OCCUPANT USE FACTORS INFLUENCING OPTIMAL RESULTS FROM ENERGY CONSERVATION STRATEGIES

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ABSTRACT

Although residential conservation strategies can have a dramatic impact on energy consumption, the involvement of the occupant can have a deterring and/or an enhancing influence on optimal results. Occupant impact on the use of residential heating conservation strategies was assessed by monitoring use factors and energy consumption data of nine families living in an energy test house. The families tested two supplemental space heating strategies, use of a sunspace and a woodstove. The families used each strategy separately for one week periods. An assessment of a hot water conservation strategy, use of flow restricting showerheads, was made by 15 live-in families, nine during the winter and six during the summer. The families used the showerheads either for a one or two-week period. Energy consumption data were compared against a baseline week in which none of the conservation strategies were used. A computer-based data acquisition system tracked energy consumption as well as room temperatures and other environmental data. Questionnaires completed daily and weekly collected user behavior data including evaluations of user involvement, resulting thermal comfort, and impact on family routines and habits. The results showed that resident implementation of strategy requirements was related to energy savings. Energy savings varied with available time in the home for opening/closing sunspace doors for optimal heating, with the level of previous experience with the woodstove strategy, and with compensating behavior such as substituting baths versus using flow restricting showerheads.

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Energy efficiency in residences has been promoted not only to decrease national energy consumption by the residential sector but also to assist families in controlling household energy expenditures. Much of the variation that exists among residences in the level of energy consumption occurs as a result of differences in the dwelling units (Morrison, 1977); however, about 40% of the variation has been found to occur due to occupant use behavior (Socolow, 1978). Results of recent research in the behavioral aspects of energy use indicate that occupants' use of home energy systems can contribute to the energy use variation that occurs in residences (Kempton & Krabacher, 1987; Costanzo, Archer, Aronson, & Pettigrew, 1986). Data on how energy use behavior can affect the ultimate energy savings of strategies can be useful to consumers as well as to professionals assisting families in improving their energy management skills.

The purpose of this paper is to examine the energy use practices of 15 volunteer families, who lived in an energy test house and implemented conservation strategies in space heating and hot water consumption. Specifically, data were analyzed to identify occupant use factors contributing to levels of (1) energy consumption for space heating when a sunspace and a woodstove are used separately as supplemental heating sources, and (2) hot water consumption with the use of flow restricting showerheads.

PROCEDURES

Overall Design

Data for this paper were obtained from a four-year project in which 15 volunteer families lived in an energy test house for periods of either six weeks (heating strategies, nine families) or four weeks (cooling strategies, six families) and employed selected conservation strategies in residential space heating, space cooling, and water heating (Turner, Klett & Gruber, 1988). Specifically, the data reported here represent occupant use factors and energy consumption data on nine winter families' use of two supplemental residential heating strategies: the use of (1) a sunspace and (2) a woodstove. Each strategy was tested by each family for one week periods. Data on the use of the hot water conservation strategy, use of flow restricting showerheads, were based on use data from all 15 families. The families trial tested this strategy for either a one or two-week period. The residence periods of the families occurred during the years 1982 to 1985 with the nine winter families living in the house during the winter months from November through April and the six summer families living there during the months of June to August. Selection of these time periods was based on degree day data for North Carolina.

It is important to highlight that the purpose of the project from which the data for the paper are taken was to study the interaction between the user and the implementation of residential conservation strategies. Project participants were not instructed or otherwise encouraged to try to save as much energy as they could. This distinction is important when considering the findings presented in this paper.

Conservation Strategies (Broad Study)

The conservation strategies examined in the project from which the data in this paper are taken were selected from the popular literature on energy conservation in the 1970's. Selection of the strategies was based on the following criteria:

1. Could be readily used by families.

2. Would have limited interaction effects on other strategies tested.

3. Could be easily installed or used in the energy test house.

Conservation Strategies Tested (Reported in this paper)

Heating energy savings data were based on energy consumption for the weeks when the two supplemental heating strategies were used compared against a baseline period when they were not used. This baseline period was the week when the heating thermostats were set at 65.0°F with no other heating sources available. During the week when the thermostats were set at 65.0°F and during the weeks that the sunspace and woodstove were added for supplemental heating, thermoguards were placed over the thermostats and locked by the project personnel. The savings in hot water consumption resulting from use of the flow restricting showerheads was determined by comparing the gallons of hot water used per adult shower when the flow restricting showerheads were installed, to the gallons of hot water used with a baseline week in which regular showerheads were installed. The procedures used in implementing these strategies are described below.

Sunspace. During the week that the sunspace was used to provide supplemental heating, the heating thermostats were set at 65.0°F. The nine families were told to use the sunspace for extra heating as needed, and were asked to actively control the supplemental heating provided by the sunspace system by opening and closing the two sets of double doors that connected the living room with the sunspace (see Figure 1). The sunspace temperature was monitored by the families by a large Fahrenheit thermometer located on the outside wall of the sunspace in easy view through the glass of the double doors. The families were asked to open the double doors when the sunspace temperature reached or exceeded 80.0°F and to close the double doors when the sunspace temperature fell below 80.0°F. Also, a thermostatically-controlled fan, set on 80.0°F, delivered warm air to the living room and the master bedroom through vents connected to each room. The use of the fan assured that some heat transfer would occur, but maximum heat transfer was to be obtained by the opening of the sunspace doors.

Woodstove. During the week that the woodstove was used to provide supplemental heating, the heating thermostats were set at 65.0°F. The nine families were asked to use the woodstove for extra warmth as needed. Each family received instructions on the proper use of the woodstove and also received a demonstration of its operation. Some of the participants had never used a woodstove. The use of the woodstove involved bringing in wood from the outside, feeding wood into the stove, and stoking the burning logs to maintain even and continuous burning. Decisions had to be made regarding when and how much wood to add and how much to adjust the air vents on the woodstove to achieve the desired level of burning and heat production.

Flow Restricting Showerheads. The strategy of using flow restricting showerheads was employed for one or two weeks of the families' stay in the test house. During that time, families were free to shower as often as they liked, for as long as they liked, and could choose to take baths instead of showers. One female participant did, in fact, take only baths. It should be noted that this preference was independent of the use of the showerheads.

Participating Families

All participating families were volunteers who agreed to live in the house for either the six or four-week period. The families were recruited by the project director and paid a $400 honorarium for their participation. The families were selected by two primary characteristics--family size and age(s) of children present in the home.

Family size ranged from two persons (a couple) to five persons (husband, wife, and three children) and the ages of the children varied from preschool to teen-age. The family type was married husband and wife which allowed assessment of two adult respondents as well as comparisons of male and female responses.

For the winter families, the ages of the adults ranged from 25 to 70 years. The educational levels of the adult family participants ranged from high school to doctoral degrees. In six of the nine families, both adults were employed full time. In one family, the wife was on disability leave. In two of the families, the male was employed full time and the female was not gainfully employed. The remaining family was a retired couple. The employment positions included university teachers, a physical therapist, a social science researcher, a civil engineer, a physician's assistant, a government vehicles inspector, a printer, a policeman, a secretary, and a receiving clerk. Participants' incomes ranged from $15,000 to over $50,000.

For the summer families, the ages of the adults ranged from 23 to 50 years. The educational levels of the the adult family participants ranged from high school to doctoral degrees. Both spouses in five of the six families were fully employed: however, for one family the husband was on disability leave. The remaining family was composed of a male who worked full time and a female who was employed part time. The positions included university teachers, policemen, factory and textile workers, a researcher, a librarian, an insurance adjuster, a cashier, a stock clerk, and a secretary. The family incomes ranged from $20,000 to $34,999.

Energy Test House

The energy test house, Garrett House, is a pre-World War II, two-story brick house located on the campus of North Carolina Agricultural and Technical State University. The house was retrofitted with a passive solar greenhouse, a woodstove and other energy conserving measures. The house contains 2770 ft.^{2} based on inside dimensions. A floor plan of the house is shown in Figure 1. The house is currently rated as an energy efficient structure by the local electrical utility. To meet this rating, insulation was added to the walls, floors, and ceilings; storm windows and weather-stripping also were added. Other energy conservation hardware additions to the house included an active solar water heating system and a freestanding

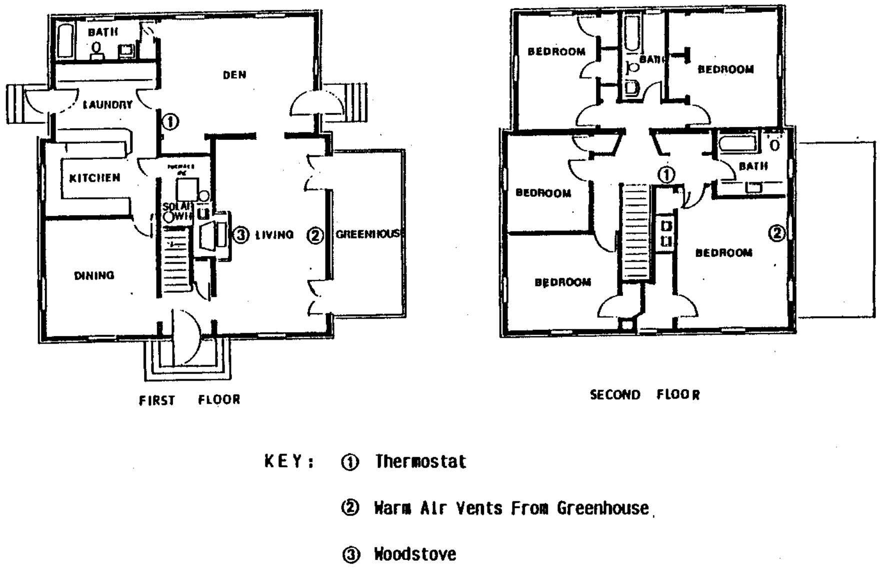

Figure 1. Floor Plan of Garrett House

woodstove vented into the existing fireplace. The primary heating system is a forced air furnace that uses natural gas and the primary cooling system is a central air conditioning system (Turner, Klett, & Ahmed, 1984). Both the gas furnace and air conditioning unit are centrally controlled by thermostats located on both floors (see Figure 1).

User Data Measurement

The demographic and behavioral data were collected by three sets of questionnaires completed by the respondents. All questionnaires were self administered by the respondents while in the test house and left for the project staff to collect daily. Demographic and attitudinal information were obtained from an extensive questionnaire completed both before and after the live-in experience in the test house. User response data to the two supplemental heating strategies and the use of flow restricting showerheads were collected at the conclusion of the week each strategy was tested. Respondents were surveyed regarding implementation activities and concerns with the strategy they just used. A daily activity log completed by the families provided information as to when family members were in the house, as well as their room choice and activity level while in the house. The log contained a grid of the 24 hour day, broken down in half hour periods. The daily activity log also identified when each family member took showers or baths, as well when the clothes washer and dishwasher were used.

Perceived thermal comfort was measured by weekly and daily responses of the adult family members to the thermal environment. A weekly response sheet assessed the participants' response to the thermal environment during the use of a specific strategy and was completed at the end of the week the strategy was used. A daily assessment of perceived thermal comfort was made between 7:00 and 10:00 p.m., after the respondents were sedentary for at least one hour. This assessment was recorded on 7-point Likert-type perceived thermal comfort scales developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE, 1981). Respondents also completed a clothing check list designed by ASHRAE to determine the insulating value of the clothing they were wearing at the time they completed the scales. The current comfort standards, ASHRAE Standard 55-81, represent the upper, lower, and optimal temperatures associated with acceptable thermal comfort reported by sedentary or slightly active persons. The comfort standard for winter is the temperature range between 68.0^{o}F and 74.5^{o}F, with an optimal temperature of 71.0^{o}F and a thermal clothing value (clo value) of 0.90. The standard was developed with a relative humidity of 50%. For a full description of variables influencing perceived thermal comfort, see Turner (1985).

Temperature and Energy Data Acquisition System

The temperature data were monitored and collected by the use of a data acquisition system based on a 64K microcomputer. Temperature sensors placed in five rooms were scanned every ten seconds and averaged hourly. A whole house temperature was computed by calculating the daily average of the temperatures in the living room, dining room, family room, master bedroom, and kitchen. Gas consumption was calculated using daily gas meter readings divided by the actual number of degree days during the week. A degree day is defined as the difference in Fahrenheit temperature between 65.0°F and the average outside temperature for a particular day. This procedure produced normalized gas consumption data which permitted comparison across families and strategies. Although the energy consumption data were normalized according to variations in outside temperature (degree days), the data do not reflect differences in solar radiation (sunshine) or wind velocity. Hot water usage was monitored in gallons both by the data acquisition system and by manual daily readings of a water meter connected to the water heater. The gallons saved were determined by comparing the hot water consumption associated with showers taken by the adults in each family for the week[1] when the flow restricting showerheads were used with a baseline week in which regular showerheads were installed. Showering events were identified by matching reports on the daily activity log with computer tracked hot water consumption data. Data that included any water usage other than the identified showering, such as dishwashing and clothes washing, were not included in the hot water consumption analysis.

RESULTS AND DISCUSSION

STRATEGY #1: Using Sunspace for Supplemental Heating

For the test weeks in which the sunspace was used as a supplemental heating source, the average whole house temperature for the families ranged from 69.7°F to 72.2°F, with an average of 69.5°F. With the exception of Family 2, the average room temperatures for the families fell within ASHRAE's comfort zone (see Table I). Perceived thermal comfort ratings were made on 7-point scales with "1" being very comfortable. The families' perceived thermal comfort ratings ranging from 2.0 to 4.5 verified that they found the room temperatures to be moderately comfortable.

Savings from the use of the sunspace for supplemental heating were determined by comparing each family's gas consumption per degree day for the week the sunspace was used as a supplemental heating with the gas consumption per degree day for the week when the thermostats were set at 65.0°F and no supplemental heating source was used. The difference between the gas consumption for the two weeks is expressed as the percentage change in energy consumption over the 65.0°F baseline. The baseline energy consumption ranged from 3.8 to 28.9 cubic feet of gas per degree day, with an average consumption of 16.5 cubic feet of gas per degree day (see Table I). As previously stated, although the energy consumption data were normalized according to variations in the outside temperature (by use of degree days), other factors influencing energy consumption such as solar radiation (sunshine) and wind velocity were not controlled for in the data analysis.

As shown in Table I, several levels of savings were achieved. Two families saved a considerable amount of energy (73% to 85%), three saved a moderate amount (23% to 43%), two families saved a small amount (8% to 17%), and one actually used 21% more energy in comparison to the baseline week. The average gas consumption savings during the weeks of sunspace use was 40%.

A number of factors affected the variation in energy savings resulting from the use of the sunspace. With regards to heating efficiency, of most obvious importance was the amount of solar radiation reaching the sunspace. More heat was absorbed on sunny days than on partly cloudy or cloudy days. Outside temperature and wind velocity also affected the heating efficiency of the sunspace.

Optimal use of the sunspace required user involvement in the form of opening and closing the two double doors to the sunspace when the inside temperature reached or exceeded (doors were to be opened) or fell below 80.0°F (doors to be closed). In addition to the families' role, some warm air was delivered to the house independent of the doors by an electric blower. This blower was thermostatically controlled set to deliver warm air on a 80.0°F on/below 80.0°F off cycle. The fan was not controlled by the families. A previous analysis of the sunspace temperature data revealed that the optimal period for solar heating was between 10:00 a.m. and 6:00 p.m. in that the sunspace temperature most frequently reached and fell below 80° during that time period (Turner, Klett & Gruber, 1985). Therefore, an important determinant of sunspace contribution to energy consumption was whether the families were available to open/close the doors to the sunspace as appropriate.

Daily occupancy data were compiled for when the house was occupied by an adult during this time period and specifically if an adult was in the home when the temperature reached 80.0°F. The data indicate that the number of times that the doors should have been opened during the week ranged from 3 to 7 times per household. The percentage of time that a person was actually in the home at the time that the doors connecting the living room to the sunspace needed to be opened ranged from 0% to 100% (see Table I).

The daily occupancy rate along with the amount of sustained sunshine contributed to the achieved energy savings resulting from the use of the sunspace. Those families with the highest energy savings (Families 4 and 7) had more sunspace use opportunities (5 and 6 times, respectively) but also were in home at least 60% of the time when they needed to open the doors. This combination of available sunlight and being available to open the doors contributed to the high energy savings.

The groups of users who obtained moderate to low savings experienced a wide range of sunspace use opportunities (1 to 7 times) and were likewise differentially available to operate the doors (0% to 100%) when appropriate. It should be noted that for Family 1, heat delivered by the fan must

Table I. Strategy: Using sunspace for supplemental heating.

Relative Level of Energy Savings	Family No.	No. Times Sunspace Temp. Over 80°F	Percent in Home for Sun-Space Opport.[a]	Gas Consumption (Cu.Ft.Gas/Degree Day) Baseline (65°F)	Gas Consumption (Cu.Ft.Gas/Degree Day) Sunspace	Energy Savings Over 65°F Baseline Cu/Ft/Gas	Energy Savings Over 65°F Baseline % Change	Whole House Temp. °F[b]	Perceived Thermal Comfort Rating[c]
High	4	5	60%	16.3	2.4	13.9	85%	72.2	3.6
	7	6	67%	24.2	6.6	17.6	73%	70.0	3.0
Moderate	3	4	25%	16.4	9.4	7.0	43%	70.1	2.0
	1	7	00%	21.3	14.0	7.3	34%	68.8	4.5
	9	1	100%	28.9	22.2	6.7	23%	68.0	4.4
Low	8	5	40%	11.4	9.5	1.9	17%	71.7	4.3
	2	4	25%	14.5	13.3	1.2	8%	65.7	3.0
Used More	6 5[e]	3	100%	11.6	14.0	-2.4	-21%[d]	71.8	3.5
Average		4.4	52%	19.0	11.1	7.9	40%	69.5	3.5

[a] Represents the percent of time the sunspace temperature exceeded 80°F and the families were in the home.
[b] ASHRAE Thermal Comfort Standard, 55-1981: 68.0°F to 74.5°F, 71.0° optimal.
[c] Ratings range from 1, "very comfortable," to 7, "very uncomfortable."
[d] Negative savings indicate increased use.
[e] System was used sparingly due to warm weather.

have contributed to their energy savings as the adults were never home to open and close the sunspace doors. In the case of Family 9, being home during the one time that the sunspace reached 80°F was not enough to obtain higher savings throughout the week.

Being in the home and having opportunities to use the sunspace as a supplemental heating source were not the only factors affecting energy savings. Examination of Table I shows that Families 2 and 3 had the same number of sunspace use opportunities (4 times) and were in the home during 10:00 a.m. to 6:00 p.m. the same percentage of time (25%). However, as the energy savings data in Table 1 indicate, the families energy consumption differed dramatically. This difference is likely due to the contribution of the thermostatically controlled fan that delivered warm air into the house. For Family 3, who achieved both a warmer house temperature and greater energy savings, during their week of sunspace use, the days were more sunny and the temperature remained high in the sunspace. As a result, the fan ran longer to deliver the warm air into the living space. In the case of Family 6, is is unclear why more energy was used during the week of sunspace use.

Although the relationship between daily occupancy rate for the specified time period and the achieved energy savings is not perfect, being in the home to take advantage of sunspace use opportunities did reduce the need to use the gas furnace and thus reduced gas consumption. The combination of optimal weather conditions and optimal user practices led to the greater savings; however, other data not collected could have offered clearer explanations of the interaction of the daily occupancy and energy savings achieved. A flaw in the original design was that connectors were not installed on the sunspace doors which would have indicated when the doors were opened and closed. Thus, there is some uncertainty that the families, when in the home, opened and closed the doors when appropriate. A general question was asked in the end of the week user questionnaire about their attending to the sunspace doors; the results suggest that when in the home the families opened/closed the doors as instructed.

STRATEGY #2: Using the Woodstove for Supplemental Heating

For the test weeks that the woodstove was used for supplemental heating, the average whole house temperature for the families ranged from 67.4°F to 72.9°F, with an average of 68.4°F (see Table II). For about half the families, the average whose house temperature was below the low end of ASHRAE's comfort range. Despite this, all families reported at least moderate perceived thermal comfort; the average for the families was 3.2 on a 7-point scale, with "1" being "very comfortable." Perceived thermal comfort ratings ranged from 1.9 to 4.0.

The savings from the use of the woodstove as a supplemental heating source were determined using the same procedures as described for the sunspace strategy. As shown in Table II, several levels of energy savings

Table II. Strategy: Using woodstove for supplemental heating.

Relative Level of Energy Savings	Family No.	Experience Level	Gas Consumption (Cu.Ft.Gas/Degree Day)		Energy Savings Over 65°F Baseline		Whole House Temp. °F[a]	Perceived Thermal Comfort Rating[b]
			Baseline (65°F)	Woodstove	Cu/Ft/Gas	% Change		
High	7	Extensive	24.2	9.2	15.0	62%	67.4	2.6
	9	None	28.9	13.6	15.3	53%	68.7	3.0
	3	Extensive *[c]	16.4	8.4	8.0	49%	----[d]	1.9
Moderate	4	None	16.3	11.8	4.5	28%	67.5	4.0
	1	None *	21.3	17.0	4.3	20%	66.2	4.0
	2	Limited *	14.5	12.8	1.7	12%	67.8	3.3
None	5[e]	Extensive	3.8	3.8	0.0	0%	72.9	4.0
Used More	8	Limited *	11.4	11.7	-0.3	-3%[f]	68.3	3.1
	6	Limited *	11.6	15.0	-3.4	-29%	68.7	---[g]
Average			16.5	11.5	5.0	21%	68.4	3.2

[a] ASHRAE Thermal Comfort Standard, 55-1981: 68.0°F to 74.5°F, 71.0° optimal.
[b] Ratings range from 1, "very comfortable," to 7, "very uncomfortable."
[c] Denotes families who had an extra week of experience with the woodstove prior to the test week.
[d] Data not available due to power failure.
[e] System was used sparingly due to warm weather.
[f] Negative savings indicate increased use.
[g] Data not reported by respondents.

were achieved. Three families saved a considerable amount of energy (49% to 62%), three other families saved a moderate amount (12 to 28%), one family saved no energy, and two families actually used more energy (3 to 29% more) in comparison to the 65°F baseline week. The average savings for the week when the woodstove was used was 21%.

Since the optimal use of a woodstove depends heavily on decisions related to stoking and adjustment of vents to obtain desired heating, the experience level of the users was examined in relation to actual energy savings[2]. Of the nine families who tested the woodstove as a supplemental heating source, three had extensive previous experience, four had some limited experience, and two had no experience using a woodstove prior to participating in the project. In addition, five of the families used the woodstove in the test house one week prior to the woodstove test week. This week of use was done for purposes beyond the focus of this paper. The experience and exposure levels of the families to using a woodstove are presented in Table II. The effect of previous experience appears to be that past experience using a woodstove contributed to families being able to take advantage of using it as a supplemental heating source. The two exceptions to this pattern involved Family 9 and Family 5. In the case of Family 9, they had no previous experience using a woodstove, yet they demonstrated considerable energy savings (see Table II). As for Family 5, they had extensive previous experience but achieved no improvement in energy use. This family did have a very low baseline usage rate and it was unseasonably warm during a good deal of the time they were in the house, thus limiting their use of the woodstove and its contribution to the home's heating load.

STRATEGY #3: Using Flow Restricting Showerheads

The amount of hot water saved by using flow restricting showerheads was determined by comparing hot water consumption used in showering by adult family members[3] during either a one or two week period when these showerheads were used with hot water consumption used in showering by the same adults for a baseline week when regular showerheads were used.

For six of the families, water consumption data were not easily separated as distinct events of showering versus other hot water use activities such as clothes washing and dishwashing. Consequently, hot water consumption data for these families were not analyzed. Hot water consumption data were analyzed for the remaining nine families. The data reveal that a decrease in hot water usage with the flow restricting showerheads was observed for five of the nine families (see Table III). In two cases, the water usage remained the same, and in two cases the amount used with the flow restricting showerheads was greater than the number of gallons consumed with the regular showerheads.

Table III. Average level of hot water consumption per adult shower with regular and flow restricting showerheads.

Relative Level of of Hot Water Savings	Family No.	Level of Hot Water Use per Shower: Regular Showerheads gallons/(events)[a]		Level of Hot Water Use per Shower: Flow Restricting Showerheads gallons/(events)		Hot Water Reduction: Gallons	Hot Water Reduction: % Change
High	15	15.8	(2)	6.2	(3)	9.6	61%
	4	11.3	(2)	5.8	(6)	5.5	49%
	7	14.1	(6)	8.3	(6)	5.8	41%
Low-Moderate	3	5.2	(14)	3.9	(7)	1.3	25%
	11	7.6	(3)	6.8	(2)	0.8	10%
None	8	10.8	(8)	10.8	(6)	-0-	--
	9	6.2	(8)	6.3	(5)	-0-	--
Used More	6	10.0	(4)	15.1	(4)	-5.1	-34%
	1	11.7	(9)	14.7	(14)	-3.0	-25%
Average		10.4	(6.2)	8.7	(5.9)	1.7	14%

[a] The number of events presented in parentheses represents the number of identified showers taken by adults in each family.

Based on testing performed in the the test house by project personnel, a 50% savings was expected from the use of the flow restricting showerheads; however, the percentage change in hot water consumption for the flow restricting showerheads ranged from a reduction of 61% of gallons used to an increase of 34% of gallons used. The average savings for the nine families was 14%. In the two cases of increased hot water usage, dislike of the showerheads led to substitution of baths and to compensating behavior of taking longer showers to "get out the soap."

CONCLUSIONS AND IMPLICATIONS

Although energy use behavior can account for over a third of the variation in energy use by families, past research efforts have not identified clearly the factors influencing the energy use behavior. This intensive study of a limited number of families has permitted the observation of use factors influencing the families' use of the selected strategies. Three identified factors influenced the energy usage of the families--daily occupancy rate, level of experience with the strategy, and substituting/compensating behavior.

Even though the results of this study suggest that substantial energy savings with the use of supplemental heating sources is possible, these findings should only be considered preliminary. Because of the variations in user experience and actual use of the strategies, the usage patterns and energy consumption levels reported may be considerably different if the period of study were greater than one week. In the present study, it might be expected that with use and experience, increased energy savings could be achieved by those users with limited or no experience with the strategies. Future studies examining the effect in experience and changes in skill on use level are needed to more adequately determine the costs and benefits of implementing a particular conservation strategy. In addition, tracking user behavior and system performance over time will provide a more realistic assessment of user and system performance under varying weather and temperature conditions.

In addressing methodological considerations, it is important to realize that a major goal of this study was to measure the energy savings potential of selected residential energy conservation strategies and to conduct this measurement in a setting approximating a "real home" environment. The energy test house provided this opportunity to achieve this goal. The house afforded the opportunity to invite actual families to live in a residence and provide use and user evaluation data on the implementation and outcome of the use of the strategies. Consequently, the study allowed an unique opportunity to go beyond a simulation project or controlled laboratory assessment, and provided the advantages and limitation or examining the use of the strategies under "near normal" conditions.

Although there are a number of positive aspects to the design and procedures followed in this study, there are also important limitations. Because the study is based on the energy use of 15 <u>volunteer</u> families, considerable caution needs to be applied when considering the results and implications of these results. First, the issue of volunteerism cautions that the energy use practices and energy savings achieved <u>might</u> be related to the fact that the families were interested in participating in an energy research project. Conceivably, this interest might have reflected a strong bias towards being energy conservation minded and knowledgeable and experienced with energy conservation practices. If so, the results obtained in this project might not represent energy use patterns of "typical families." However, on the basis of interviews with the families about their energy use practices in their own homes and with possible prior experience with the energy use practices tested in this project, an "energy conservation experience bias" was not evident. Most of the families were unfamiliar with the set of energy conservation strategies tested, though some did have some experience with individual strategies.

A second basis for caution is due to the fact that the sample was small (15 families) and their experience with each strategy was limited (in most cases one week). Whether this was enough time for the families to adjust to the use of each strategy and develop a routine that would maximize energy savings potential cannot be determined. It does appear that experience does improve energy performance, but other conditions such as environmental factors (e.g., weather, indoor and outdoor temperature), system operation factors (e.g., operational demands, system efficiency) and personal factors (e.g., availability and motivation to operate energy systems, skill level) also play important roles in determining optimal energy conservation performance.

A third reason the results of this study are limited is that the focus of the study was on the interplay between users and the implementation of conservation strategies rather than on motivating or asking the families to try to save energy by using the strategies. The energy use data represent the results from implementing a strategy not from families "trying their best" to conserve energy. In the project, the families had no way to monitor energy consumption and were not given feedback on their consumption patterns. Families in their own homes, paying their own utility bills, may have reacted differently and achieved different levels of conservation.

Despite certain limitations, the study has implications for consumers and professionals concerning behavior-related aspects of using conservation strategies. Consumers and professionals advising consumers should realize that the simple adoption of a strategy will not guarantee specified savings. Consideration should be given to identified occupant living patterns or possible reactions to strategies that may impact on the desired savings. As identified in this paper, strategy-specific factors such as daily occupancy rate, experience level, and substituting/compensating behavior should be explored before adoption of a particular strategy. Although not all strategies are best for all families, a good match can produce more positive results both in occupant satisfaction and in achieved energy savings.

Policymakers and program managers in the utility industry should also be cautious in assuming that the adoption of strategies will lead to automatic savings. The interaction of the user with a particular program/conservation strategy can greatly influence the attained savings. Attention to questions about the level of user involvement and the possible effect of the interplay between the user and the program/strategy (1) could serve to control/allow for the impact of user involvement and (2) could lead to programs that are more acceptable to consumers and contribute to greater energy efficiency.

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FOOTNOTES

[1] For several families, flow restricting showerheads were used for a two week period. For these families, the data were adjusted to represent one week of shower hot water consumption.

[2] Another factor that is likely related to optimal use of the woodstove is operational management. Factors, such as the frequency in which the woodstove is tended and wood is added and the amount of wood that is added and the length of time the stove is allowed to burn all contribute to optimal efficiency. For purposes of this study, operational management was not specifically tracked, rather, the families were encouraged to use the woodstove as they please without any demand to record completion of operational tasks.

[3] Hot water use involving children was not analyzed to permit comparisons across families.