J. ENVIRONMENTAL SYSTEMS, Vol. 9(2), 1979-80

ENERGY CONSERVATION EFFECTS OF CONTINUOUS IN-HOME FEEDBACK IN ALL-ELECTRIC HOMES*

LOU MC CLELLAND

STUART W. COOK

Institute of Behavioral Science
University of Colorado

ABSTRACT

Feedback devices continuously displaying electricity consumption in cents per hour in twenty-five of 101 energy-efficient, all-electric homes in Polk's Landing, Carrboro, North Carolina, were associated with an average electricity savings of 12 per cent. Homes with monitors had lower consumption in all eleven months analyzed (September 1976-July 1977), with the greatest differences in months with moderate weather and low overall consumption. This suggests that the conservation actions taken by households with monitors primarily affected energy uses other than heating and cooling.

Several recent studies have investigated the effects of daily energy consumption feedback on the use of electricity. Seligman and Darley (1977), Becker (1978), and Winett, Neale, Williams, Yokley, and Kauder (in press) all studied centrally air conditioned homes during summer months [1-3]; Winett, Neale, and Grier (in press) studied electrically heated homes in winter [4]. Electricity savings of 10 to 20 per cent over study periods of three to eight weeks were found; savings generally were larger in periods of more extreme weather, indicating primary effects on heating and cooling energy. (For feedback studies with less frequent feedback and/or very small samples see references [5-10].) Reported here is an

* This work was performed under contract EC-77-S-02-4165.A001 to the authors from the U.S. Department of Energy. This is publication number 176 of the Institute of Behavioral Science.

doi: 10.2190/L8BU-ECLK-PEC5-KKTW
http://baywood.com

analysis of the electricity consumed for heating, cooling, and other uses over eleven months in twenty-five all-electric homes equipped with devices continuously displaying electricity use in cents per hour.

ANALYSIS OF ELECTRICITY CONSUMED

Setting

The setting for the study was the Polk's Landing development, Carrboro, North Carolina: 101 single-family homes, moderately-priced (average $34,500), built 1975-76, 100-160 square meters ($\overline{X} = 124$). The homes are all-electric with identical energy-conservation construction packages (e.g., full insulation in ceilings, walls, and crawl spaces; double glazing; heat pumps); they are occupied by singles (13%), couples (63%), and families with children (24%).

Twenty-five of the homes are equipped with "Fitch energy monitors," a device which measures the electrical current from a transformer connected to the home's main power line. The current used at a given moment by the residence is translated into cents per hour according to a cents per kilowatt-hour (kwh) figure set manually on the device. The cents per hour figure is then displayed alternately with time of day by light-emitting diodes on a panel inside the home. The twenty-five homes equipped with monitors were first occupied between May and December 1976; the homes without monitors between fall 1975 and December 1976. Although the monitor-equipped homes were the last of the 101 homes to be built and occupied, they are essentially identical in construction to the remaining seventy-five and are scattered throughout all sections of the project. Residents had no knowledge of or choice in obtaining monitors at the time of purchase (homes were purchased from plans before construction was complete).

Records of electricity consumption for each home, identified by lot number only, were obtained for the eleven months September 1976-July 1977 from Carolina Power and Light. The twenty-five homes with monitors are significantly larger in size than those without (131 vs. 121 square meters, $F(1, 99) = 9.24$, $p < .01$) and are occupied by slightly larger families (2.28 vs. 2.05 persons per house, $F(1, 99) = 2.76$, $p < .10$). As noted above, they were also built and occupied later. Larger homes use somewhat more energy per month (average correlation over eleven months = .20, df = 85, $p < .10$). Singles used less electricity than couples, and couples less than families with children, in each of the eleven months ($\overline{X}_s = 1365$ kwh, $\overline{X}_c = 1518$, $\overline{X}_f = 1754$); for 7 of the 11 months $F(2, 85)$ was over 3.28 ($p < .05$). Within the seventy-six homes without monitors, there is neither a significant nor consistent relationship between date of first occupancy and consumption.

In order to estimate the magnitude of the effect of monitors on electricity consumption independent of household size and home size, these confounding

Table 1. Monitor Effects for Eleven Months

Month	$\bar{X}_{kwh}$	*N of homes* *With*	*Without*	*F-ratio*	*Effect*[a]
July 1977	1667	23	67	1.9	11.7
June	875	23	69	1.8	13.6
May	775	24	70	1.9	12.3
April	945	24	69	3.5[b]	13.4
March	1102	24	69	3.9[c]	15.5
February	2250	24	69	0.8	5.8
January 1976	3158	25	75	2.0	8.1
December	2404	23	73	3.3[b]	12.5
November	1936	21	71	1.5	8.9
October	1065	16	70	0.7	6.1
September	883	12	70	4.3[c]	20.7

[a] Monitor coefficient as percentage of mean consumption.
[b] $p < .10$.
[c] $p < .05$.

effects were removed statistically with multiple regression analyses. Kwh consumption was regressed on family size, square meters, and presence-absence of monitors for each of the eleven months. The monitor effect is then estimated by the unstandardized regression coefficient for monitor presence-absence as a proportion of mean consumption for the month. The F-ratio associated with this regression coefficient tests the significance of the increment in R^2 due to monitor presence-absence after the effects of house and household size have been removed.

Results and Discussion

The results are shown in Table 1. Monitors are associated with lower consumption in all eleven months. The differences neither increase nor decrease over time, averaging about 12 per cent, but do tend to be larger in low-consumption months ($r = -.51, p < .10$). This suggests that the conservation actions taken by households with monitors primarily affected energy uses other than heating and cooling. Although exactly what these households did to conserve is not known, most obvious energy-saving physical modifications to the structure are ruled out by the energy-conservation construction package in all homes in the development.

The monitor's apparent greater impact on non-heating and cooling energy uses indicates that the monitors may have served more to teach residents what activities consume the most energy than simply to draw attention to the cost of energy. Most people already know that electric heating and cooling are high energy users, and whether these systems are on or off can be sensed quite easily without a monitor. Conversely, the relative energy needs of other household appliances are not well known and cannot be readily learned from feedback delayed a month (such as a utility bill) or even a day. It is thus perhaps not unreasonable that the effects of continuous-display monitors differ from those of daily feedback, which seems to be most effective in promoting conservation of heating and cooling energy [2-4].

That the energy savings were achieved in already-efficient structures is of some practical import, indicating that technological and behavioral approaches to energy conservation can complement one another rather than compete as has sometimes been suggested.

Assuming a 12 per cent annual savings and three cents per kwh, $125 invested in an energy monitor (1978 retail price without installation) would have a payback period of 1.9 years for homes with consumption levels of about 18,000 kwh annually. Nationally, 12 per cent savings of the 7.6×10^{18} joules (10^{18} joules = 0.948×10^{15} Btu) consumed per year in residential housing (Hirst, 1976) represents the equivalent of over 5 per cent of U.S. oil imports [11].

REFERENCES

1. C. Seligman and J. M. Darley, Feedback as a Means of Decreasing Residential Energy Consumption, *Journal of Applied Psychology, 62,* pp. 363-368, 1977.
2. L. J. Becker, Joint Effect of Feedback and Goal Setting on Performance: A Field Study of Residential Energy Consumption, *Journal of Applied Psychology, 63,* pp. 428-433, 1978.
3. R. A. Winett, M. S. Neale, K. Williams, J. Yokley and H. Kauder, The Effects of Individual and Group Feedback on Residential Electricity Consumption: Three Replications, *Journal of Environmental Systems,* in press.
4. R. A. Winett, M. S. Neale and H. C. Grier, The Effects of Self-Monitoring and Feedback on Residential Electricity Consumption, *Journal of Applied Behavior Analysis,* in press.
5. S. C. Hayes and J. D. Cone, Reducing Residential Electrical Energy Use: Payments, Information, and Feedback, *Journal of Applied Behavior Analysis, 10,* pp. 425-436, 1977.
6. R. Kohlenberg, T. Phillips and W. Proctor, A Behavioral Analysis of Peaking in Residential Electrical Energy Consumers, *Journal of Applied Behavior Analysis, 9,* pp. 13-18, 1976.
7. M. H. Palmer, M. E. Lloyd and K. E. Lloyd, An Experimental Analysis of Electricity Conservation Procedures, *Journal of Applied Behavior Analysis, 10,* pp. 665-672, 1977.
8. W. E. Seaver and A. H. Patterson, Decreasing Fuel Oil Consumption Through Feedback and Social Commendation, *Journal of Applied Behavior Analysis, 9,* pp. 147-152, 1976.

9. R. A. Winett, S. Kaiser and G. Haberkorn, The Effects of Monetary Rebates and Daily Feedback on Electricity Conservation, *Journal of Environmental Systems, 6,* pp. 327-339, 1976-1977.
10. R. A. Winett, H. H. Kagel, R. C. Battalio and R. C. Winkler, The Effects of Monetary Rebates, Feedback, and Information on Residential Electricity Conservation, *Journal of Applied Psychology, 63,* pp. 73-80, 1978.
11. E. Hirst, Residential Energy Use Alternatives: 1976 to 2000, *Science, 194,* pp. 1247-1252, 1976.

ACKNOWLEDGEMENT

We thank R. B. Fitch of Fitch Creations, Inc. and B. L. Montague and Sherwood Smith of Carolina Power and Light Company for helping us obtain the records, and acknowledge the help of Hart Weichselbaum, Gary McClelland, and Laura Belsten in the analysis.

Direct reprint requests to:

Lou McClelland
Campus Box 468
Institute of Behavioral Science
University of Colorado
Boulder, CO 80309