J. ENVIRONMENTAL SYSTEMS, Vol. 8(3), 1978-79

THE EFFECTS OF FEEDBACK ON RESIDENTIAL ELECTRICITY CONSUMPTION: THREE REPLICATIONS

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ABSTRACT

This project extended the findings of prior research by demonstrating that daily feedback could reduce electricity consumption by about 10 per cent to 20 per cent in three types of residential structures, with occupants of varying income levels, during peak-load (seasonal) periods, and for lengths of time approximating a cooling or heating season in milder climates. The study's results indicated that maximum effectiveness of feedback was reached with higher use consumers during the warmest weather, suggesting that the larger residential consumer should be the target of conservation programs, with such programs optimally focused on cooling and heating. A number of important parameters of feedback procedures were discussed, and methods were outlined that may more widely promote feedback on energy use.

A number of recent studies have demonstrated that frequent feedback (at least several days per week) can reduce residential energy consumption by about 10 per cent to 15 per cent [1-6]. However, each of these projects have had one or more shortcomings that limit the generality of these findings, including:

doi: 10.2190/6Y43-BM72-NUNK-3HH1
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1. the use of highly selected *volunteer* or otherwise special participants;
2. the lack of *replication* of findings across a range of income levels and residential structures;
3. only limited demonstration of the capability of feedback to modify energy use *during peak-load* (seasonal or time of day) periods, and for a *length* of time approximating a *heating or cooling season*; and
4. limited follow-up data on *maintenance* of effects after termination of feedback.

It is also still unclear which are efficacious or noneffective parameters in feedback procedures, that often include prompting, informational, monitoring, reinforcement, goal setting, and social comparison components [7].

Feedback seems to be a particularly important conservation strategy to investigate, since reductions achieved with feedback surpass national conservation goals being deliberated by Congress. In contrast to these positive findings, recent reports suggest limited short-run responsiveness to *small* (politically feasible) price changes or monetary rebates not accompanied by frequent feedback [8, 9]. Finally, it seems possible for feedback to be delivered to residential and commercial consumers by the use of various self-monitoring strategies, metering devices, and the media [10]. The effectiveness of such eventual wider-scale applications may rest on the knowledge gained from field studies which may not evaluate cost-effective techniques per se, but rather attempt to delineate important feedback parameters, appropriate target groups, and optimal timing involved in feedback programs.

The present study extended prior research by investigating different types of daily feedback systems with consumers of different income levels who lived in three kinds of residential structures. Recruitment methods minimized the possible problem of selection bias of some prior studies. Feedback was also used during peak and non-peak (seasonal) periods for a time approaching the length of a heating or cooling season in mild climates. Follow-up data were also available for periods up to about two months after feedback was terminated.

METHOD

Setting and Participants' Characteristics

The project was conducted from late April to early September, 1977. During that time of the year, major increases in electricity use were primarily attributable to air conditioning. All participants lived in Greenbelt, Maryland—a suburb of Washington, D.C. Residents in Area "A" all lived in two-story, two-bedroom, wooden townhouses, thirty to forty years old, with no or minimal attic insulation. All participant households had at least one window air conditioning unit. The townhouses were attached in groups of from four to eight units.

The average gross family income of this area was reported as $15,000 to $20,000. There was an average of 1.6 adults and .5 children per participant household. During the baseline period, participant households averaged 10.7 KWH per day.

Area "B" residents lived in townhouses, also attached in groups of four to eight units, that had three floors (e.g., finished basement) and three bedrooms. The units were eight years old and all had central air conditioning; attic insulation was also limited in these townhouses.

The average gross family income in this area was $20,000 to $25,000. Each townhouse was occupied by an average of 2.1 adults and 1.9 children. Participant households in this area averaged 20.8 KWH per day during the baseline period.

Area "C" consisted of large, single, detached homes, with three to four bedrooms and three to four floors. All of these houses were about ten years old, and all were equipped with central air conditioning; occupants reported some limited attic insulation.

The average gross family income in this area was $30,000 to $35,000. Participant households reported an average of 2.2 adults and 2.2 children, and electricity use during baseline averaged 29.7 KWH per day.

Table 1 summarizes the characteristics of the three areas. In each area, virtually every household was owned by the occupant, and each household had its own electricity meter. Thus, while the occupant characteristics of Areas "B" and "C" were similar, and households in both areas had central air conditioning, the three areas were different in terms of physical structure and size of household, income, and electricity consumption.

Figure 1 is a schematic map showing the location of the residences, KWH use, and experimental conditions. While existing physical areas were used for different experimental conditions, as noted in Figure 1, within each area the amount of shade and sunlight did not appreciably favor an experimental condition.

Recruitment Methods

All participants were recruited using a personal door-to-door approach. Potential participants were given a written and verbal

Table 1. Characteristics of the Three Areas

	Area A	Area B	Area C
Description	57 Attached Townhouses	21 Attached Townhouses	43 Detached Houses
Size	Small–2 Story	Medium–3 Story	Large–3-4 Story
Age	30-40 Years Old	8 Years Old	10 Years Old
Cooling	Window Units	Central	Central
Gross Family Income	$15-20,000	$20-25,000	$30-35,000
Baseline Average (Per Household, Per Day)	10.7 KWH	20.8 KWH	29.7 KWH
No. Adults	1.6	2.1	2.2
No. Children	.6	1.9	2.2

description of the project, with a staff person returning a few days later to pick up a signed consent form. After baseline periods, all participants assigned to feedback groups received a note requesting their attendance at a meeting held outdoors on their court or block. Separate meetings were arranged for each experimental condition. Comparison group households did not attend a meeting. At each meeting, participants were given a thorough explanation of the feedback procedures; several participants in each area could not attend a meeting and were visited in their homes.

Using these methods, 73 per cent of households originally *contacted* agreed to participate in the project. There were no significant differences between experimental and comparison groups in per cent of contacted households agreeing to participation.

Assignment to Feedback or Comparison Group

Figure 1 also shows that households in the different areas in the feedback and comparison conditions were *clustered* in specific courts or blocks. This procedure was followed for several reasons:

1. to potentially enhance feedback's effectiveness through social comparison by neighbors,
2. to use *group* feedback in definable areas and limit the types of feedback to one location, and
3. to reduce logistical problems in distributing feedback forms.

Assignment of experimental conditions to specific locations was made several days prior to a meeting; comparison households were informed of their status after feedback had started.

Thus, while assignment was neither truly random nor matched,

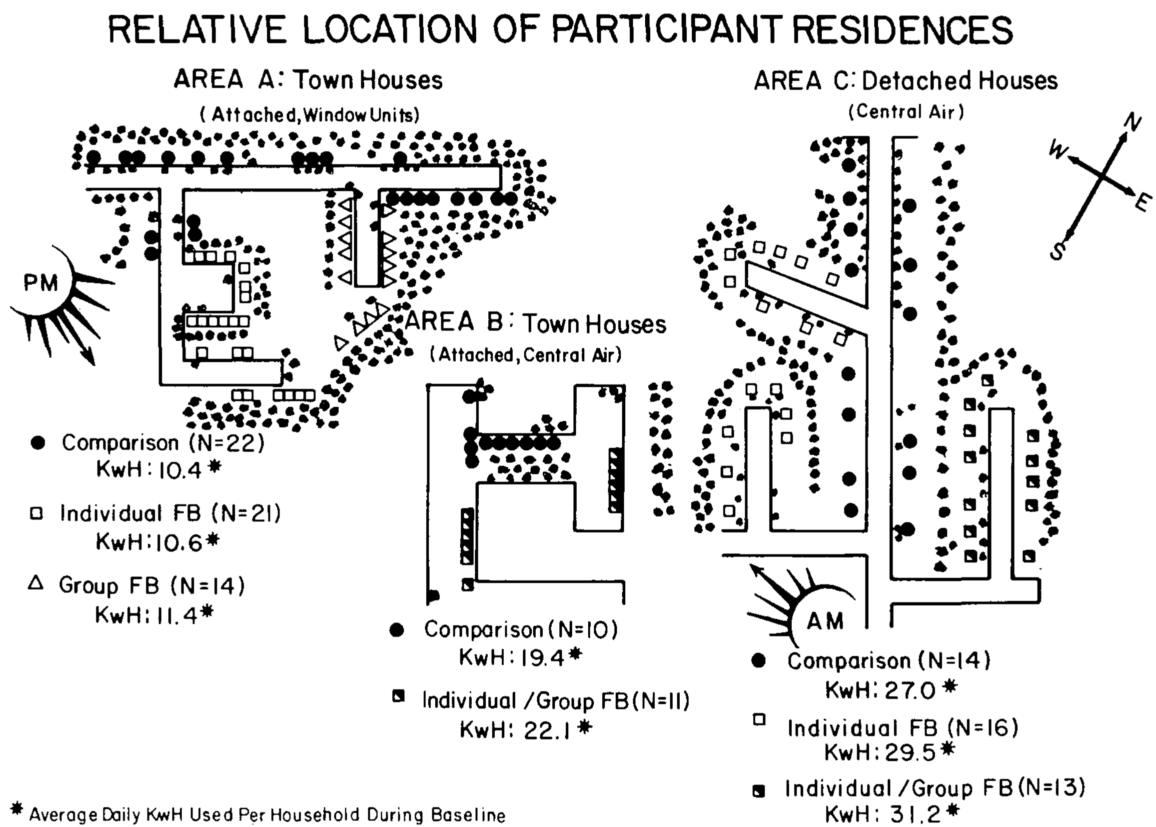

Figure 1. The relative location, treatment condition, and average KWH/day use of the three areas in the project.

feedback and comparison groups from each area were composed of residences that were *virtually identical* in physical and demographic characteristics and average daily KWH used.

Dependent Measure

Electricity meters of all participant households were read every day, including weekends, during baseline and feedback conditions, and once per week during follow-up. Meter readers[1] read each meter at about the same time every day and recorded the position of the dials of each meter on prepared forms. Meter readers had limited knowledge of the project's procedures and were unaware of group assignment. Nine times during baseline and three times during feedback conditions the meter readers overlapped in their readings, unaware that the other reader had also recorded the same meters on those days. Agreement in readings during the overlaps, using the formula "dials agreed upon/total dials read," was over 99 per cent.

Feedback Procedures

Following baseline periods that lasted twenty-one days in Area "A," twenty-nine days in Area "B," and twenty days in Area "C,"[2] baseline daily KWH use averages were calculated for each household. During the group meetings, each participant was presented with this average. Those participants receiving group feedback alone were only given the daily average for their whole group, while participants receiving individual and group feedback were given both their individual average and the group average. After an explanation of a weather correction procedure (below) and the expected increase in use because of warmer weather, each household also set a reduction goal. A chart depicting the ease or difficulty in achieving per cent reductions was used to guide goal selections and indicated that a 10 per cent or more reduction was difficult; participants' average reduction goal was 5 per cent.

Written feedback to participants was given every day for a period of five to six weeks. The feedback consisted of KWH used the prior day and the per cent increase or decrease, which was computed using a formula based on the comparison group's baseline and prior day's use in a *given area*. This procedure has been described in detail previously [6].

[1] Mrs. Catherine Vanderzoon and Lawrence and Mimi Noel were the meter readers; during the project, they never missed a day's reading.

[2] Logistical considerations led to unequal baseline periods.

The feedback form indicated whether or not a reduction was better than the household's goal. Households performing better than their goal received a gold star. In addition, at the bottom of each form, their percentage decrease or increase was extrapolated in terms of KWH and dollars to the entire Washington metropolitan area.

All this information was presented on color-coded forms with an ascending series of smiles or frowns at the top of the form corresponding to different levels of decreases or increases in use. The forms were delivered in envelopes to the doorstep of the households to limit the interaction and reinforcement value of the staff person[3] distributing them.

Feedback Procedures by Area

As indicated in Figure 1, individual feedback (IFB) and group feedback alone (GFB) were used in Area "A;" a combination of individual *and* group feedback (IGFB) was used in Area "B;" individual and individual *and* group feedback were used in Area "C." Group feedback followed the same procedure as individual feedback, but the figures presented on the feedback sheets were total group KWH use and group per cent increase or decrease. The group goal was the average of individual goals. Thus, some participants in Area "A" were never given feedback information on their individual use; participants in Area "B" received daily information on their own *and* their group's use; while some participants in Area "C" received individual information and others received the combination.

The overall experimental design consisted of:

1. Area "A": IFB (N = 21), GFB (N = 14), C (Comparison) (N = 22).
2. Area "B": IGFB (N = 11), C (N = 10).
3. Area "C": IFB (N = 16), IGFB (N = 13), C (N = 14).

Treatment conditions were first implemented in Area "A," then "B," and later "C." This progression of treatments reflected efforts to develop and replicate effective procedures within the constraints of limited project funds.

RESULTS

Analyses of variance using the average daily KWH consumption per household indicated that *within* each area there were no

[3] Mrs. Mary Coyne distributed feedback sheets and never missed a day's distribution.

significant differences in baseline use between feedback groups and comparison groups. However, because KWH use by groups was not exactly equal within areas, data are represented in terms of "percentage of baseline." These data are presented in two ways:

1. For each period (baseline, feedback, follow-up), the daily (or weekly) per cent baseline for each group is presented graphically.
2. A percentage baseline score across the entire feedback period was calculated for each household in each group, and these data were used in analyses of variance. The same procedure was used for the weekly follow-up data.

In all analyses and for all groups, a household was dropped from the data on any day that its prior day's KWH use ÷ daily baseline use, divided by the weather correction factor was $< .50$. This procedure provided a nonintrusive method to correct for vacations or periods when residences were minimally occupied.

Area "A"

Figure 2 shows the daily use of the three groups during baseline and feedback periods and the weekly use during the follow-up period, as a function of percentage of baseline. The figure also indicates approximate KWH use each day and high daily (or average weekly) temperature.

The figure indicates little difference in the pattern of electricity use during baseline, but consistently less use by the IFB group during the six-week feedback period. IFB did better than C on thirty-three of forty-two days. The GFB group performed well for about the first week, but then its consumption overlapped with the C group. During the follow-up period, there were no differences in electricity use. It is also apparent that daily electricity use closely followed the high daily (or weekly) temperature.

Using percentage of baseline for each household during the feedback period, a difference between the groups approaching significance was found, $F(2, 54) = 2.34$, $p = .11$. T-test comparisons indicated that the IFB differed from the GFB and C group at the .15 level, with no differences between the GFB and C group. There were no significant group differences during the weekly follow-up periods.

During the feedback period, the percentages of baseline use were: IFB = 93 per cent, GFB = 104 per cent, and C = 100 per cent. During the follow-up period, the percentages were: IFB = 151 per cent, GFB = 159 per cent, and C = 158 per cent.

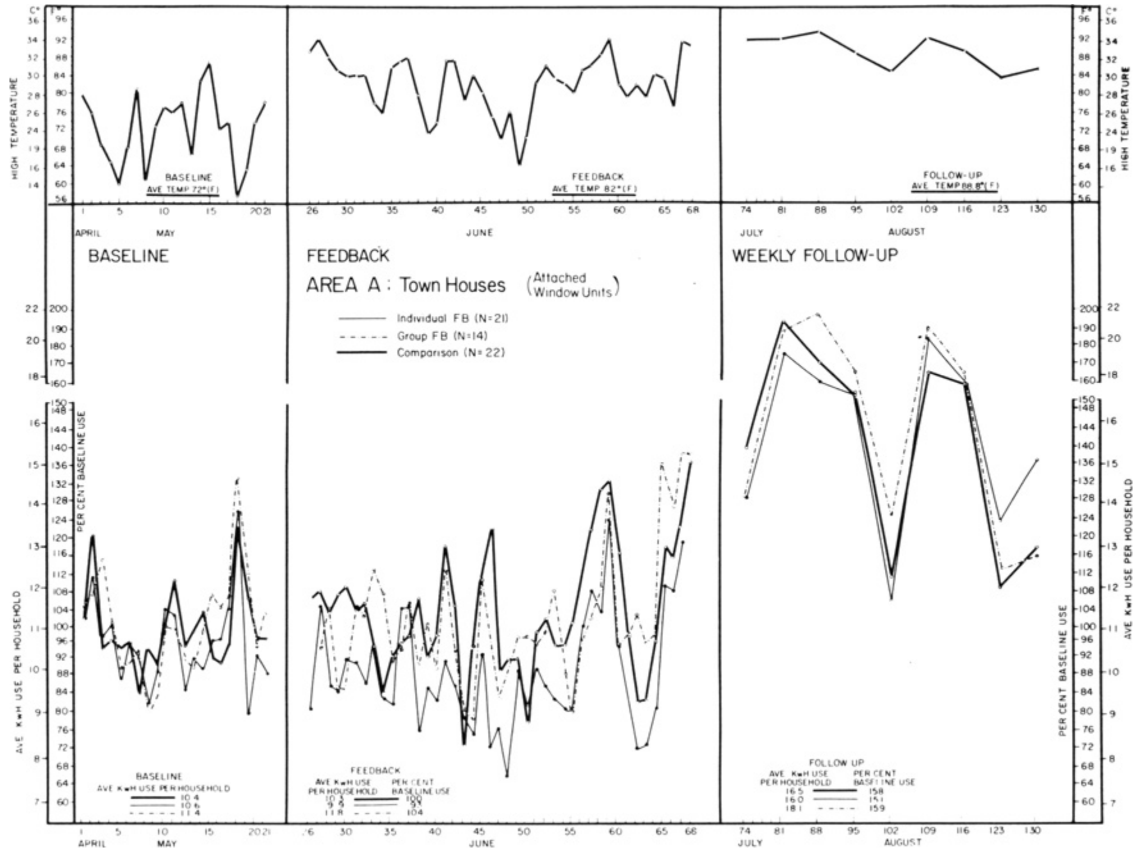

Figure 2. Electricity use of the three groups in Area "A" represented as per cent baseline, with an approximate KWH scale, during baseline, feedback, and follow-up periods.

Area "B"

Figure 3 represents percentage of baseline use by the two groups in Area "B." Baseline use patterns were similar except for two warm days when the C group exceeded IGFB. However, during the feedback period, the IGFB group consumed less electricity (e.g., per cent baseline) than the C group on thirty-one of thirty-four days. The figure suggests some persistence of this pattern during the follow-up period. Electricity consumption was markedly influenced by the high temperature.

Using percentage of baseline use by households, effects approaching significance were found during the feedback period, $F(1, 19) = 3.62$, $p = .075$, and follow-up period, $F(1, 19) = 3.63$, $p = .15$. During the feedback period, the IGFB group used an average of 102 per cent of baseline, and the C group used 124 per cent. Figure 3 also shows that the C group averaged *less* KWH per day (19.4) during the baseline than the IGFB group (22.1), but used *more* KWH than IGFB during the feedback period (24.1 vs. 22.5). The percentage use during the follow-up period was 196 per cent for IGFB and 220 per cent for C.

Area "C"

Visual inspection of Figure 4 indicates no differences in the pattern of use during baseline by the three groups. During the six-week feedback period, electricity use was markedly influenced by the high temperature which was variable, but mild, during the first three weeks, but extremely and consistently hot during the last three weeks. During the first three "cool" weeks, the IFB group was consistently below the C group; the IGFB group and the C group performed about the same. In the last "hot" three weeks, the IFB and the IGFB groups were consistently and *markedly* below the C group. On some very hot days, differences in use between IFB, IGFB, and C groups approached an average of 30 per cent, or about fifteen to twenty KWH per household. During the follow-up periods, some maintenance of effects is apparent.

Using participants' percentage of baseline use across all the feedback days, a significant treatment effect was found, $F(2, 40) = 4.35$, $p < .02$. T-test comparisons indicated both IFB and IGFB performed better than C ($p < .05$). During the feedback period, IFB averaged 148 per cent; IGFB, 152 per cent; and C, 187 per cent. The C group, which had averaged *less* KWH per day (27.1) per household during baseline than IFB (29.5) and IGFB (31.2), averaged *more* than these two groups during the feedback period (50.4, C; 43.5, IFB;

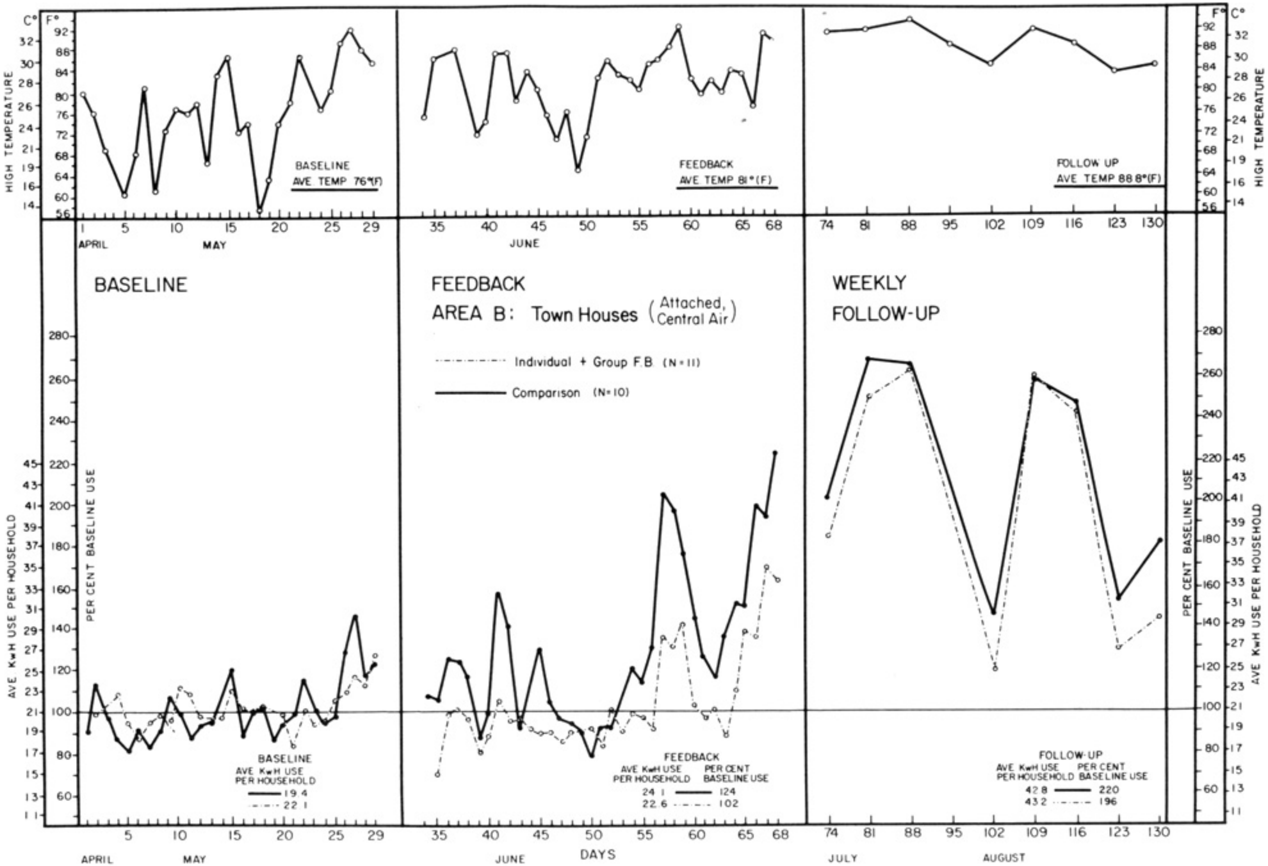

Figure 3. Electricity use of the two groups in Area "B" represented as per cent baseline, with an approximate KWH scale, during baseline, feedback, and follow-up periods.

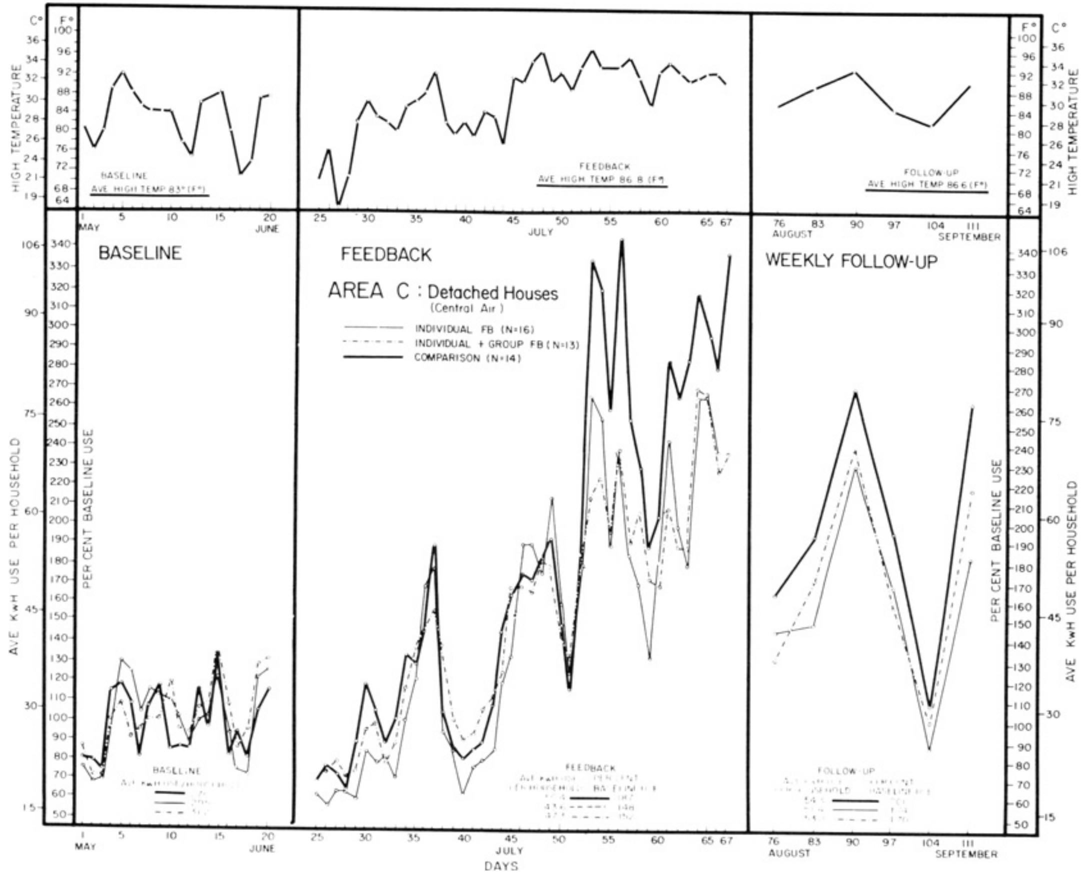

Figure 4. Electricity use of the three groups in Area "C" represented as per cent baseline, with an approximate KWH scale, during baseline, feedback, and follow-up periods.

47.4, IGFB). No statistical differences were found during follow-up using household scores, but the two feedback groups performed better than the C group (C, 201%; IFB, 174%; IGFB, 170%).

Summary

Table 2 summarizes the results of the study in the three areas. In each area, when individual feedback was used alone or in combination with group feedback, reductions in electricity consumption of between 7 per cent to 20 per cent were found. Larger reductions occurred during the warmest weather with higher use consumers, and there was some evidence for maintenance of effect once feedback terminated.

Additional Data

At the end of the feedback period, questionnaires concerning energy use patterns, conservation methods, and program processes were distributed to all participants in groups receiving feedback. Approximately 90 per cent of the questionnaires were returned. Particularly salient findings included:

1. Gross family income was correlated with baseline average both within each area ("A" = .46, $p < .05$; "B" = .67, $p < .01$; "C" = .65, $p < .01$) and across the feedback sample (.59, $p < .001$).
2. higher ratings of the importance of setting reduction goals were correlated with lower proportional use levels during feedback periods in each area ("A" = -.28, $p < .10$; "B" = -.50, $p < .10$; "C" = -.41, $p < .05$), and higher ratings of usefulness of receiving daily feedback were also correlated with lower proportional use levels during feedback periods

Table 2. Outcomes in the Three Areas

	Area A	*Area B*	*Area C*
Conditions	IFB (21) GFB (14) C (22)	IGFB (11) C (10)	IFB (16) IGFB (13) C (14)
Feedback Reduction	7 per cent for IFB	20 per cent	20 per cent for Both
Consistency of Effect by Day	High	Very High	High, When Warm
Highest Average Use (Per Household Per Day)	20 KWH	50 KWH	100 KWH
Maintenance	No	Some	Some
Best Effects	—	When Warm	When Very Warm

("A" = $-.45$, $p < .01$; "B" = $-.38$, $p < .10$; "C" = $-.32$, $p < .10$).
3. Virtually all participants who reduced their electricity consumption relative to their comparison group attributed their savings to *less use of air conditioning.*
4. All respondents who received group feedback alone indicated it was only minimally useful and noted they may have reduced more with individual information.
5. Few persons reported talking with their neighbors about energy conservation during the project.

DISCUSSION

Limited resources precluded a complete replication of all three feedback combinations across the three different housing structures and income levels. However, when the present findings are coupled with other research, important parameters of feedback techniques, appropriate target groups, points of intervention, and potential outcomes are suggested. Group feedback, which yielded negligible reductions, contained all the elements—demand characteristics of being in an experiment, daily prompting, goal setting—of the other methods, except participants receiving group feedback were never given information on their individual electricity consumption. In Area "C," where individual feedback was used alone and in combination with group feedback, both approaches reduced consumption, but there was no difference in the effectiveness of the two feedback procedures. These results point toward *individual information* as the efficacious component of these procedures. However, it must be noted that our individual "feedback package" contained many other social influence strategies—goal setting, prompting, public meetings, social valuation (e.g., faces on feedback sheets)—and the relative contribution of each component to making *individual feedback* effective (or more effective) is still unclear. Obviously, it is important to do further parametric work to clarify these issues so that broader applications of feedback methods can be cost-effective. Fortunately, such work has been recently reported by others and does suggest that each of the various components of the package may have a significant function and optimal form [1, 11, 12].

Conservation achieved with feedback techniques in this and other projects indicates that such social strategies may yield meaningful reductions (10 to 20%) by affecting simple behaviors such as thermostat settings. Data from this study further suggest important differences in use patterns rarely discussed by policymakers, but noted previously by Seligman and Darley in their feedback work [5]. Even *within* the three areas, where dwelling structures were virtually identical, households with the same demographic characteristics could vary greatly in daily KWH use. Not surprisingly, these differences became magnified in the higher use area during the very hot weather. For example, in Area "C," during three consecutive days when the high temperature was over 90° (F), one household consumed ninety, ninety-seven, and ninety-eight KWH, while another almost identical household used twenty-five, twenty-five, and thirty-five KWH! Such differences undoubtedly reflect differential use of air conditioning by consumers with basically the same equipment.

Likewise, in Areas "B" and "C" (see Figures 3 and 4), overall reductions achieved with feedback were generally largest during the hottest, peak-use time. The difference in use between the feedback groups and the comparison group during the warmest days was about fifteen to twenty KWH per household (see Figure 4).

Although, as noted above, much more research on component analysis is needed, the differential use patterns and reductions achieved during peak-use times provide some *guidelines* for conservation programs:

1. The high user should be the target for conservation efforts. If it is not logistically or politically feasible to identify such households, then data from the present study suggest that efforts be directed toward higher income areas, not lower income areas. Not only was it found that income was associated with electricity use ($r = .59$), but examination of Figures 2 to 4 provides some comparative use data from lower-middle to upper-middle households during peak-use times. On extremely hot days, households from Area "A" only averaged about twenty KWH per day, while households in Area "C" were averaging about eighty to 100 KWH per day. Reductions achieved in higher use households could have a much greater impact on demand than comparable reductions in lower use areas.
2. It is also clear from inspection of Figures 2 to 4 that electricity use across areas is relatively low during cooler weather but very high during hot weather (about 85° in the humid summer seemed to be the "cut-off point"). Intensive conservation programs would best be mounted during the summer cooling and winter heating seasons. Such short, but intensive, programs could sustain interest for periods of six to eight weeks, the length of the maximum heating and cooling seasons in moderate climates. The data from the present study indicate that feedback procedures can be effective for

that length of time, with perhaps some reductions maintained for longer periods without feedback (see follow-up periods on Figures 3 and 4).

Overall, it appears that an effective conservation program aimed at the residential sector would develop marketing strategies to promote procurement of conservation products (e.g., insulation materials; solar equipment, where feasible), be directed toward higher users during peak-use times, focus on heating and cooling, and provide individual feedback to support consumers' efforts.

Feedback in such programs may be provided in a number of ways. Energy monitors are being developed that can display KWH used, cost at the current rate of use (per hour) and cumulative cost [13]. A recent study directly evolving from the current work demonstrated that consumers can be easily taught to persistently and reliably monitor their own *conventional* electricity meters. The "self-monitoring" strategy yielded significant reductions in electricity consumption during the winter heating season [14]. The use of the media to provide feedback to entire communities is also being explored, as well as extensions of these feedback techniques to the commercial sector [10]. It may even be cost-effective in areas where the utility rates are extremely high (for example, New York City) to employ persons to give feedback in ways very similar to this project [10].

All these feedback and conservation strategies seem straightforward and revolve around relatively simple "appropriate technology." [15] The development of a decisive energy policy and, of course, rising prices could create the climate where such social and technical innovation could help to abate the energy problem.

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ACKNOWLEDGEMENTS

This study was supported by Grant No. 5S07-RR05636-11 from the Division of Research Resources of the National Institutes of Health. We extend our thanks to Greenbelt Homes, Inc., and particularly Ken Kopstein, for their help with this project.

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