Behavioral Approaches to Residential Energy Conservation

CLIVE SELIGMAN, JOHN M. DARLEY and LAWRENCE J. BECKER

Center for Environmental Studies, Princeton University, Princeton, N.J. 08540 (U.S.A.)

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This article outlines some of the research conducted by social psychologists to reduce residential energy consumption. The results of two attitudinal surveys demonstrated that homeowners' summer electricity consumption could be predicted from their energy-related attitudes. Personal comfort and health concerns were the best predictors of consumption. Psychologically derived techniques to reduce summer electricity consumption were experimentally examined in three separate studies. In study 1, almost daily consumption feedback was found to reduce electricity usage 10.5%. In study 2, subjects receiving frequent feedback, who were also asked to adopt a difficult conservation goal, reduced their electricity consumption 13.0%. In study 3, a device that signaled homeowners when they could cool their houses without air conditioning by opening their windows led to a reduction in consumption of 15.7%. It was concluded that the resident can play an important role in energy conservation that complements engineering solutions.

INTRODUCTION

The social sciences, including psychology, have been far less involved than the physical and engineering sciences in efforts to conserve energy. As a consequence, much less is known about the human (as opposed to the technological) side of the energy crisis, even though it is people who make the decisions to use the machines that consume energy. Only recently have we begun to learn about how people perceive and respond to their "energy environment" and how their attitudes and motivations affect their energy consumption behavior. Nonetheless enough has been learned to indicate that people have an important role to play in any comprehensive energy conservation plan.

Three pieces of evidence collected by the Twin Rivers project [1] clearly show the importance of the human role in residential consumption. First, in a sample of 28 identical townhouses, variation in energy consumption was found to be as great as two to one [1]. Since these houses are identical in floor plan, position in the interior of a townhouse row, builder, construction materials, and climate, it is likely that most of the consumption variance is due to the different behavior of the people in the houses. Secondly, in houses where there has been a change in residents, it has been found that the energy consumption of the house with the new residents cannot be predicted from the energy consumption of the same house with the previous residents [2]. Thirdly, even after houses had been successfully retrofitted (with 20 - 25% savings), the variance in energy consumption among the houses remained almost the same as it was before the retrofits took place and the rank order hardly changed [3].

These results demonstrate quite convincingly that the energy consumption of a house cannot be completely understood without reference to the people in the house. In the remainder of this article, we will review the research that our group has conducted in applying psychological theory and procedures to the problems of encouraging residential energy conservation. First, we shall discuss research aimed at finding the attitudinal determinants of residential energy consumption. Secondly, we will present several psychologically derived strategies to induce people to reduce their energy consumption and discuss the evidence we have collected bearing on the success of these strategies.

ATTITUDES AND ENERGY CONSUMPTION

Does it matter what people think of the energy crisis? Obviously many people think that it does. The consumers of polls of attitudes toward energy issues include politicians, government bureaucrats, journalists, and businessmen. The politician may be in search of votes, the newspaperman of a good story, the oil company executive of guidance with advertising campaigns; nevertheless all share the critical assumption that what people think about energy directly affects how much energy they consume.

Is this assumption reasonable? For example, do people who think the energy crisis is a hoax consume more energy than people who think it is genuine? In spite of the large number of energy attitude surveys that have been conducted [4], there is surprisingly little evidence that relates homeowners' attitudes to their actual energy consumption. First, because it is hard to obtain, many surveys have not collected actual energy usage data, assuming instead that homeowners' self-reports of past, present, and future consumption accurately reflected real energy consumption patterns. But we regard this as an unwarranted assumption. For instance, just after a national fuel shortage, people are likely to say that their most recent fuel bills show savings, because they feel that the interviewer would regard any other answers as unpatriotic. But whether they actually did save is a separate matter. Secondly, partly because of complex and difficult to decipher bills, and partly because until recently energy has been sufficiently cheap so as not to have been worth monitoring, people are often quite unaware of the rates at which they consume energy. For these reasons, until someone documents that there is a strong relationship between actual and self-reported energy consumption patterns, we are skeptical of this assumption.

It is perhaps for the reason that previous surveys have not looked at actual energy consumption that attempts to predict conservation behavior have failed. Murray *et al.* [5] were not able to find any statistically significant relationships between reported temperature reduction or use of major appliances and any non-demographic variables. Curtin [6] tried without success to predict reported past conservation behavior and expected difficulty of future conservation from fourteen demographic and attitudinal variables. Newman and Day [7] did collect actual energy consumption data but, because they were primarily interested in describing how consumers use energy, they did not attempt to relate consumption to attitudinal dimensions.

Twin Rivers surveys

In the summer of 1976 we conducted two energy attitude surveys [8]. Our purposes were twofold: (i) we wanted to see whether we could distill from the many varied attitudes that people have about energy a few basic attitudinal dimensions that reflect people's conceptualizations of energy consumption; (ii) we wanted to know whether these attitudinal dimensions relate to actual energy consumption.

The respondents of our first summer questionnaire were 56 couples living in Twin Rivers, New Jersey. The respondents are relatively homogeneous: the average husband is in his mid-thirties, his wife in her early thirties. The majority of couples have one or two children. 42 of the couples in the survey sample live in three-bedroom townhouses and 14 live in two-bedroom townhouses. Within each bedroom size, the townhouses are identical in floor plan and have identical central air-conditioning systems. In the summer, electricity use for the air conditioner accounts for 70% of all electricity usage in these houses.

Notice that by concentrating the survey in Twin Rivers something was lost and something was gained. Because of the relative homogeneity of the residents, it is not possible to be sure that the attitudinal patterns that emerge from an analysis of their data are representative of the national pattern. However, because of the physical homogeneity of the houses, the variance in energy consumption is greatly reduced. Therefore, differences in energy consumption due to attitudinal patterns can be detected more easily.

What attitudes and patterns of thought determine an individual's energy consumption decisions? On initial analysis, it seemed likely that the answer to this question depended on the kind of energy consumption under consideration. Gasoline consumption, for instance, would be likely to relate to a person's perceptions of the convenience of public transportation alternatives, while attitudes determining air conditioning consumption would be more likely to involve dimensions such as the comfort consequences of hotter inside temperatures.

To get an initial fix on attitudes relevant to air conditioning usage, we generated twenty-eight attitudinal questions (see Table 1) that represented seven attitudinal categories. The categories were: (1) perceived bother of conserving energy, *e.g.* "it is just not worth the trouble to turn off the air conditioner and open the windows every time it gets a little cooler outside"; (2) discomfort in conserving energy, *e.g.* "while others might tolerate turning off the air conditioner in the summer, my own need for being cool is high"; (3) health questions, *e.g.* "it's essential to my health and well-being for the house to be air conditioned in the summer"; (4) the legitimacy of the energy crisis, *e.g.*, "the energy crisis is a hoax"; (5) belief in science, *e.g.* "science will soon provide society with a long lasting source of energy"; (6) morality, *e.g.*, "it is immoral for America to consume 40% of the world's energy resources"; (7) the role of the individual, *e.g.* "to what degree has overconsumption by individuals contributed to this country's energy problem?". Responses to the questions were made on seven-point scales. Except for some background questions, which were asked first, the questions were randomly ordered on the questionnaire.

During the first week of July, potential respondents were telephoned and asked if they would be willing to answer an attitudes-toward-energy questionnaire that was developed by a group of university researchers. People who agreed were told to expect two questionnaires to be dropped off at their home on a certain day. Each member of the couple was asked to fill out his or her questionnaire independently. All of the questionnaires were distributed and picked up from the residents' homes within a two week period. The respondents were also asked to give us their permission to obtain a record of their electricity consumption from the local utility company's files. All residents agreed. Actual electric consumption (kilowatt-hours) for June, July, and August was determined for each couple in the sample.

A statistical technique called factor analysis [9] was used to reduce the respondents' attitude scores to a relatively few attitudinal factors. Four factors emerged* and Table 1 shows the factor loadings (*i.e.* the correlations between particular attitude variables and factors). The conventional way of interpreting the meaning of a factor is to examine the content of those attitudinal variables that load highly on a factor. An examination of those variables that have loadings of 0.45 or greater on a rotated factor suggests the following interpretation of the factors:

Factor 1. The five variables (2,5,7,17, and 24) having loadings greater than 0.45 are clearly concerned with *personal comfort and health.* This indicates the importance of personal comfort and health in decisions to regulate the use of the air conditioner. People who score high on this factor are not necessarily more concerned with their health and comfort than other people, but they do perceive a close connection between those variables and air conditioning usage. For them, to be cool is to be healthy and comfortable.

Factor 2. This factor seems to reflect two related concepts. Variables 6, 18, 20, and 25 indicate a concern for the effort or bother involved in conserving energy. Variables 1, 23 and 26 are concerned with the individual's ability to pay for his energy needs. These two concepts are related in that we can characterize this factor with the statement: "conserving energy in the home requires a great deal of effort for too little dollar savings". We might name this factor the *high-effort-low-payoff factor.*

Factor 3. The two variables (12 and 19) loading highest on this factor point to the *role of the individual* in contributing to and alleviating the energy crisis. Individuals who score high on this factor regard the ordinary homeowner as having little or no role in the national energy consumption crisis. Feeling this, a person who scored high on this factor could be quite convinced of the reality of the

*The 28 attitudinal questions were subjected to a principal factor analysis, with squared multiple correlations used as communality estimates. Eight factors were extracted with eigenvalues greater than 1, and the factors were varimax rotated. As the first four factors accounted for 48% of the total variance of the attitudinal variables and 80% of the total eight factor variance, only these four were interpreted.

TABLE 1

Rotated factor loadings: Survey 1

Variable	Factor 1	Factor 2	Factor 3	Factor 4
1. Consumers have the right to use as much energy as they want and can pay for.	0.19	(0.53)	0.29	0.04
2. I find it very difficult to fall asleep without an air conditioner on at night.	(0.61)	0.28	0.38	−0.03
3. Nuclear power will eventually provide us with most of our energy needs.	0.06	−0.11	0.02	0.01
4. Science will soon provide society with a long lasting source of energy.	0.26	0.10	−0.06	0.22
5. It's essential to *my* health and well-being for the house to be air conditioned in the summer.	(0.76)	0.28	0.16	−0.06
6. It is just not worth the trouble to turn off the air conditioner and open the windows every time it gets a little cooler outside.	0.27	(0.62)	0.19	0.00
7. How uncomfortable would you be if you turned your thermostat setting up 3 degrees from its usual setting?	(0.55)	0.00	0.11	−0.01
8. How much of a savings per month on your summer electricity bill *would it take to induce you* to turn your thermostat setting up 3 degrees from its usual setting?	0.25	0.23	0.05	−0.16
9. I never feel guilty about having my air conditioning on.	0.30	0.17	0.25	0.11
10. It is immoral for America to consume 40% of the world's energy resources.	−0.02	−0.25	−0.28	0.03
11. If everyone in the country tried to conserve energy at home, there would probably be *little or no real impact* upon the nation's overall energy consumption.	0.22	0.03	0.33	0.07
12. To what degree has overconsumption by individuals contributed to this country's energy problem?	−0.23	−0.22	(−0.65)	0.16
13. The energy crisis is largely due to real worldwide shortages of fuels needed to produce energy.	−0.02	−0.02	−0.09	(0.69)
14. I almost never think about the energy needs of Americans 100 years from now.	0.07	0.18	−0.06	−0.16
15. It is immoral to consume any more energy than I absolutely need.	−0.02	−0.39	−0.03	(0.51)
16. American technology in the past has come to grips with all major crises and it will no doubt soon discover a solution to the energy problem.	0.19	−0.09	−0.07	0.22
17. While others might tolerate turning off the air conditioner in the summer, my own need for being cool is high.	(0.74)	0.30	0.00	−0.08
18. How difficult would it be for you to adjust to an indoor temperature of not less than 75 °F in the summer months?	0.40	(0.49)	0.13	0.00
19. To what degree would more conservation of energy on the part of individuals alleviate the energy problem?	−0.04	−0.21	(−0.79)	0.13
20. It's not worth it at all to sweat a little in the summer to try to save a little energy.	0.21	(0.58)	0.11	−0.05
21. The energy crisis is largely due to the federal government's lack of an adequate energy policy.	−0.13	0.16	0.08	0.12
22. The energy crisis is largely due to supply and price manipulations by the major oil companies.	0.17	0.01	0.00	−0.16
23. Trying to save pennies a day conserving energy is just not worth it.	0.41	(0.48)	0.33	−0.17
24. It's essential to my family's health and well-being for the house to be air conditioned in the summer.	(0.74)	0.19	0.13	0.02
25. It's just *not* worth the trouble to turn the thermostat up every time it gets a little cooler outside.	0.08	(0.59)	0.22	−0.15
26. I would only conserve energy if I could not afford to pay for it.	0.25	(0.76)	0.00	−0.12
27. The energy crisis is a hoax.	0.23	0.21	0.13	−0.44
28. If we were able to put a man on the moon within 10 years, we could certainly solve the energy crisis within a short time period.	0.16	0.14	0.13	−0.29

() indicates loading > 0.45

national energy crisis and still not take steps to conserve because he would consider his energy savings irrelevant to the aggregate consumption pattern.

Factor 4. The two variables (13 and 15) loading greater than 0.45 reflect the extent of individuals' beliefs about whether there are real shortages of fuels and whether it is immoral to consume too much energy. Tentatively we can label this factor as a concern with the *legitimacy of the energy crisis, i.e.* those who believe there is a real shortage of fuels believe it is immoral to overconsume. Variable 27, "the energy crisis is a hoax", loads third highest on this factor, −0.42, consistent with our tentative interpretation of the factor.

On the basis of the factor analysis, a picture begins to emerge of how homeowners perceive their energy consumption. The basic considerations seem to involve judgements about effects of conservation on health and comfort, monetary return for one's conservation efforts, the impact of the individual consumer on conservation, and the legitimacy of the energy crisis. Since men and women might be educated differently about energy, and this might be reflected in their having differential attitudinal structures about the abstract topic of energy, separate factor analyses on males and females were conducted. Happily for the simplicity of our data analysis, the same four factors as reported above were apparent for both males and females.

For any individual in this sample, then, a score on each of these four factors can be calculated. To predict a particular house's consumption, one would want to know the factor scores of both the husband and wife. Thus eight factor scores (four from the husband and four from the wife) were employed as predictors of each household's summer electric consumption. An overall multiple regression analysis revealed that a total of 55% of the variance in consumption was accounted for by the predictors, $R^2 = 0.553$, $F\,(8,47) = 7.26$, $P < 0.001$. In psychological research, this is a strikingly high attitude–behavior correlation. Thus, our attitudinal variables were very successful in predicting energy use.

The relationship between each factor and energy use was examined by correlating the two spouses' scores on a given factor with consumption. Table 2 presents males' and females' correlation for each factor. The combined effect of the male and female scores on the *comfort and health* factor was highly significant, accounting for 30% of the variance in actual electric consumption, $R^2 = 0.301$, $F\,(2,53) = 11.41$, $P < 0.001$. The more a household perceived conservation as leading to discomfort and ill health, the more energy the household consumed. Moreover, the health and comfort attitude of the female was more strongly linked to air conditioner usage than was that of the male. This makes sense. Other information we have indicates that the wife is more likely than the husband to be home during the day and to control the energy use during that time.

Scores of the *high effort–low payoff* factor also significantly predicted consumption, $R^2 = 0.245$, $F\,(2,53) = 8.61$, $P < 0.001$, as did the households' scores on the *role of the individual* factor, $R^2 = 0.115$, $F\,(2,53) = 3.43$, $P < 0.05$. The more energy conservation was perceived as requiring great effort for little

TABLE 2

Predicting actual summer electric consumption from attitudinal factors: correlations between attitudinal factors and electricity consumption in survey 1.

Factor	Simple correlations		Multiple correlation
	Male factor score	Female factor score	
Comfort and health	0.40**	0.53***	0.55***
High effort–low payoff	0.41**	0.42**	0.50***
Role of the individual	0.33*	0.03	0.34*
Legitimacy of energy crisis	−0.08	0.19	0.26

*$P < 0.05$
**$P < 0.01$
***$P < 0.001$

monetary return and the less importance attached to the role of the individual in contributing to and alleviating the energy crisis, the more energy was consumed. Scores on the factor involving the *legitimacy of the energy crisis* accounted for only a trivial proportion of variance, $R^2 = 0.066$, $F\ (2,53) = 1.88, P > 0.10$.

The results have shown (1) that homeowners' attitudes towards energy can be conceptualized into a few basic factors, and (2) that these attitudinal factors can predict actual energy consumption. Homeowners perceived their use of energy according to their judgement of the effect of energy conservation on personal comfort and health, the effort required to conserve and the monetary payoff for doing so, the ability of the individual to have an impact on the energy problem, and their belief that the crisis is legitimate. Together these factors were capable of explaining a total of 55% of the variance in actual electric consumption. Examined singly, the *comfort and health* factor, the *high effort–low payoff* factor, and the *role of the individual* factor were significant predictors of energy use. The *comfort and health* factor emerged as the best single predictor of consumption, accounting for a greater percentage of consumption variance than any other factor.

A second survey of 69 couples was conducted in September 1976 in the same community to attempt to confirm the general results of the first survey [8]. The results of the second survey showed that the same factors emerged and that together they again accounted for a significant portion of the variance. However, in the second survey the *comfort and health* factors were the only statistically significant predictors of actual energy consumption.

A major result of these analyses is the importance of the resident's attitudes toward his or her own comfort and health as a determinant of actual energy consumption. While individuals do indeed perceive the energy crisis in terms other than simply comfort and health, only comfort and health concerns were consistently predictive of actual energy consumption in both surveys. It is necessary to remain cautious about the importance of the *high effort–low payoff* factor and the *role of the individual* factor, since they were not statistically significant predictors in the second survey. Finally, we also need more information about the connection between people's perceptions of the reality of the energy crisis and their energy consumption patterns. Is there really as little relationship as our results seem to suggest?

If larger scale surveys confirm the present results, the design of national energy conservation campaigns can be more sensibly addressed than one suspects it has been. What does the medical research show about the links between health and air conditioning usage? If, contrary to what many people now assume, there is no positive relationship between air conditioning and health, then air conditioning usage might be reduced. For people who regard air conditioning as essential to their comfort, the *high effort–low payoff* factor ought to be addressed. They ought to be informed that there are highly cost effective low effort ways of cooling without air conditioning, *e.g.*, by installing window and attic fans, by regulating the use of window shades and drapes, and opening windows in the evening when outside temperature falls below inside temperature. National energy saving appeals have their best chance of being successful if they are fitted to the actual patterns of existing attitudes of energy consumers.

MOTIVATING THE RESIDENT TO CONSERVE: FEEDBACK RESEARCH

Survey research represents one approach that psychologists have taken to study the relationship between people and their energy consumption. As we have seen, surveys can tell us a great deal about the characteristics or attitudes of people that are important for energy consumption. Another approach to the problem is to be less concerned with individual differences in attitudes and habits and to be more concerned with the immediate environments in which people live that make them more or less conscious of their energy behavior and that facilitate or hinder energy conservation.

Since we are concerned with residential energy use, let us consider the house as an "energy environment". Appliances are run, the air conditioning cycles, hot water is used, lights are turned on and off, and the homeowner has no way of determining what amounts of energy are used by these devices. The utility bill that the homeowner gets does not break down energy use into these components. Nor does the bill appear close in time to the energy usage; it arrives on a monthly basis at best. Frequently, the bill is an estimate. Clearly the homeowner lives in an information deficient energy environment. But what would happen if we gave the homeowner more information about his energy consuming behavior, *i.e.* if we closed the "feedback loop" between the homeowner and his or her house? The resident has a number of controlling actions available to him, most important of which is thermostat control. In general, feedback research has shown that performance feedback, displayed to the human operator, is critical in producing effective performance [10]. During the individual's learning of the control tasks, informational feedback has been repeatedly shown to improve the rate and level of learning [11, 12]. It can also improve motivation to perform the task [13], and in general the more immediate the feedback follows the control action, the more optimal the performance [11].

We have now conducted several summer feedback experiments in Twin Rivers aimed at reducing electricity consumption.

Study 1

The purpose of the first feedback study [14] was to determine the effects of an immediate consumption feedback procedure on the reduction of electricity consumption. Electricity consumption was examined because the study was conducted during the summer when, in the studied houses, 70% of the electricity used is for central air conditioning. Moreover, air conditioning use can be modified to a large degree by the homeowner. In this particular case, a 1 °F increase in thermostat setting would result in approximately 12% savings in air conditioning consumption [15].

The subjects of this study were 29 homeowners who lived in identical three bedroom townhouses. The homeowners were randomly assigned either to a feedback group or to a control group. Beginning in July 1975, the electric meters at each home in both groups were read by a research assistant each weekday afternoon for a month. A daily average temperature was computed from the hourly readings for each day (the 24 hour day began at 5 p.m. to coincide with the meter readings). For each house, a regression line was plotted to predict daily electric consumption from daily average temperature. The squared multiple correlations of these regression lines ranged from 0.57 to 0.98. By inference, the electric meter reading was proportional to a reading that would have been taken from a meter on the air conditioning system plus a constant. For each house, then, it was possible to predict its future rate of energy usage based on outdoor temperature.

Beginning in August, the research assistant not only read the electric meters each weekday but also, from Tuesday through Friday for the houses in the feedback group, calculated the ratio of actual over predicted consumption. (Predicted consumption was based on the immediate 24 hours' temperature readings inserted into the regression equation for each house.) This ratio was displayed in a lucite device that was attached to the outside of the kitchen window in each home. The display was approximately 12 cm by 8 cm (5″ × 3″) consisting of a holder and small plastic numbers that could be inserted to show the percentage consumption reading. If the homeowner's predicted performance was that he would use ten units of energy and he actually used eight units, then his display for that day would read "80%". Note that this means that an individual who received feedback attempted to improve his electricity consumption relative to a standard derived from his past consumption rather than some theoretical standard or one derived from other units.

The feedback ran for three weeks. The same day the feedback began, each household received a letter explaining the feedback procedure, *i.e.* how predictions of their electricity consumption were made and what the numbers in the lucite device meant. The letter also focused the homeowners' attention on air conditioning; they were told that in the summer the largest use of electricity was due to air conditioning. The control group was sent the same letter except for the part dealing with the feedback procedure. Therefore, summarizing the similarities between conditions, all households, regardless of condition, had their electric meters read five days a week, were told they were in an energy study, that air conditioning was the largest use of electricity, and that we hoped they would reduce their air conditioning usage. Thus both demand characteristics to reduce electricity consumption and information received about how to do it were the same for both groups. The feedback group differed from the control group in that it received the daily information about their consumption and an explanation of how that information was presented.

TABLE 3

Mean daily electric consumption (kWh) in study 1 — feedback

Standard deviations are given in parentheses.

	Condition	
	Feedback	Control
Sample size	15	14
Pre-treatment	68.33 (10.45)	69.14 (11.04)
During treatment	48.56 (7.94)	54.25 (5.12)

The results are shown in Table 3. Before looking at the effects of the experimental treatment, it is necessary to test whether the groups differed prior to the treatment. The average daily consumption in the pre-treatment period was computed. The feedback and control groups did not differ, $F\ (1,27) = 0.04$. The mean daily consumption of the feedback group during the feedback period was 10.5% less than the control during the same period. This difference between the feedback and control groups was statistically significant, $F\ (1,21) = 4.81$, $P < 0.04$, in an analysis of variance that included the feedback factor, as well as subjects' pretest scores as a blocking factor.

The results have shown that providing homeowners with feedback information about their rate of energy consumption can be an effective strategy for conserving energy. Feedback is thought to be effective for two reasons. First, feedback cues individuals to the procedures that are most successful in achieving the task. Feedback given frequently to homeowners can show them which of their attempts to reduce energy was effective. Of course, in the present study homeowners were cued right from the beginning to focus on their air conditioning use. However, by attending to the feedback, homeowners may have found other ways to conserve energy used for air conditioning, for example, by opening and closing drapes. Secondly, feedback serves to motivate a person to try harder or persist longer at a task to reach a goal. If a person has a particular conservation goal and the feedback informs him that his performance falls short of that goal, there would typically be an attempt made to improve subsequent performance. If a person meets his conservation goal, only the amount of effort needed to maintain that level of achievement may be expended. The implication is that a difficult conservation goal should lead to greater effort being expended than an easy goal, with the possibility that more energy conservation would follow from increased effort.

Study 2

Our second feedback study [16] was conducted to test the hypothesis that feedback would lead to more energy conservation if individuals were asked to adopt a difficult conservation goal rather than an easy one. One hundred Twin Rivers families who lived in identical three-bedroom townhouses were recruited to participate in the study. The households were randomly assigned to five groups. The households in two of the groups were asked to set a difficult conservation goal. Within each of these levels of goal difficulty, the households in one group were given feedback concerning their conservation performance and those in the other group were not given feedback. The households in one group were asked simply to continue using electricity as they normally would; they constituted a control group.

The easy conservation goal was to reduce electric consumption 2% for the treatment period, and the difficult goal was to reduce it 20%. These figures were chosen on the basis of an examination of the conservation achieved by the subjects in the previous study. Reduction in consumption was measured against the predicted consumption for each household on the basis of its consumption during the first half of the summer. Predicted consumption contained an adjustment for weather differences between the earlier period and the treatment period. The adjustment was accomplished in the following way. The median difference in average daily consumption between the earlier period and the treatment period to date was computed for the control group, and was then subtracted from the average daily consumption during treatment for each subject in the feedback groups before feedback was computed. Feedback was given in terms of the percentage of electricity conserved or wasted by a household from the beginning of the treatment period to the day the feedback was given. It was computed by subtracting actual from predicted consumption and dividing the difference by predicted consumption.

Every Monday, Wednesday, and Friday morning during August 1976, all households had their electric meters read. Each time after all meters were read, feedback was calculated and plotted on a 15 cm × 23 cm (6 in × 9 in) graph attached to the kitchen windows of the homes in the two feedback groups. To control for the effects of the experimenters' attention, the homes in the other three groups also had charts attached to their kitchen windows that were marked each meter-reading day. These charts were the same size as the graphs on the feedback homes, but simply allowed for a mark to be made which indicated that the meter had been read on that day.

The results are given in Table 4. There was no significant difference among the groups in mean daily consumption during the pre-treatment period, $F\ (4{,}95) < 1$. During the treatment period, the only experimental group with significantly lower electric consumption than the control group was the difficult-goal-with-feedback group, $F\ (1{,}94) = 9.22$, $P < 0.005$. This group used 13.0% less electricity than the control group. In addition, the two groups that received feedback saved significantly more energy than the two (non-control) no-feedback groups, $F\ (1{,}94) = 8.35$, $P < 0.005$.

These results show that feedback is especially effective if the homeowners are motivated to save a considerable amount of energy. Homeowners who received feedback but who were only trying to save a little energy did not conserve more than a control group that was not given feedback nor asked to save energy.

The results also showed that three of the experimental groups did not conserve significantly more energy than the control, despite the considerable amount of attention paid to them — they were asked to adopt a conservation goal, in one group feedback was also given, all had charts on the patio window that were marked several times a week, and all knew they were in an energy conservation study and that their energy usage was being monitored. Therefore, it is not likely that the energy conservation effect of feedback plus goal setting can be explained away by the Hawthorne effect, which argues that performance improvements can sometimes be the result simply of increased attention paid to subjects.

The magnitudes of the percentage reductions in average daily consumption between each of the two feedback groups and the control group can be compared to the percentage reduction achieved in the feedback group in

TABLE 4

Mean daily electric consumption (kWh) in study 2 — feedback and goal setting

Standard deviations are given in parentheses.

	Condition				
	Difficult goal feedback	Easy goal feedback	Difficult goal no feedback	Easy goal no feedback	Control
Sample size	20	20	20	20	20
Pre-treatment	38.68 (14.21)	36.82 (8.03)	39.02 (10.86)	39.37 (11.19)	36.85 (14.23)
During treatment*	34.70 (8.31)	38.03 (3.62)	39.35 (4.05)	40.34 (5.14)	39.87 (4.33)

*Adjusted for pre-treatment differences by analysis of covariance.

the previous study. The latter figure, 10.5%, falls between the percentage reduction for the easy-goal-with-feedback group (4.6%) and the percentage reduction for the difficult-goal-with-feedback group (13.0%). Although there were differences between the two experiments in how feedback was computed and reported to the subjects, the percentage reduction figures can be taken as a rough indication that, on the average, the subjects in the first feedback study (who were asked simply to do the best they could with respect to reducing their consumption) adopted (either consciously or unconsciously) a consumption reduction goal that was somewhere between 2% and 20%.

Study 3

Feedback is a way of providing information to homeowners that informs them whether they are consuming too much energy. Presumably, homeowners whose feedback indicates wasteful consumption take corrective actions to reduce their energy usage. Feedback is thus a signal that some energy control action is required. For our feedback studies, we have explicitly told our subjects that their best energy saving action is thermostat control. Thus waste-indicating feedback means, to our homeowners, that they should modify the thermostat setting to reduce consumption. But there are also other ways to highlight the importance of thermostat control and to indicate when it should be exercised.

In the third study [17] we wanted to look at the effects of a device that signaled homeowners when the outside temperature was below 68 °F and their air conditioner was still running. Homeowners were informed that when the outside temperature was below 68 °F, air conditioning was no longer necessary, and the house could be cooled effectively with just the windows opened.

The device used a blue light that was displayed in the homeowner's kitchen. The blue light was connected both to the air conditioner and to a thermostat situated on the outside wall of the house. The blue light would blink repeatedly when the air conditioner was on *and* when the outside temperature was below 68 °F. The only way the homeowner could stop the blue light from blinking was to shut off the air conditioner. When the outside temperature was 68 °F or higher, the blue light was off regardless of whether the air conditioner was on or off.

Forty residents were randomly assigned to one of four conditions: blue light plus feedback, feedback only, blue light only, and a control (no feedback and no blue light). The feedback was given three times a week in a manner similar to that described in the previous study except for the computation of feedback. In the present study, consumption per degree-hour was computed for each house before the study began and predicted consumption was based only on the consumption per degree-hour index. In addition, feedback was given only for the period between the last feedback point and the current one. It was not based on all the days since the study began, as was the case in the preceding experiment. The experiment lasted from mid-August to mid-September.

There were no significant differences among the groups before the treatments began, $F(3,36) < 1$. During the treatment period, only those days in which the outside temperature dropped below 68 °F were included in the analysis since the blue light was operative only then. The results are shown in Table 5. Homeowners who had the blue light device

TABLE 5

Mean daily electric consumption (kWh) in study 3 — Feedback and blue light signaling device

Standard deviations are given in parentheses.

	Blue light feedback	Feedback alone	Blue light alone	Control
Sample size	10	10	10	10
During treatment*	18.30	20.61	18.24	22.76
	(2.96)	(5.69)	(4.50)	(6.02)

*Adjusted for pre-treatment differences by analysis of covariance.

used 15.7% less electricity than the homeowners who did not, $F(1,35) = 4.64$, $P < 0.04$. Thus, the blue light device proved effective in alerting the homeowners to a savings opportunity, and they took it.

In view of the previous studies in which consumption feedback had an effect, the failure of the feedback manipulation in the present study requires explanation. From interviews with the subjects after the experiment was over, it was revealed that most residents did not believe the feedback. The credibility of the feedback was not an issue in the previous two successful feedback studies. Apparently, in this study, the feedback scores jumped around too much to be believable. Residents repeatedly saw no relationship between their conservation actions and the feedback scores. As a result, the feedback was ignored. The main differences between the feedback given in the different experiments were in the methods of computation and display. In the two previous experiments, feedback was based on either a regression model or a control group correction. In this study, consumption per degree-hour was the basis. In the first study, feedback was not displayed over time, only for each feedback period. Thus swings in feedback over time were less salient. In the second experiment, feedback was displayed over time on a chart, but each feedback score was based on the whole period since the experiment began. Thus the feedback, being averaged over longer times, was actually smoother than it would have been if individual feedback periods were used. Thus it appears that in the third experiment, both the method of computation and the way it was displayed served to exaggerate the swings in the feedback, making it less credible. This result, of course, underscores the importance of providing feedback that is credible.

CONCLUSIONS

As the last study reminds us, our research on consumption feedback is hardly finished. But we are encouraged to continue. It appears that frequent, credible energy consumption feedback coupled with encouragement to adopt a reasonable but difficult energy conservation goal can be an effective conservation strategy for homeowners. One of the most urgent questions that arises concerning consumption feedback is its effectiveness over time. For practical application of the feedback technique, its efficacy over long periods of time would need to be demonstrated. Our studies looked only at periods of about one month. Practical consideration would also require that the development, building, and installation of feedback devices be cost effective. Finally, future research should address the issue of the best kind of feedback to display to the homeowner. In our studies, we have concentrated on feedback that compared an individual's rate of energy use to his rate at an earlier time. Would feedback that promoted comparisons with other people be more effective?

State-sensing information systems, such as the blue light signaling device that we designed, also seem promising sources of energy consumption savings. More than general consumption feedback, these systems focus people's attention on specific conservation actions and do so exactly when these actions are appropriate. Indeed it is not hard to envision an energy control panel, perhaps situated somewhere in the kitchen, that provides homeowners with detailed information about the house's energy performance and also indicates which energy conserving actions are appropriate to take at different times.

Sinden [18] has suggested a variety of techniques and devices for promoting energy conservation in the home. Some of these retrofits, once done, are continually effective, *e.g.*, attic insulation. Here the psychological analysis is directed at convincing people to make the one-time decision to initiate the retrofit. Others, *e.g.*, close fitted window shades to be drawn at night, require the individual to act habitually on a frequent basis to achieve the conservation benefits. Here a different sort of psychological thinking is required. First, are there groups of individuals who are likely to be able to develop the habitual action patterns necessary for these innovations? Second, are there psychological elements that can be included in the design of these "action-requiring" conservation innovations that induce all people to use them successfully? Here, too, feedback has a role to play; it can demonstrate to the homeowner that his actions to reduce energy consumption do in fact succeed. Again, one needs to recall that it is enormously difficult for the homeowner to recover this information from his utility bills. For instance, if the effectiveness of a thermal conservation device is under test, then some sort of temperature-corrected feedback is absolutely essential. Therefore, one use of energy consumption feedback is a temporary one demonstrating to the innovator that the energy conserving innovation is successful. This demonstration, occurring at the beginning of the innovation period, would be important in motivating the innovator to develop the set of habits necessary to use the innovation.

One final point. When social scientists, engineers, and physical scientist discuss energy conservation, the discussion all too frequently turns to the potential energy savings that each discipline can "produce". It seems to us that this is an unprofitable form in which to cast what could otherwise be an important discussion. Research [19] leads us to suspect that over 50% of the energy used in residential space thermal regulation could be saved by a variety of retrofits [18]. Exactly which retrofits make sense for any particular structure must be determined by physical scientists and engineers. Economists can define economic incentive structures so that these modifications are economically feasible for the homeowner. Above and beyond general questions of economic feasibility, homeowners will need to be convinced that they will be able to get a trustworthy, reliable, and effective installation of an energy-conserving innovation, a task for the psychological researcher. And the innovations will need to be designed to enable the homeowner to use them effectively, a task for human factors specialists. As a matter of public policy, legislation may be passed mandating the construction of new energy-efficient residential units; political scientists and others will need to work with physical scientists and engineers on the specification of such standards. Accomplishing these goals with any degree of success requires the efforts of all of these disciplines and requires these efforts to go forward in interdependent and closely coordinated fashion. The research reported in this article and other articles in this issue has indicated the importance that must be attached to the homeowner in conservation efforts.

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