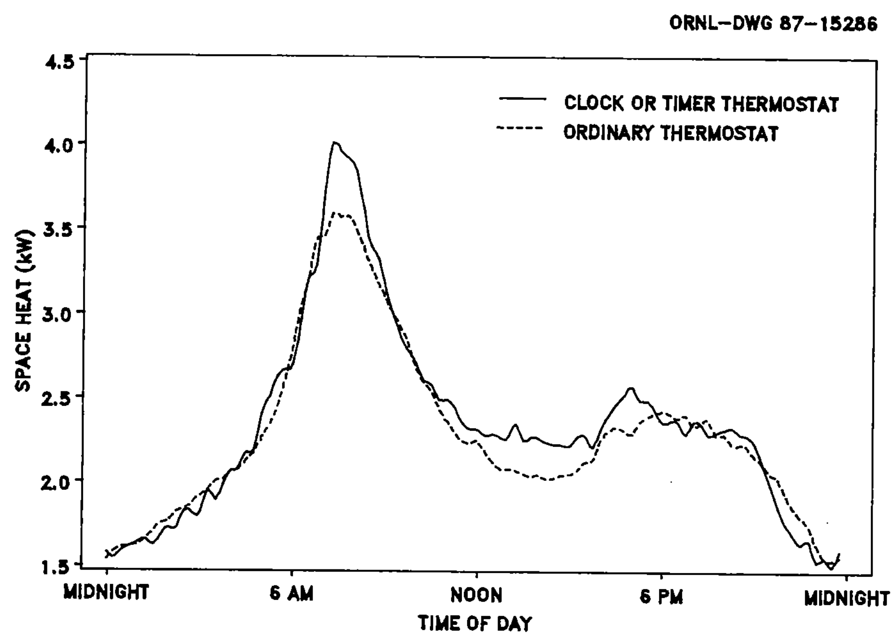

Fig. 4. Average winter space heating load profiles for homes with and without clock thermostats, 1984/1985.

be explained by two coincident behavioral patterns, 1) some of the people with clock thermostats aren't using them and 2) some of the people without clock thermostats are practicing manual setback on a regular basis. Therefore it would be inappropriate to infer setback behavior from the presence of a clock thermostat, or conversely, to assume a lack of setback behavior when no clock thermostat is in place. Considering the unreliability of self-reported temperatures discussed above, the accurate assessment of nighttime temperatures is a difficult problem indeed.

In the HRCP, indoor temperature, not thermostat set-point, was measured at each house. The difference between these two measures is demonstrated by comparing Figs. 5 and 6. In Fig. 5, indoor temperature appears to drop in electrically heated homes so that the homes are colder in March than in November, even though the average outdoor temperature was warmer in March. It was hypothesized that customers were turning down their thermostats to save money or because they became accustomed to colder temperatures as the winter progressed. However,

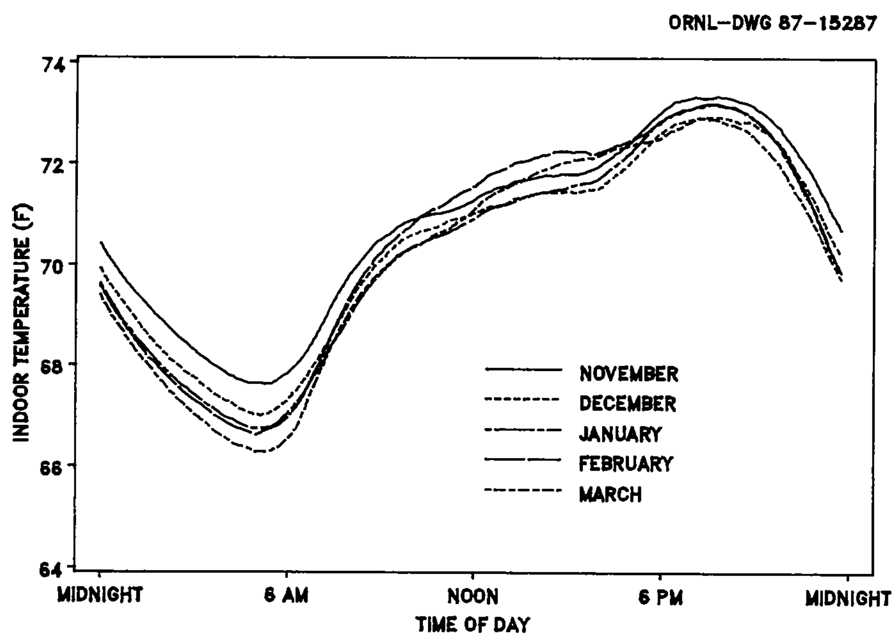

Fig. 5. Average monthly indoor temperature profiles for electrically heated homes, November 1985 to March 1985.

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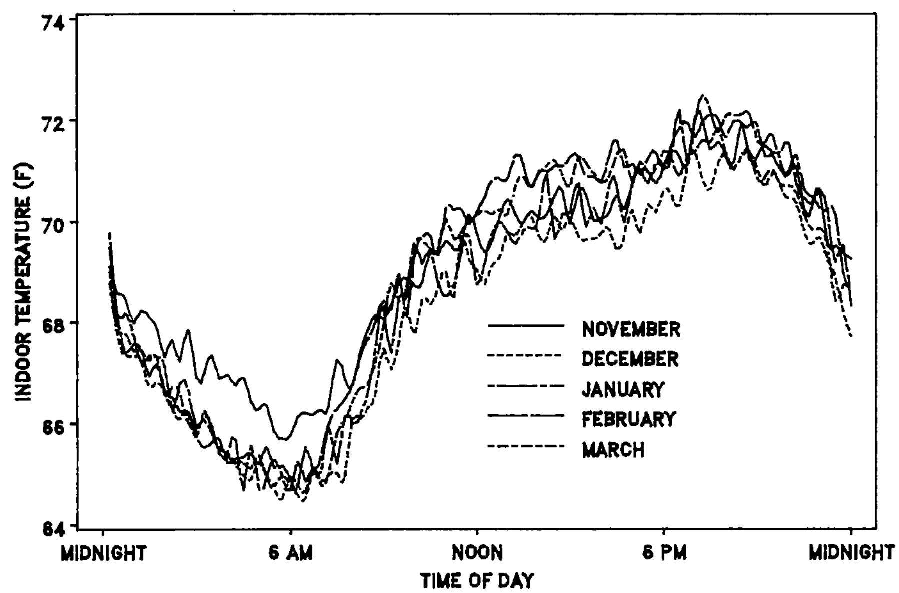

Fig. 6. Average monthly indoor temperature profiles for electrically heated homes when the data is constrained to points where the space heating system has just come on, November 1985 to March 1985.

when the data set was constrained to only those points where the space-heating system has just come on, reflecting the temperature at the bottom of the deadband around the thermostat set point, this phenomenon disappeared (see Fig. 6). It is important to remember then that measured indoor temperature fluctuations are not always accurate reflections of the customer's thermostat management.

Solar gains, infiltration, or frequent door and window openings can all cause the indoor temperature to vary from the thermostat set point. Occupants' understanding (or lack thereof) of how the thermostat controls the furnace can conversely cause the thermostat set point to vary widely from the indoor temperature (e.g., many customers believe turning the thermostat to a higher setting will cause the house to warm up more quickly).[6]

4.2 Space-Heating Energy Use

The best regression equation for space-heating energy use was based on the customers' energy use at 8:00 a.m (see Table 4). At this time of

Table 4. Regression analysis results for space heating energy use

Dependent variable	Adjusted R^2 (%)	Significant[a] variable	Coefficient (standard error)
Average space-heating energy use	4	intercept	1.6 (0.5)
		small family	0.5 (0.3)
		PP&L area[b]	-0.4 (0.2)
8:00 a.m. space-heating energy use	18	intercept	0.8 (0.8)
		house area	0.9 (0.3)
		senior citizens	1.3 (0.4)
		small family	0.9 (0.5)
		central furnace	1.6 (0.4)
Midnight space-heating energy use	6	intercept	2.2 (0.2)
		senior citizens	-0.5 (0.2)
		mobile home	0.8 (0.3)
		central furnace	-0.7 (0.3)
		PP&L area	-0.5 (0.2)

[a]Statistically significant at the 95% confidence level unless other-wise noted.

[b]Statistically significant at the 93% confidence level.

peak energy use, the tested lifestyle variables accounted for 18% of the variations among households. Homes with senior citizens used about 1.3 kW more at this time (they used about 0.5 kW less at midnight). Smaller families used about 0.9 kW more at 8:00 a.m. and homes with central heating systems used about 1.6 kW more. The electricity use was also proportional to floor area, increasing about 0.9 kW for every 1000 ft^2. Other variables were tested and found to be insignificant, including house type (MULTI or MOBIL), the attitude question, the presence of a heat pump, income as either a continuous variable or high- and low-income tests, the use of portable heaters, the presence of children in the household, and the PPL area test.

The multiple correlation for average space heating load was much poorer; only 4% of the variations were explained by the lifestyle variables. None of the variables tested were significant except for the small family and PP&L area indicators. At midnight (when the energy use is at a minimum), the explanatory power of the model was still very small, only 6%, but more variables were significant, including senior citizens, mobile homes, central resistance furnaces, and the PP&L area.

4.3 Water-Heating and Base Energy Use

Water-heating energy use was more closely tied to the tested variables as evidenced by the fact that 49% of the difference in average energy use could be accounted for by the lifestyle variables. The energy use was a strong function of the number of residents at all the tested times: 8:00 a.m., 7:00 p.m., and the overall average. Another examination of water-heating energy use on an annual basis also showed that the number of residents was a dominant factor.[7] Table 5 summarizes

Table 5. Regression analysis results for water-heating and base energy use

Dependent variable	Adjusted R^2 (%)	Significant[a] variable	Coefficient (standard error)
Average water-heating energy use	49	intercept	0.2 (0.1)
		number of residents	0.2 (0.02)
		senior citizens[c]	-0.08 (0.04)
8:00 a.m. water-heating energy use	33	intercept	-0.2 (0.2)
		number of residents	0.4 (0.06)
		high income	0.3 (0.1)
7:00 p.m. water-heating energy use	39	intercept	0.2 (0.1)
		number of residents	0.3 (0.03)
		senior citizens	-0.2 (0.1)
Average base[b] energy use	32	intercept	0.3 (0.2)
		portable heaters	0.3 (0.1)
		number of residents	0.07 (0.03)
		high income	0.3 (0.1)
		house area	0.4 (0.1)

[a]Statistically significant at the 95% confidence level unless other-wise noted.

[b]Base = total energy use minus space and water-heat energy use.

[c]Statistically significant at the 93% confidence level.

the results of the regression analysis of the water-heating energy use. The water-heating load increased about 0.2 kW/person on the average, about 0.4 kW/person at 8:00 a.m., and about 0.3 kW/person at 7:00 p.m. Homes with senior citizens used about 0.2 kW less in the evening and homes with incomes above $40,000/year used 0.3 kW more in the morning than other homes. Some variables expected to be significant were not, such as teenagers in the home or the presence of dishwashers. The attitude, PPL, and income variables also were insignificant.

The base load was calculated by subtracting the space- and water-heating loads from the total load. This base load should reflect the energy used for lighting and appliances. The base load was found to increase with increasing numbers of residents at the rate of about 0.07 kW per person (see Table 5). Households with an income greater than $40,000 per year used about 0.3 kW more than other households. Base energy use was also related to house size with the base energy use increasing about 0.4 kW for every 1000 ft^2 of floor area. The model showed a positive correlation between portable heater use and base energy use because the space heating provided by portable heaters was not measured as space heat and was therefore included in the base heat definition. These homes tended to have base loads about 0.3 kW higher than homes without portable heaters. The base use was not significantly related to income (as a continuous variable), low levels of income, education, the attitude test question, or the PPL area test.

5. COMPARISON Of PRE- AND POST-RETROFIT BEHAVIOR

Indoor temperatures may be affected by outdoor temperatures. Therefore, the comparison of pre- and post- retrofit behavior was based on data collected during about 40 days selected from the 1984/85 winter and 40 days selected from the 1985/1986 winter. These days were selected by choosing matching pairs of comparable days. Days were defined as comparable if both their average and minimum temperatures matched within 5°F (most days were matched much more closely) and if their day of the week was the same. The days were chosen so that the distribution of outdoor temperatures during the 40 selected pairs of days was similar to the distribution of outdoor temperatures during these two winter periods. The selected pairs of days were then tested using paired t-tests on both the daily average temperature and the daily minimum temperature. These tests confirmed that the two selected groups of days were comparable.

We used two groups of customers for our comparison of pre- and post-retrofit energy use behavior, one to represent the average level of conservation retrofits and the other to represent a much higher level of conservation retrofits. Both groups were limited to homes where the residents stated that their primary heating source was electricity. The first group (88 customers) were alike in that they all had ceiling and floor insulation installed with other minor retrofits such as water heater insulation, low-flow showerheads, etc. The average retrofit cost in these homes was $6500. The second group (185 customers) was not constrained by measure selection. The average retrofit cost in this total group of homes was $4500, about $2000 less than in the homes selected in the first group because they had both floor and ceiling insulation installed.

5.1 Indoor Temperature

Examination of pre- and post-retrofit indoor temperature profiles showed that daytime behavior is unchanged but nighttime temperatures are raised by about 0.4°F following retrofit for the larger group of customers. As indicated in Fig. 7, the difference is much greater, 1.0°F, for the ceiling and floor insulation group. The greatest difference between the two seasons for both groups appears to occur at about 5:00 or 6:00 a.m.

Bar charts (see Figs. 8 and 9) comparing daytime and nighttime temperature changes between the two seasons show that about 2/3 of the households did not change their indoor temperature by more than 2°F. More than 2/3 of the customers in the floor and ceiling insulation group who changed their indoor temperature chose warmer temperatures following retrofit. However, among the total sample, almost as many customers choose colder temperatures as warmer temperatures. These temperature changes for the total sample were also examined using a paired t-test. This test showed that none of the average temperature increases (daytime average increase of 0.08°F, nighttime average increase of 0.37°F, and overall average increase of 0.11°F) were statistically different from 0.0 at the 90% confidence level.

Another examination of the Hood River data base also showed no statistically significant changes in the measured temperature.[3]

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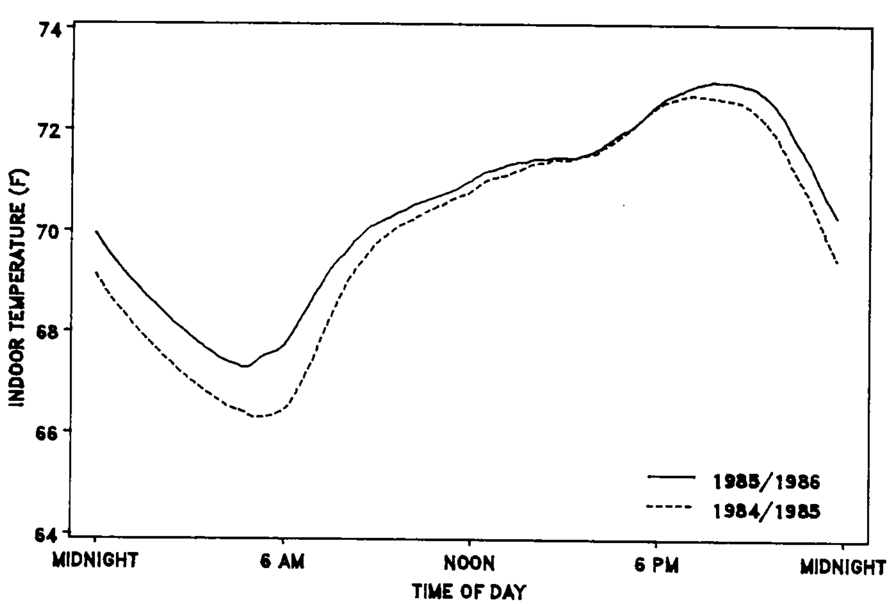

Fig. 7. Comparison of pre- and post- retrofit indoor temperature profiles for the ceiling and floor insulation group.

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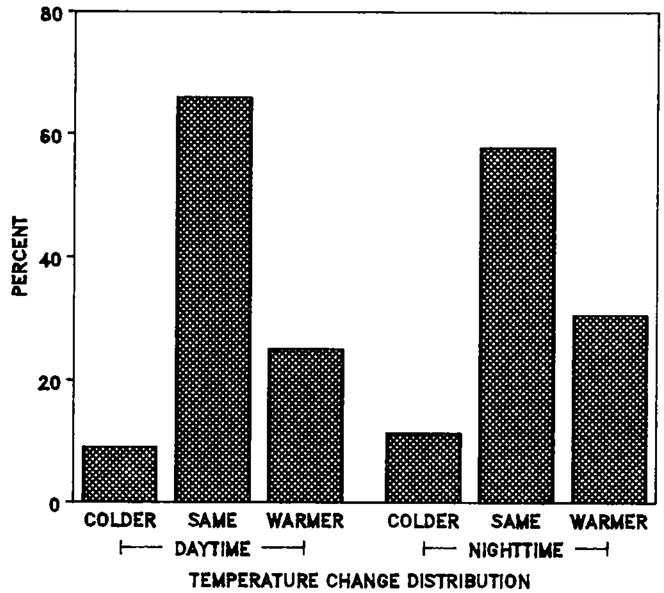

Fig. 8. Distribution of pre- and post- retrofit indoor temperature changes for the group of customers with floor and ceiling insulation installations.

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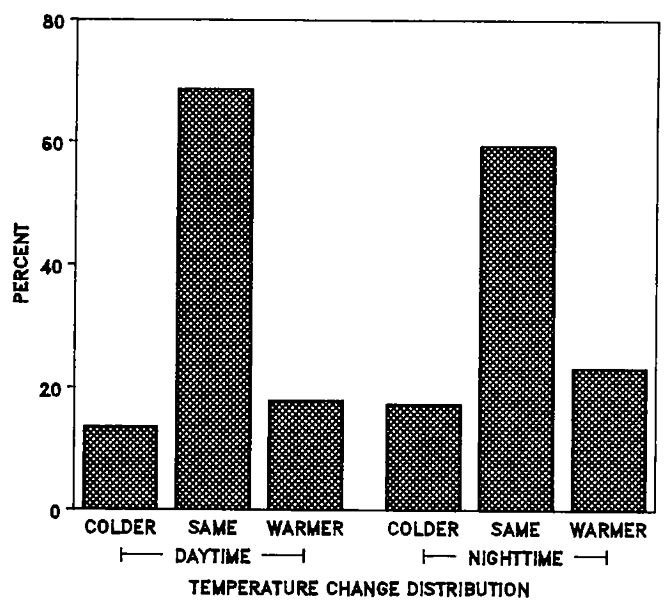

Fig. 9. Distribution of pre- and post- retrofit indoor temperature changes for the total sample.

However, an econometric model developed using this data predicts an average increase of 0.3°F attributable to improvements in structural efficiency.[3] This econometric model included monthly outdoor temperature as an independent variable rather than normalizing the weather separately as was done in this study. Also, the severe weather period during November 1986 (several 100-year records were broken) was used as input for this econometric model but was excluded in the analysis presented here.

Although the average temperature change for the group as a whole was insignificant, Figs. 8 and 9 show that some customers are changing their indoor temperatures. Because the difference in indoor temperatures between the two seasons was shown to be greatest at about 5 a.m., this time was chosen to test the explanatory value of several lifestyle-related variables. The model tested whether the following factors would help explain the differences between before and after temperature choice at 5 AM: (1) the presence of senior citizens, children, or teenagers in the home, (2) heating system type (central, heat pump, or baseboard) and whether portable heaters were used, (3) education level of the household head, (4) family size, (5) household income, (6) temperature choice before the retrofit, (7) floor area of the home, (8) the total cost of the measures installed, (9) the average total energy use before retrofit, (10) an attitude variable based on the resident's belief that they have a right to use as much energy as they can afford, (11) an energy cost variable that differed between customers on the PP&L rates and the Hood River Co-op rates (Co-op rates were much less than PP&L rates which had risen steeply in the years immediately preceding the HRCP programs), (12) building type (single family, multifamily, or mobile homes), (13) the group identity based on the spectral analysis discussed in Sect. 2.3, and (14) the presence of a dishwasher in the home.

The reduced version of this model, with most variables found to be statistically insignificant removed, explained about 45% (adjusted R^2) of the variation in before and after temperatures for the floor and ceiling insulation group. Only three variables (before-retrofit temperature choice, use of portable heaters, and area of the home) were significant. Homes with warmer pre-retrofit temperatures and larger homes were more likely to lower their temperature (see Figs. 10 and 11), while smaller homes and homes with cooler pre-retrofit temperatures raised their temperatures. Homes with portable heaters were likely to have temperature increases about 1.5°F greater than homes without portable heaters.

This same model explained about 34% (adjusted R^2) of the variation in the total sample and several other variables were found to be significant. The effects of pre-retrofit temperature choice and house size were about the same. The presence of a college-educated household head led to lowered post-retrofit indoor temperatures, while the reverse was true for a non-college-educated household head (Fig. 12). Homes with an average pre-retrofit load of less than 2 kW showed a dramatic increase in their indoor temperature following retrofit (Fig. 13). A high income level was associated with higher post-retrofit temperatures at 5 a.m., but Fig. 14 shows that throughout the rest of the day, income has very little effect.

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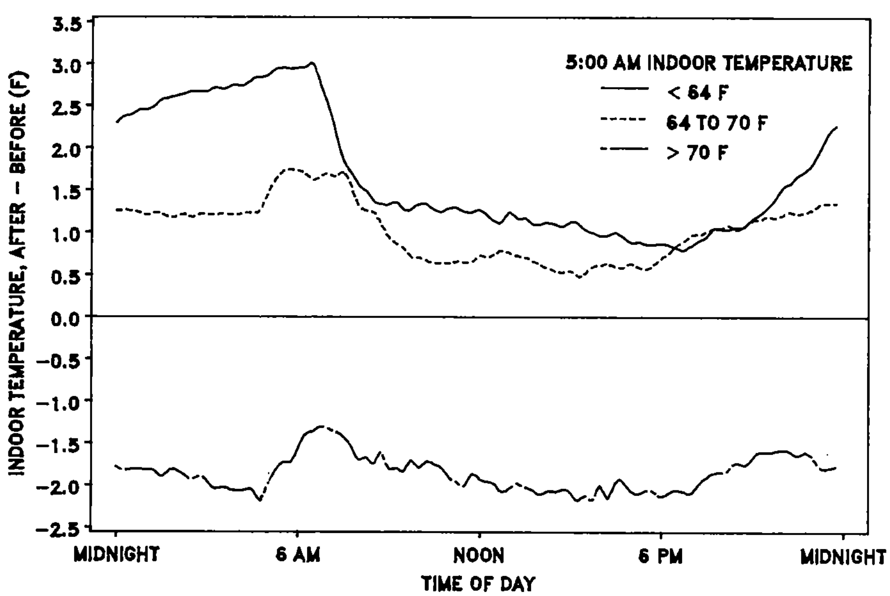

Fig. 10. Change in indoor temperature profiles for groups of homes based on their pre-retrofit indoor temperature at 5:00 a.m., floor and ceiling insulation group.

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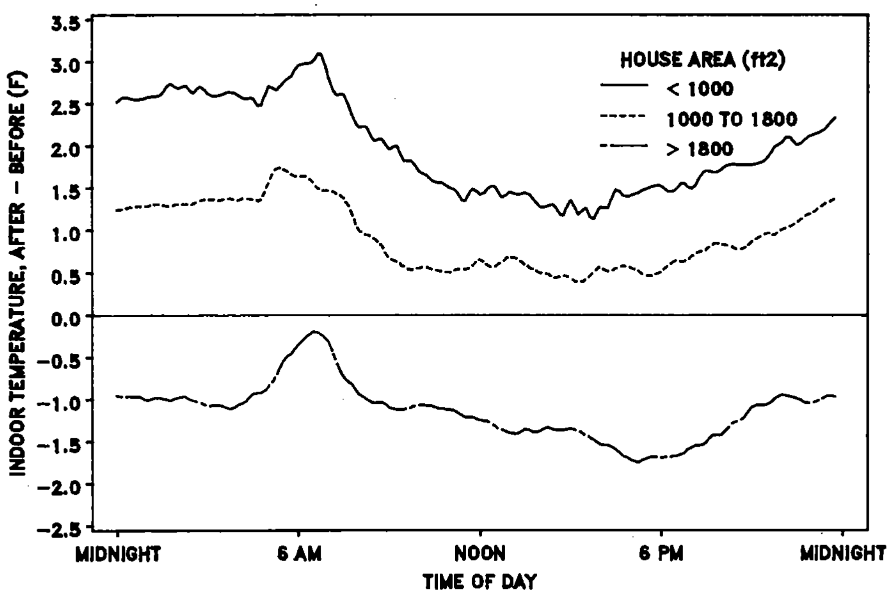

Fig. 11. Change in indoor temperature profiles for groups of homes based on their floor areas, floor and ceiling insulation group.

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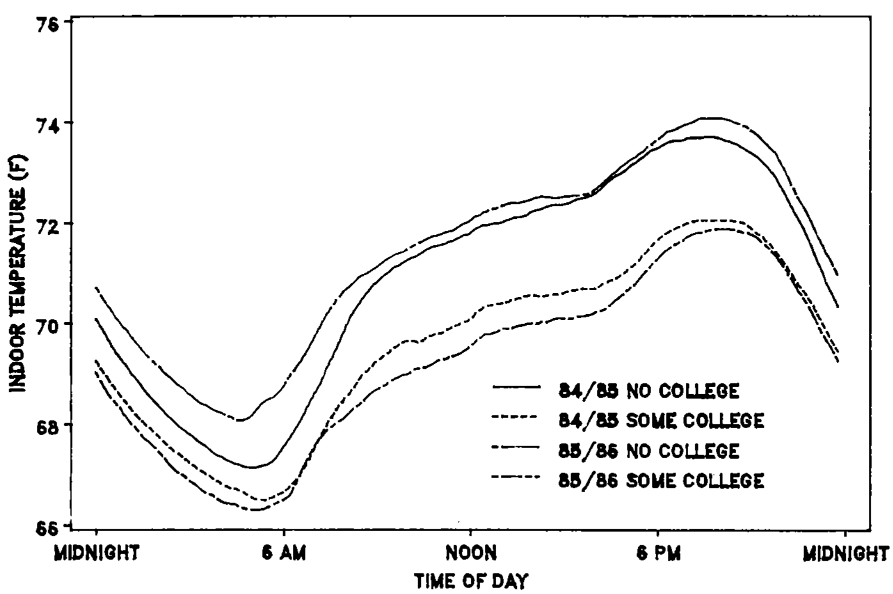

Fig. 12. Indoor temperature profiles before and after retrofit for homes in the total sample with and without a college-educated resident.

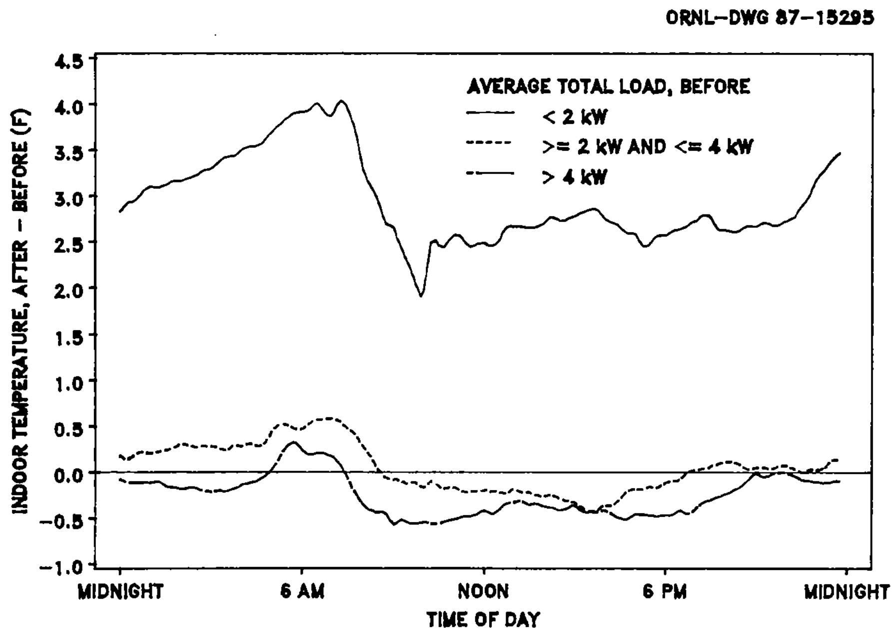

Fig. 13. Indoor temperature profiles before and after retrofit for homes in the total sample grouped according to pre-retrofit total load levels.

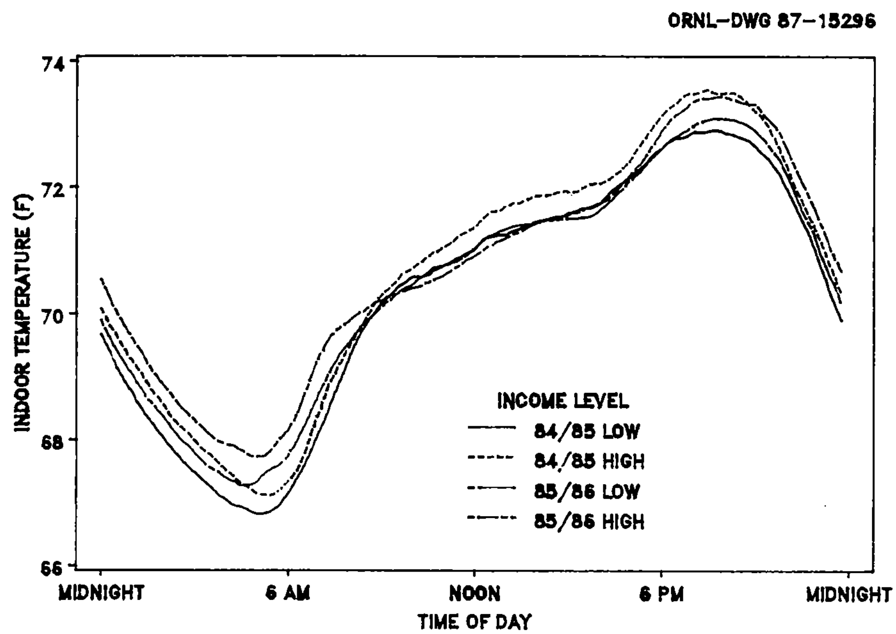

Fig. 14. Indoor temperature profiles before and after retrofit for homes in the total sample grouped according to income level.

5.2 Energy Use

Before retrofit, the ceiling and floor insulation group used an average of 0.0133 kWh/dd per 1000 ft^2 for wintertime space heat compared to 0.0093 kWh/dd per 1000 ft^2 after retrofit (30% saving). The corresponding winter total energy use saving was 19%. For the total sample group the wintertime space heat saving was about 24% and the total energy use saving was about 15%.

In another analysis of almost 3000 HRCP participants, the annual total energy savings were also found to be about 15%.[8] The average savings for these 3000 homes represents about 43% of the predicted savings.

6. COMPARISON OF WOOD-BURNING AND ELECTRICALLY HEATED HOMES

The comparison of wood-burning and electrically heated homes was based on the same set of similar days discussed in Sect. 5. The average electrical space heating energy use for 121 customers in HRCP who claim that their main heating fuel is wood or prestologs is predictably less than the average space heating energy use of 193 customers whose main heating fuel is electricity. Their profiles become slightly closer (compare Figs. 15 and 16) following retrofit because the wood-heated homes saved less total energy (14% on a per square foot basis) than the electrically heated homes (18%, also on a per square foot basis).

Indoor temperatures in both wood and electrically heated homes appeared to be slightly elevated (about 0.2 to 0.3°F) following retrofit. The wood-heated homes were about 1.3°F warmer than electrically heated homes both before and after the conservation retrofit (Fig. 17). The warmer temperatures in wood-heated homes could be caused by the placement of the indoor temperature monitor in or near the room with the wood stove. Indoor temperatures vary throughout a house. This

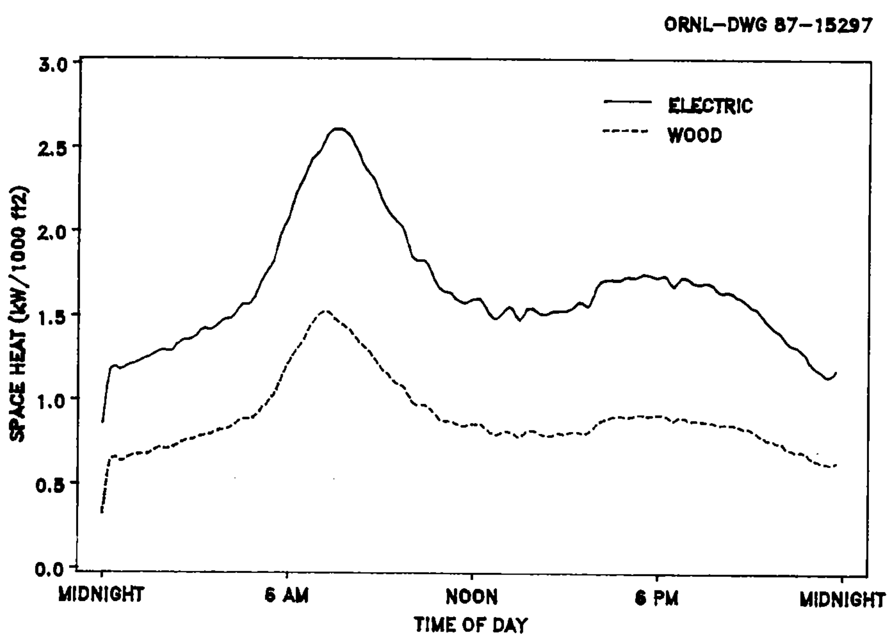

Fig. 15. Space heating load profile for electric and wood-heated homes, before retrofit.

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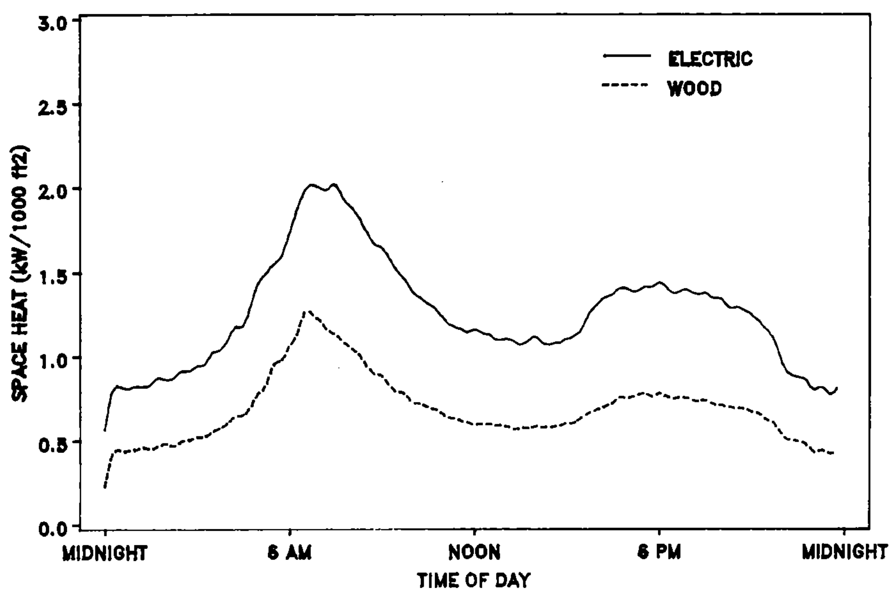

Fig. 16. Space heating load profile for electric and wood-heated homes, after retrofit.

ORNL-DWG 87-15299

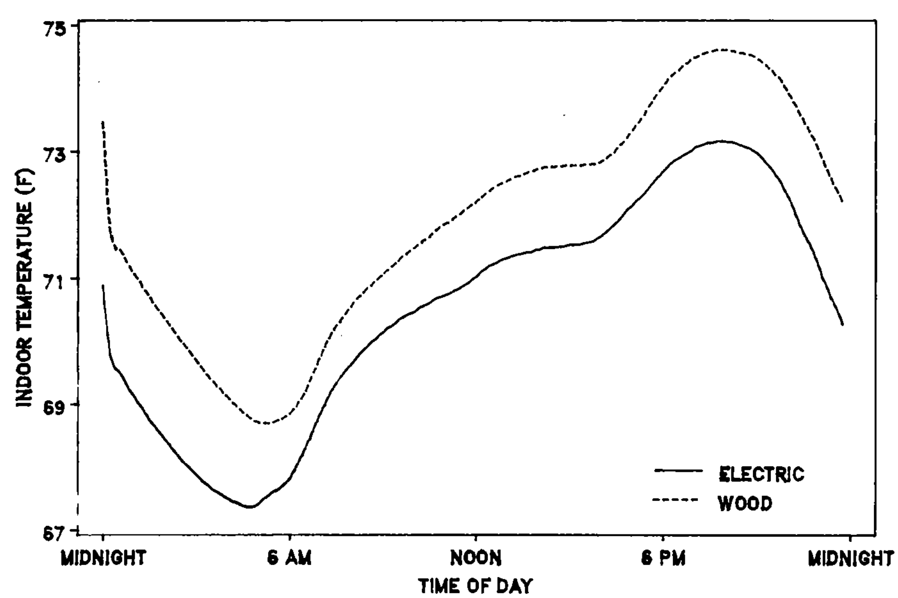

Fig. 17. Indoor temperature profiles for electric and wood-heated homes following retrofit.

effect would likely be magnified in homes heated by a wood stove as compared to homes heated by a central system with ductwork. The average whole-house temperatures of wood and electrically heated homes may therefore be more similar than would be measured by a single temperature probe.

7. RESULTS AND CONCLUSIONS

This analysis addressed two separate questions: (1) are lifestyle variables important in defining energy use and can they be incorporated into energy use estimation procedures to improve the accuracy of energy savings predictions, and (2) are energy savings less than predicted because customers are electing to receive a portion of the savings in the form of improved comfort. The major conclusion is that while take-back occurs in some houses, its overall effect is very small in magnitude and can not explain the large differences between predicted and achieved energy savings due to conservation retrofits. In addition, the results of this study indicate that minor adjustments and improvements can be made to audit procedures, but that these adjustments will not eliminate the large savings discrepancies noted.

Other conclusions based on this study include:

- In general, the explanatory power of selected lifestyle variables, although statistically significant, was too weak to be useful in predicting space-heating or total energy use.
- The number of occupants was the most significant factor in determining water heating energy use, explaining 49% of the difference in average water heating use. This relationship should be incorporated into audit predictions of hot water use and energy savings. (Interestingly, the presence of teenagers in the household was not significant, although it is often mentioned as leading to increased hot water use.)
- Although changes in the indoor temperature before and after retrofit did occur, the changes were small and were not universal or consistent among the households. About 2/3 of the households did not change their indoor temperature by more than 2°F. Among the total sample, almost as many customers chose colder temperatures as warmer temperatures. Homes with lower pre-retrofit temperatures and smaller homes were more likely to raise their temperatures. These factors explained about 45% of the variation in before and after temperatures for a group of customers that had floor and ceiling insulation installed. For the total group of electrically

heated homes, the effects of lifestyle variables accounted for about 34% of the variation in before and after temperature differences for the total sample. The effects of these variables are large enough to incorporate into audit predictions as some sort of correction factor. However, the average magnitude of this takeback correction is very small and would not significantly improve the accuracy of the audit predictions.

- Only 4% of the differences in average space heating loads were explained by lifestyle variables.
- The accuracy of energy saving predictions depends on the accuracy of the indoor temperature used in the audit calculations. However, this study found that self-reported temperatures are unreliable (as evidenced by comparison of the reported and measured nighttime temperatures). Also, only 6% of the differences in average indoor temperature were explained by lifestyle variables.
- Temperature setback patterns cannot be assumed based on the presence or absence of clock thermostats because daily indoor temperature profiles of both groups were found to be the same.
- Lifestyle variables explain 32% of the differences in base energy use.

REFERENCES

1. E. Hirst and R. Goeltz, *Comparison of Actual and Predicted Energy Savings in Minnesota Gas-Heated Single-Family Homes*, ORNL/CON-147, Oak Ridge National Laboratory, Oak Ridge, TN, March 1984.

2. E. Hirst, D. White, and R. Goeltz, *Comparison of Actual Electricity Savings with Audit Predictions in the BPA Residential Weatherization Pilot Program*, ORNL/CON-142, Oak Ridge National Laboratory, Oak Ridge, TN, November, 1983.

3. T. Dinan, *An Analysis of the Impact of Residential Retrofits and Indoor Temperature Choice*, ORNL/CON-236, Oak Ridge National Laboratory, October 1987.

4. T. K. Stovall and M. A. Kuliasha, *An Analysis of Lifestyle Effects on Residential Energy Use*, ORNL/CON-170, Oak Ridge National Laboratory, sponsored by DOE Office of Buildings Energy Research and Development, Oak Ridge, TN, February 1985.

5. T. K. Stovall, *Hood River Conservation Project Load Analysis*, ORNL/CON-240, Oak Ridge National Laboratory, Oak Ridge TN, 1987.

6. W. Kempton, "Homeowner's Models of the Heating System and Heat Loss: Effects on Home Energy Management," *Proceedings from the ACEEE 1986 Summer Study on Energy Efficiency in Buildings*, Vol. 7, pp. 7.135-7.145, American Council for an Energy-Efficient Economy, Washington, DC, August 1986.

7. E. Hirst, R. Goeltz, and M. Hubbard, *Determinants of Electricity Use for Residential Water Heating: The Hood River Conservation Project*, unpublished report, sponsored by Bonneville Power Administration, Portland, OR, June 1986.

8. E. Hirst, R. Goeltz, and D. Trumble, *Electricity use and Savings in the Hood River Conservation Project*, ORNL/CON-231, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 1987.

Appendix A

Spectral Analysis Details

Spectral analysis requires time-series data and has been used in the past to discern between weather-driven and lifestyle-driven space heating loads.[4] Spectral analysis fits a series of sine and cosine terms to a given profile to identify the underlying frequencies of the profile and the contributions of these frequencies to the profile. For example, a spectral analysis of total house load for a group of houses would show lifestyle patterns with fundamental frequencies of 24 h (daily activities), 12 h (morning and evening activity periods), 4 to 6 h (cooking and cleanup), and a host of other frequencies, depending on the electricity-consuming activities engaged in at the group of houses.

This spectral analysis technique was applied to the HRCP data set in an attempt to group together customers with similar energy use patterns. This analysis covered each customer's total energy use time series data during the month of November, 1984. Customers were assigned to groups based on their two highest spectral density peaks. The largest group of customers, almost 200, was dominated by 12 and 24 h cycles. A second group of about 50 customers was distinguished by the dominance of cycles longer than 24 h. The last group of about 40 members showed a tendency toward shorter cycles of 6 h or less. The average (over the month of November) space heat and total energy use profiles were then calculated for each group. These profiles, shown in Figs. 18 and 19, reflect the trends identified by the spectral analysis. Group 1's curve is a relatively smooth, double humped curve showing the early morning heating load and the morning and evening activity periods. Group 2's curve is noticeably flatter than the others, with shallower troughs and smaller peaks. The last group's curve is exceptionally peaky and rough. Load curves that average at least 30 randomly chosen homes are generally much smoother than this curve. Because this curve represents the average of about 40 homes over a month's time, the roughness must actually reflect the fluctuating nature of these customers' energy use.

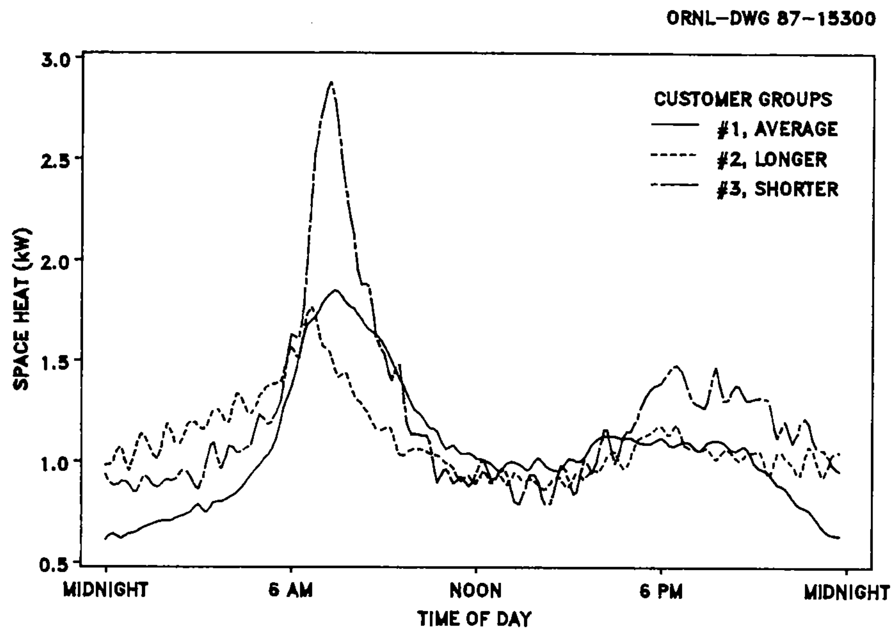

Fig. 18. Hood River November 1984 space-heating energy use, customers clustered using spectral analysis.

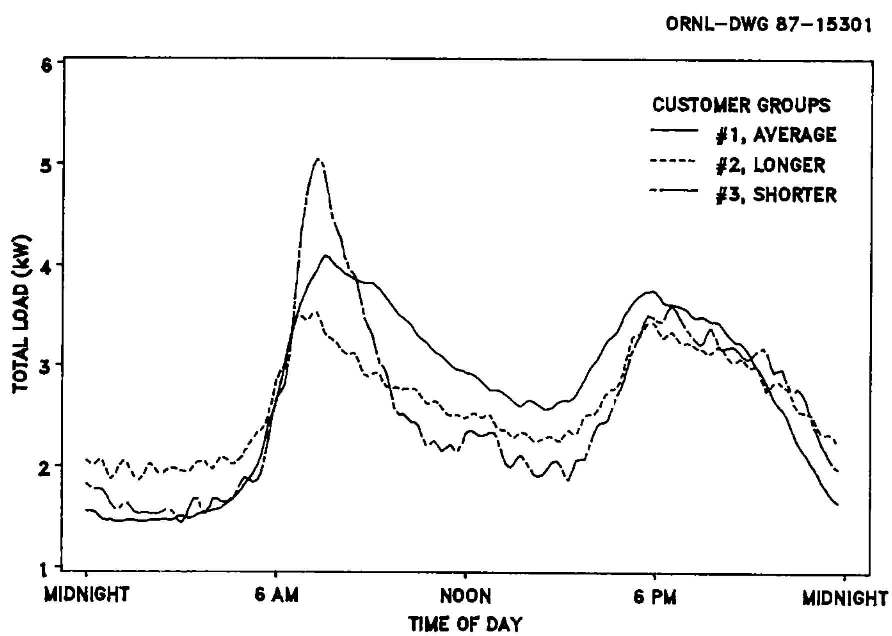

Fig. 19. Hood River November 1984 total energy use, customers clustered using spectral analysis.

This spectral group identity was then tested as another explanatory variable in the regression analysis to discover whether these energy use patterns were related to take back behavior. They were not.

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