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THE EFFECTS OF DAILY FEEDBACK ON RESIDENTIAL ELECTRICITY USAGE AS A FUNCTION OF USAGE LEVEL AND TYPE OF FEEDBACK INFORMATION

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ABSTRACT

This study was conducted with 353 families during the Summer of 1977. Families received daily feedback each day except Sunday. Feedback (the independent variable) consisted of either the kilowatts consumed the previous day, the cumulative kilowatts consumed since the first of the month, the cost of the electricity consumed the previous day or the cumulative cost of the electricity consumed since the first of the month. The dependent variable was the number of kilowatts of electricity consumed daily. Results indicated that feedback was effective in reducing consumption for high consumers but had the opposite effect for medium and low consumers. Data is presented to show the differential effect of the four various types of daily feedback.

INTRODUCTION

One of the most important problems facing our society today is the problem of energy conservation. The rapidly dwindling known supplies of oil, coupled with accelerating energy needs has created a crisis like atmosphere which has stimulated activity in both political and scientific areas. In view of our current state of technical knowledge and our proven ability to advance rapidly in modern science and technology as demonstrated in the past few decades, there is reason for optimism regarding a solution to the problem. The use of solar energy, nuclear energy, fusion, more efficient use of the vast resources of coal or the

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harnessing of natural forces such as wind, may provide a long range solution to the problem. In the meantime, it may be that the problem of how to make existing resources last until systems which use alternative sources of energy are in place, lies in the domain of the social scientist, rather than the politician or natural scientist. In this interim period of development, the principles of human behavior as defined by the studies of social scientists may provide for a smooth transition from an environment dependent upon certain forms of energy to an environment dependent upon other forms of energy.

In attempts to provide these solutions, social scientists have studied the effects of monetary reinforcement, conservation, information, feedback, and prompts, upon energy conservation.

Numerous studies have demonstrated the effectiveness of contingent monetary payments in reducing energy consumption. Foxx and Hake, using a graduated cash rebate system plus a variety of other incentives, reduced by 20 per cent the number of miles driven by twelve college students [1]. In a study conducted by Winett and Nietzel, a graduated cash payment plus information group achieved a significantly greater reduction in electricity consumption than an information group [2]. Hayes and Cone found that cash payments produced immediate reductions in consumption which were sustained even when the payment was reduced [3]. Winett, Kabel, Battalio, and Winkler, using both high and low rebate groups who also received conservation information and feedback, found that only the high rebate condition produced consistently large reductions in consumption [4]. An information group did not reduce its consumption. Winett, Kaiser, and Haberkorn found that a high rebate group reduced its consumption substantially more than a low rebate group [5]. Both groups also received weekly conservation information. Electrical peaking levels were considerably reduced using a graduated cash payment combined with feedback [6]. Information about peaking and concrete suggestions to limit peaking did not reduce peaking.

Thus, rebate plans have been successful in reducing energy consumption. However, it should be noted that these rebates were made by the experimenters and not by the energy providers. The likelihood that providers of energy resources will endorse the rebate as a viable solution to the energy problem would seem to be low. The government has endorsed the rebate concept on a limited scale; however, adapting a full scale rebate plan applicable to all consumers might result in the creation of a bureaucracy which would consume more energy than it could save.

Another way to reduce consumption might be to continuously remind consumers to do so. Along these lines, Winett (in press) used prompting procedures consisting of large and small signs and found that only large signs resulted in an increase in turning off lights [2, 7]. Bittle, Valesano and Thaler also used large signs giving information about electrical consumption and costs in a mental institution [8]. Neither consumption information nor cost information had any noticeable effect on electrical consumption within the institution.

Bittle has suggested that energy consumption could be reduced if proper feedback concerning consumatory behaviors were given to consumers [9]. These suggestions have been supported by research which has reduced electrical peaking levels and overall levels of consumption. In the study conducted by Kohlenberg, Phillips, and Proctor, an in-house feedback light reduced peaking [6]. Hayes and Cone found that daily feedback about electricity cost produced reductions in consumption [3]. While information about different ways to conserve did not produce any changes. Daily feedback about per cent changes in electricity use produced an average reduction of 10-15 per cent but was not effective during very warm weather [5]. Palmer, Lloyd and Lloyd found that daily feedback about electricity cost produced reductions in electricity use for two families [10].

Although the studies cited above have found feedback to be a method of encouraging energy conservation, this evidence is not conclusive. Carry-over effects, sequencing effects, and small numbers of select subjects have been common difficulties.

Moreover, two studies have found feedback to be ineffective. Winett et al. provided weekly feedback to families during very hot weather and concluded that feedback was not effective when the need for air conditioning was greatest [4]. Seaver and Patterson found that feedback about fuel oil consumption was not effective in reducing subsequent usage, but that feedback combined with social commendation for reduced consumption levels, was effective in reducing future fuel oil use [11]. However, these studies that found feedback to be ineffective have either used feedback temporally removed from the consumatory responses or have had to deal with extraneous variables (i.e., high temperatures).

The present study has attempted to deal with some of the above mentioned problems by employing a large number of randomly solicited participants (353 families) and by providing only one variable for each of four groups. In an effort to rule out the effects of extraneous variables, the present study has also utilized a multiple baseline across subjects, and a reversal.

In a previous study, feedback consisted of daily consumption in kilowatts, the daily cost of that number of kilowatts, and cumulative cost since the beginning of the month [12]. No attempt was made to analyze the differential effectiveness of these three types of feedback in reducing consumption. However, it would seem that cumulative cost would reduce consumption most effectively because cumulative costs are, necessarily, of greater magnitude than daily costs and also because cost feedback would seem to be more meaningful to consumers than kilowatt feedback. Accordingly, the present study attempted to analyze the differential effectiveness of four feedback types: daily consumption in kilowatts, cumulative consumption in kilowatts since the beginning of the month, daily cost, and cumulative cost since the beginning of the month.

An additional impetus to analyze the differential effectiveness of daily and cumulative costs is provided by the billing procedures of the local electricity company. It is encouraging its customers to conserve electricity through advertising the effectiveness of insulation and offering various forms of conservation information. On its monthly bill, the company includes the cumulative cost for that billing period plus the average daily cost of electricity. Since daily electricity costs are usually low compared to other living costs, such information may offset the effect of the companies' conservation efforts and minimize the consumption suppressing effects of a large monthly bill.

Subjects and Setting

Initially, a total of 376 families, who lived in a rural Southern Illinois community, volunteered to serve as participants. Twenty-three families were later excluded because they either moved, took vacations, improved their insulation, or purchased an air conditioner during the course of the study. The number of experimental families was therefore 353. All participants paid their own electric bills.

To enlist experimental participants, program representatives went door-to-door and asked the family's permission to read their electric meter each day and to provide them with information from time to time concerning their electricity consumption. The participants were informed that our program was free and that we would discontinue reading their meter and providing feedback upon their request. Participants were also advised that our program was not connected with the local electric company. Each family provided our representative with information concerning their electrical appliances and then signed a consent form. Following the initial solicitation, only occasional personal contact occurred as our representatives read meters or delivered feedback. Intermittent telephone contact with some participants occurred during the course of the study when they requested information or when a member of the research team called to verify their receipt of feedback cards.

Experimental Design

The designs utilized were a multiple baseline across groups of subjects and a reversal (see Figure 1). Initially, all experimental households (N = 353) were randomly designated to receive one of the following four types of daily feedback (see Figure 2):

1. Number of kilowatt hours used during the previous day.
2. Cumulative number of kilowatt hours used since the first of the month.
3. Dollars and cents cost of electricity for the previous day.
4. Cumulative dollars and cents cost of electricity since the first of the month.

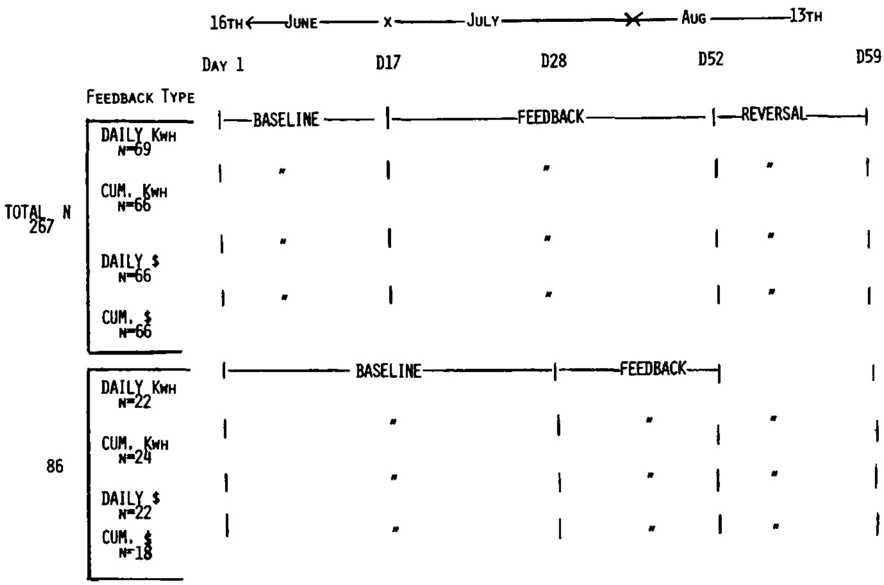

Figure 1. Experimental design.

After the groups were established, every fourth household in each group was assigned to a delay group. The delay group (N = 86) began receiving feedback ten days after the primary group (N = 267).

Procedure

The study was conducted between June 15th and August 13th, 1977 (58 days). The duration of the study was limited to this period since funds for payment of meter readers were available for only eight weeks. Electric meters were read daily, Monday through Saturday. After a sixteen day baseline, the primary group began receiving feedback on July 2nd. Baseline for the delay group continued until July 11th (26 days). All feedback was discontinued on August 6th and was followed by a return to baseline conditions (reversal) until August 13th (7 days). Feedback periods spanned thirty-five days for the primary group and twenty-six days for the delay group.

Data Collection and Analysis

Each meter was read between 7:30 and 9:30 A.M. Meter readers were a group of ten college and high school students who were employed through the summer program sponsored by the Comprehensive Employment Training Act

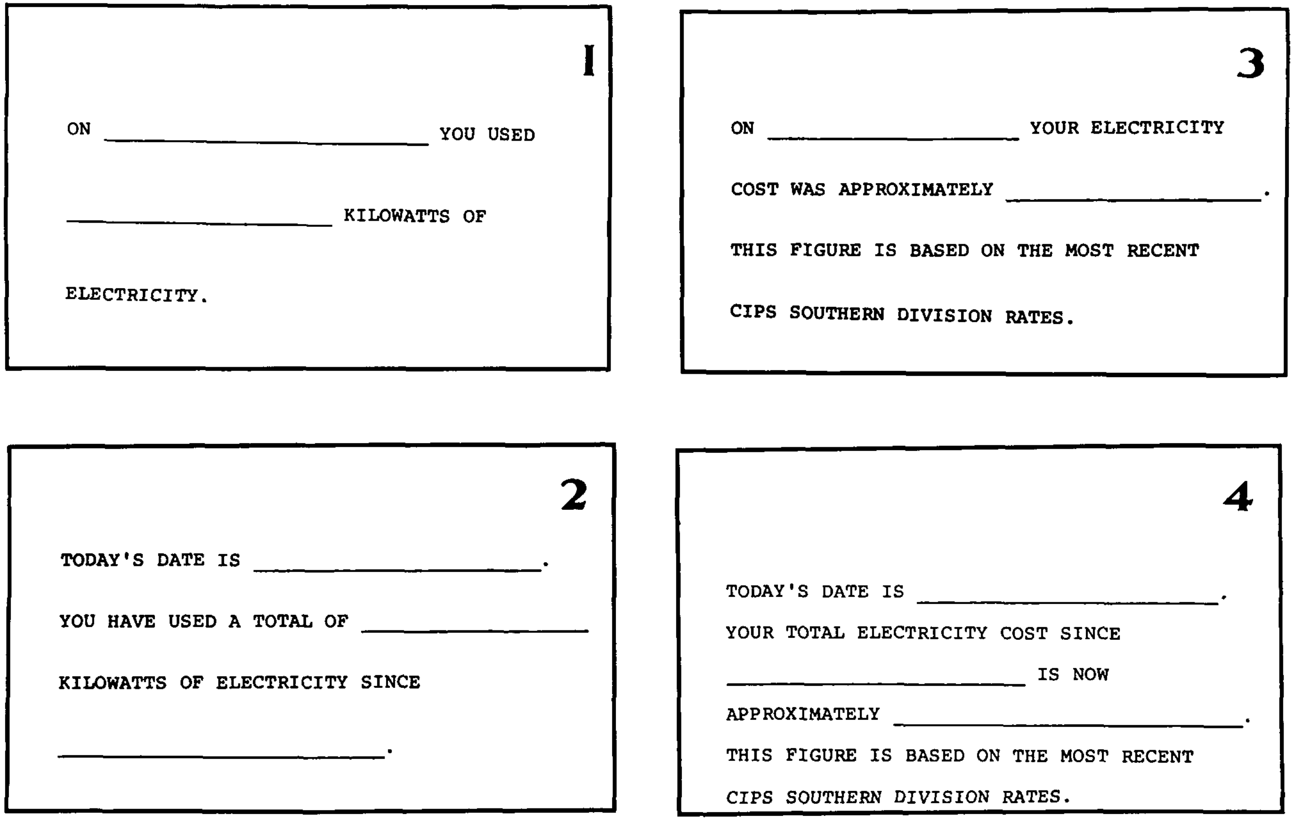

Figure 2. Four types of daily feedback.

(CETA). Readers were unaware of the experimental hypothesis and were told to direct all questions from the participants to the research team. Students were trained to read meters and were required to pass a meter reading test with 100 per cent accuracy before going into the field.

After reading a predetermined route, data collectors returned to the research facility, calculated consumption and/or cost, and recorded the data. Cost figures were calculated according to the rates currently published by the local electric company.

Feedback cards (see Figure 2) were then completed and returned to the participants between 11:00 A.M. and 1:00 P.M. Monday's feedback card reflected all consumption since Saturday's reading.

To facilitate a review of our results, and to more accurately pinpoint the families for whom feedback was effective, all data was examined in terms of the changes in consumption as a percentage of baseline consumption levels.

Three groups were established; high, medium and low consumers, with each group containing approximately one-third of all subjects. Assignment to these groups was accomplished by establishing a frequency distribution of mean daily consumption during baseline, and assigning all subjects in the lower 33 per cent to the low group (N = 129), the middle one-third to the medium group (N = 117 and the remaining subjects to the high usage group (N = 107).

The purpose of these divisions was strictly for data analysis and a subject's assignment was carried out independent of the type of feedback they received.

Reliability

To insure the accuracy of the meter readings and subsequent feedback information, a second observer occasionally accompanied the primary observer on the meter reading route and independently read the meter immediately afte the primary reader. Either a student or a member of the research team served a the second observer.

Reliability was assessed for at least seventy-nine meter readings for each primary observer. For a total of 711 meter readings, 698 agreements were recorded, yielding 98.17 per cent agreement.

RESULTS

Table 1 presents the consumption data for all 353 families during the first seventeen day baseline period. In addition to the average kilowatts consumed, the standard deviations are provided. For the High consumers, the mean daily kilowatt consumption ranged from 49 kilowatts to 63 kilowatts with the standard deviation ranging from 5.3 kilowatts to 22.9 kilowatts. For the Medi Consumer group the mean consumption rates ranged from 24 kilowatts to 27 kilowatts with standard deviations ranging from 4.9 to 6.8 kilowatts. The Low

Table 1. Average Consumption During Baseline (Kilowatts)

	Type of feedback	Feedback group			Delay group		
		N	*Mean*	*SD*	*N*	*Mean*	*SD*
High Consumers	Daily Kw	19	56	12.6	6	50	5.3
	Cumulative Kw	18	49	12.5	8	59	20.6
	Daily Cost	27	53	19.2	4	63	22.9
	Cumulative Cost	18	49	16.0	7	47	8.5
Medium Consumers	Daily Kw	23	26	5.6	8	24	6.6
	Cumulative Kw	22	25	6.2	9	25	5.8
	Daily Cost	19	27	5.1	8	27	6.8
	Cumulative Cost	25	25	4.9	3	25	5.2
Low Consumers	Daily Kw	27	11	4.4	8	12	5.0
	Cumulative Kw	26	10	5.7	7	9	2.8
	Daily Cost	20	9	4.3	10	10	4.8
	Cumulative Cost	23	10	3.7	8	9	1.8

Consumers mean consumption rates ranged from 9 kilowatts to 11 kilowatts with standard deviations ranging from 1.8 kilowatts to 5.7 kilowatts.

Figure 3 presents the consumption data for all families during the period from day eighteen through day fifty-two. During the period from day eighteen through day twenty-eight those families receiving feedback are indicated by the darkened bar graphs while those not receiving feedback are represented by the white bar graphs. From day twenty-nine through day fifty-two all families were receiving feedback. The top set of graphs represents the consumption data for high consumers, the middle set of graphs the data for medium consumers and the bottom set of graphs the data for low consumers. The data is presented as the percentage of baseline levels of consumption. During the sixteen day baseline period from June 16th to July 2nd, temperatures were moderate with a mean high temperature of 85° and a mean low of 69°. Following the onset of feedback on July 3rd temperatures rose to the mid 90's and on eleven of the first fifteen days of feedback ranged from 94° to 96°. During the entire forty-three day feedback period the mean temperature high was 91.5° and the mean low 69°. Because of this general temperature increase, over that during the baseline period, all participants increased consumption over baseline levels. Therefore, the effects of the various types of feedback cannot be determined by comparing an individual participants consumption during feedback to his baseline level. Effects can be observed, however, by comparing consumption levels on an intergroup basis and by comparing consumption rates of the immediate feedback group with the consumption of control families who received no feedback during the delay period from day eighteen through day twenty-eight.

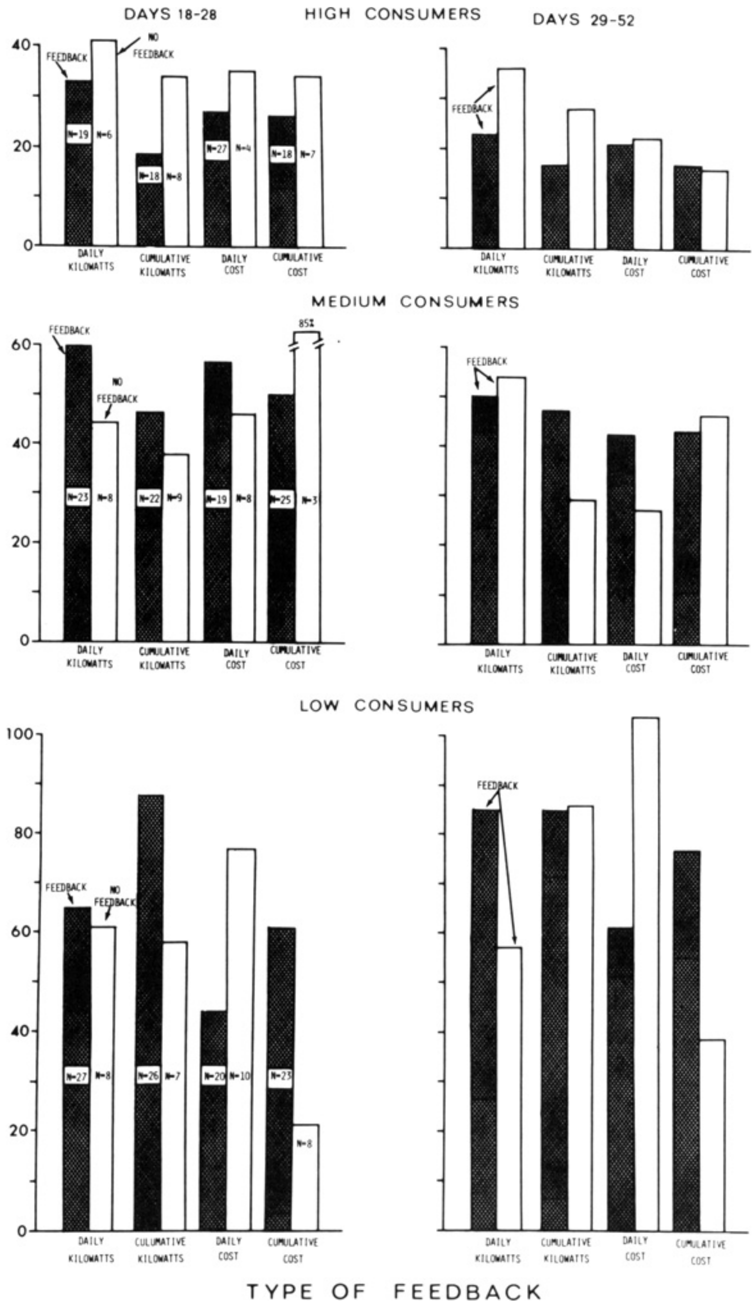

Figure 3. Mean percentage increase over baseline consumption.

For the high consumer group during days eighteen to twenty-eight (top graphs) all four types of feedback resulted in smaller increases in consumption than observed for control groups. The smallest increase in consumption occurred with the families receiving cumulative kilowatt feedback. This group increased consumption by 18 per cent as compared to a 36 per cent increase for the delay control group. Both daily and cumulative cost feedback produced about the same increase 26 per cent and 27 per cent compared to 34 per cent and 35 per cent increase for delay control groups. Of the four types of feedback, daily kilowatt feedback appeared to be the least effective with this group showing a 33 per cent increase in consumption. However, even this group, consumed considerably less than the delay control group (33% vs 41%). Thus, during the initial feedback period all types of feedback appeared to have a restraining effect on the consumption of high consumers with cumulative kilowatt feedback being the most effective.

From day twenty-nine through day fifty-two all families received feedback. For the family groups which had been receiving feedback since day eighteen the increase over baseline consumption leveled off at about the same percentage, with the two types of cumulative feedback both at +17 per cent and the daily feedback at +21 per cent for the daily cost feedback and +23 per cent for daily kilowatt. For the delayed feedback groups, all groups show reduction in the percentage increase over baseline levels. The daily kilowatt group reduced consumption by 5 per cent, daily cost by 6 per cent, cumulative kilowatt by 13 per cent and cumulative cost by 18 per cent.

For high consumers it appears that feedback does have a suppressive effect on consumption of electricity with cumulative types of feedback slightly more effective than feedback concerning only one days consumption.

The effects of feedback were considerably different however for medium and low consumers. Instead of having a suppressive effect on consumption, feedback appeared to result in increases in consumption. For the medium consumers (middle graphs) increases in consumption over baseline during days eighteen to twenty-eight was higher for three of the four feedback groups than for their no feedback controls. Only the cumulative cost feedback group showed a smaller increase. Further, the percentage increase over baseline levels was greater for all groups than was the case for all groups of high level consumers. During days twenty-nine to fifty-two the differences between the consumption of the various immediate feedback groups diminished and both daily and cumulative cost feedback appeared to have the same effect with their increases over baseline equal at +43 per cent. Both types of kilowatt feedback also stabilized consumption at approximately the same level at +47 per cent for cumulative kilowatt vs +50 per cent for daily kilowatt. For the delayed feedback control groups a different pattern emerged with daily cost feedback being most effective at +27 per cent followed closely by cumulative kilowatt +29 per cent, with both considerably lower than their no-feedback rate during the immediately

Table 2. Reversal Data (Days 53-59)

Type feedback	Feedback days →	*Percentage of baseline consumption*					
		High		*Medium*		*Low*	
		(18-52)	*(29-52)*	*(18-52)*	*(29-52)*	*(18-52)*	*(29-52)*
Daily Kilowatt		+18	+07	+34	+46	+ 79	+38
Cumulative Kilowatt		+17	–01	+34	+26	+ 37	+47
Daily Cost		+21	+07	+20	+03	+ 46	+80
Cumulative Cost		+13	+02	+32	+11	+148	+25

preceeding period (days 18-28). Daily kilowatt and cumulative cost feedback groups averaged only slightly lower than their comparison groups during this period at +46 per cent for the cumulative cost group and +54 per cent for the daily kilowatt group.

The largest increase over baseline levels of consumption occurred with the low consumer groups (bottom graphs). As was the case with medium consumers, the initial effect of feedback (days 18-28) with one exception was to increase the consumption of experimental groups above the level of the no feedback control groups. The one exception was the daily cost feedback group for which the consumption increase was 33 per cent lower than the no-feedback control. When feedback was provided to all groups (days 29-52) consumption continued to increase over baseline levels for three of the four feedback groups which had been receiving feedback since day eighteen and remained about the same for one group (cumulative kilowatt). For the delayed feedback groups during days twenty-nine to fifty-two, feedback increased consumption for all groups except the daily kilowatt group which was slightly (4%) lower.

On day fifty-three, feedback was discontinued for all groups. Meter readings were continued for one week (days 53 through 59) to observe reversal effects. During this period all but two of the twenty-four distinct groups showed reductions in consumption over the level observed during the previous three weeks (days 29-52) when all groups were receiving feedback. Table 2 presents the reversal data. It can be seen that consumption patterns during this period of reversal were similar to those previously observed during feedback with the greatest percentage increase in consumption over baseline levels occurring with the low consumer group, followed by the medium group, with the high consumer continuing to show the smallest percentage increase in consumption over baseline levels.

DISCUSSION

The results of this study suggest that feedback is effective in reducing the consumption of electricity for consumers who use large amounts of electricity.

However, for consumers who consume less, feedback appears to increase consumption.

One of the purposes of this study was to try to determine if different types of feedback produced differential effects. For the high consumer group cumulative types of feedback were more effective than daily consumption feedback only.

For medium consumer groups cumulative types of feedback were more effective initially, but equalized as the feedback continued. For low consumer groups cumulative feedback was the least effective.

This study was conducted during an extremely hot Summer period. Moderate temperatures during baseline were followed by record setting high temperatures during the initial feedback period (several days 94°+). The delay group provided control for the temperature variable during the initial feedback period. Once all groups began receiving feedback no control existed for the temperature variable. During the twenty-three days when all families were receiving feedback, temperatures were stable around 90° with only slight variations in highs and lows.

The results of this study then must be viewed in the light of the following limiting conditions:

1. Feedback was provided for a relatively brief period (35 days).
2. The temperatures during the period were extremely high; a condition which naturally causes high energy consumption, and
3. Control comparisons were limited to initial feedback periods (days 18-28).

In spite of these limitations the data indicate that:

1. Under extreme weather conditions, feedback is effective in reducing consumption of consumers who use large amounts of electricity.
2. Daily cumulative types of feedback are more effective than daily non-cumulative types.
3. Feedback during extremely hot weather increases consumption of low to medium consumers.

It thus appears that if feedback is to be used to reduce electricity consumption, during hot weather it must be used selectively. Otherwise the energy conservation of high consumers may be offset by the increases in consumption among low consumers.

The results also suggest that before providing consumers with information about consumption, such as average daily cost, utility companies should determine the effects which such information may have on consumption habits.

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