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RESIDENTIAL ELECTRICITY CONSUMPTION DURING MASTER AND INDIVIDUAL METERING WITH A NOTE ON THE UTILITY OF DEGREE DAY WEATHER CONVERSION STATISTICS*

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ABSTRACT

Electricity consumption data of four, all-electric apartment complexes were evaluated before and after conversion from master to individual meters. The effects of meter conversion were evaluated by an analysis of covariance. Of three degree-day statistics assessed for their adequacy as covariates, the sum of the absolute values of heat days and cool days was found to be best for this analysis. Results indicate significantly less electricity was consumed in the individual meter condition than in the master meter condition for all four complexes. Additional analyses suggest electricity consumption is less affected by temperature fluctuations in the individual meter condition than in the master meter condition.

The emergent field of behavioral ecology concerns itself with the relationship between human behavior and environmental issues with current or potential impact on the quality of life on this planet [1, 2]. An area of much recent interest is energy conservation. Behavioral strategies have been employed to encourage the conservation of natural gas [2] and fuel oil [3], but most efforts have been in the area of electricity conservation. While patterns of electricity consumption have received some attention [4], most investigators have

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concentrated on reducing the absolute amount of electricity consumed, regardless of the pattern of consumption.

Among the strategies used to reduce electricity consumption have been self-monitoring [5], persuasive communications [6], information to consumers [2, 4-8], and written feedback concerning the amount of energy consumed [6, 7, 9-10]. Many of these conservation efforts, such as providing charts of average yearly energy costs for typical household appliances [7] or projected monthly billing at the present rate of consumption with [2, 8] and without [9] hints on conserving electricity, have been largely ineffective compared to strategies which provide more direct feedback and/or incentives to consumers [2, 4, 6, 7, 9-11].

Researchers investigating the effects of feedback on electricity consumption have reported energy savings of up to 35 percent [9], although savings in the 10-20% range appear to be more common [10, 12]. The energy savings which result from the provision of feedback can be further increased with the addition of incentives for energy conservation. For example, the addition of monetary incentives enhanced the effectiveness of conservation packages which also included information to the consumer [2, 6, 7], information and feedback [4, 6, 7], or feedback alone [6, 7].

These findings suggest that a system which incorporates both feedback and incentives would be an optimal approach to electricity conservation. The individual meter and monthly billing system employed by most local utilities is a naturally-occurring system of this sort that provides feedback concerning the number and cost of kilowatt hours (KwH) consumed. However, this system does not impact upon the approximately 3 million renting households whose monthly energy consumption is recorded on master meters and whose energy costs are fixed, unspecified, and incorporated within fixed rental payments [13]. These consumers receive no individual feedback regarding energy consumption and have no direct financial incentive for conservation. It has been reported that these households tend to use more energy of all kinds than do households which are individually metered and billed according to their energy consumption [13].

Estimates of reductions in electricity consumption which might result from conversion of master meter units to individual meters have been provided by McLelland [13], who reviewed thirty-four meter conversion studies. Using the following formula [13], McLelland reported electricity savings ranging from 2 percent to 63 percent, depending upon the electricity energy functions of the apartment complexes considered (e.g., heating, cooling, appliances used).

$$\text{Savings} = \frac{\text{individually metered energy use}}{\text{master metered energy use}} \times 100$$

McLelland's findings are difficult to interpret, however, because they are derived from comparisons between living units whose energy characteristics varied greatly (e.g., some units were all-electric but most were not; some units were air-conditioned but most were not). The goal of the present study was to further examine and clarify the energy savings achieved by converting from master (a no feedback, no incentive condition) to individual (a feedback, monetary incentive condition) metering while controlling for differences between complexes by comparing energy consumption before and after conversion within the same complexes. Because the study was conducted *post hoc*, it was also possible to examine large complexes of many units and to avoid confounding factors, such as the use of volunteers, found in many other conservation studies [4-11]. Finally the utility of greater degree day weather correction statistics (i.e., heat days, cool days, heat days plus cool days) was investigated to determine the best degree day correlate of electricity consumption.

METHOD

Background Information

Electricity consumption data were obtained for four apartment complexes in a large metropolitan area of the Southeast. Only complexes in which all units were air-conditioned and which used electricity for both heating and cooking were evaluated. The study was conducted in cooperation with the local utility which, as an administrative policy, maintains the consumption records of its consumers for the twelve months prior to meter conversions. Subsequent consumption records are maintained for a fifteen month period with the oldest month's data discarded as the current month's data is added to the file. Due to circumstances beyond the control of the investigators, more than fifteen months elapsed between conversion and data retrieval for three of the four complexes for which data were available.

Apartment Complex Characteristics

Apartment Complex *A* was comprised of 208, one and two bedroom units ranging in size from 764 to 1127 square feet. Rents at the time of data analysis (May, 1982) ranged from $299.00 to $369.00 dollars per month for this complex. Master meter data were obtained from September, 1975 through June, 1976 and individual meter data September, 1978 through June, 1979.

Apartment Complex *B* was comprised of 118, two and three bedroom units ranging in size from 1130 to 1920 square feet. Rents ranged from $395.00 to $530.00 per month. Master meter data were obtained for the period from July 1976 through June, 1977 and individual meter data from July, 1978 through June, 1979.

Apartment Complex *C* was comprised of fifty efficiency, one-bedroom and two-bedroom apartments ranging in size from 504 to 1012 square feet. Rents ranged from $225.00 to $475.00 per month. Master meter data were obtained from January, 1978 through September, 1978 and individual meter data from January, 1980 through September, 1980.

Apartment Complex *D* was comprised of 100, two- and three-bedroom units which ranged in size from 1161 to 1464 square feet. Rents ranged from $315.00 to $365.00 per month. Master meter data were obtained from March, 1979 through February, 1980 and individual data from March 1980 through February, 1981.

Procedure

Master meter data consisted of the monthly consumption for each apartment complex. Individual meter data for each complex were computed by summing monthly consumption across all individual units. Like-month data were then compared, in sequence, for each complex. The effect of converting from master metering to individual metering was determined using an analysis of covariance. This procedure provided statistical control for the effects of temperature before assessing the effects on consumption of converting from master metering to individual metering [14].

Three degree day weather statistics were computed and evaluated for their adequacy as covariates. These were heat degree days, cool degree days, and the sum of the absolute values of heat degree days plus cool degree days. In accord with common practice, each degree day value was computed by subtracting 65 from the average daily temperature. Positive values therefore represent cool degree days and negative values represent heat degree days.

Correlations between each of the three monthly degree day statistics and monthly electricity consumption were computed for each apartment complex. The degree day statistic which proved to be the best correlate of electricity consumption was then used in regression analyses of electricity consumption on degree days for each complex under each condition (master meter or individual meter) to explicate the relationship between degree days and electricity consumption.

RESULTS

Table 1 shows the results of the correlations between the three degree day statistics and electricity consumption under the master and individual meter conditions for each of the four apartment complexes. The degree day statistic consisting of the sum of heat days plus cool days consistently provided the highest Pearson product moment correlation between degree days and electricity consumption.

The relationship between the master and individual metering conditions and energy consumption is illustrated by the regression analyses presented in Figure 1. In each analysis, both the *Y* intercept and the slope of the regression line decrease under individual metering conditions. This result indicates that both absolute electricity consumption and the sensitivity of consumption to

Table 1. Pearson Product-Moment Correlations of Heat Days, Cool Days, and the Absolute Values of Heat Days plus Cool Days with Electricity Consumption Under the Master and Individual Meter Conditions for the Four Apartment Complexes Examined in this Study

	Heat Days		*Cool Days*		*Heat Days plus Cool Days*	
Apartment Complex	*Master Meter*	*Individual Meter*	*Master Meter*	*Individual Meter*	*Master Meter*	*Individual Meter*
A	.81**	.65*	-.33	-.26	.85***	.68*
B	.78***	.61*	-.24	-.07	.89***	.77**
C	.70*	.80**	-.19	-.29	.88***	.82**
D	.87***	.76**	-.43	-.19	.90***	.87***

Significance Levels:
$^{*}p < .05$
$^{**}p < .01$
$^{***}p < .001$

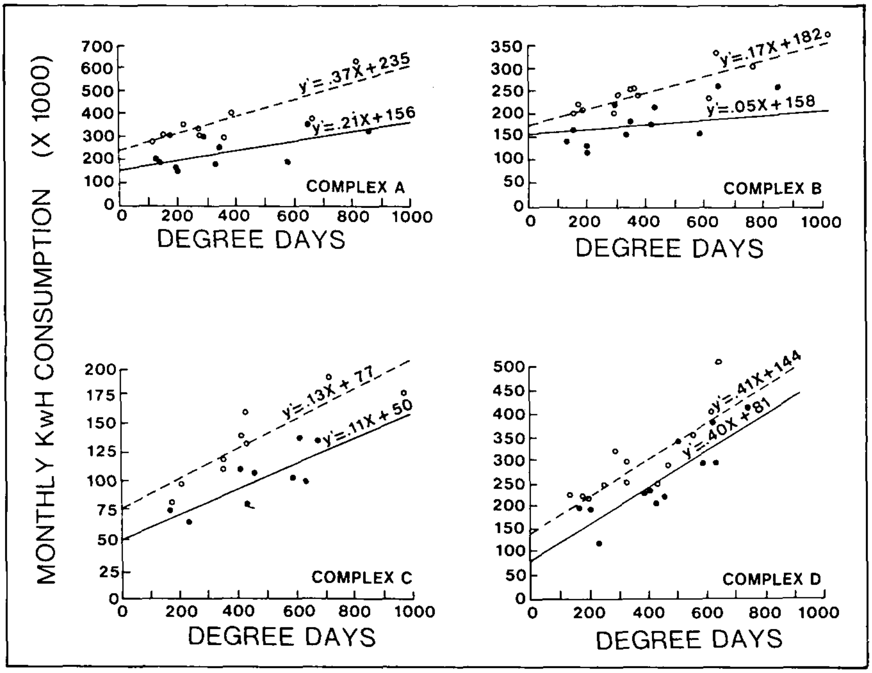

Figure 1. Regression analyses of electricity consumption in kilowatt-hours (KwH) as a function of degree days (absolute values of heat days plus cool days) before and after conversion from master metering to individual metering for the four apartment complexes examined in this study (Note: closed circles signify before conversion; open circles signify after conversion).

temperature fluctuations declines when consumers convert from master meters to individual meters. This finding is consistent across a wide range of temperature conditions. Master meter and individual meter degree days were not significantly different ($\alpha = .05$) for any of the four apartment complexes.

An analysis of covariance, with the heat day plus cool day statistic the covariate, was used to evaluate electricity consumption under master meter and individual meter conditions. This analysis yielded significantly lower electricity consumption under the individual meter conditions for all four apartment complexes: Complex *A*, $F(1,19) = 28.01$, p .001; Complex *B*, $F(1,23) = 46.23$, p .001, Complex *C*, $F(1,17) = 29.57$, p .001; Complex *D*, $F(1,23) = 34.72$, p .001. Using McLelland's formula [13], monthly relative KwH savings ranged from 2 percent to 50 percent with a mean monthly saving of 25 percent. These figures translate into mean monthly KwH savings, per unit, of approximately 620 KwH in Complex *A*, 630 KwH in Complex *B*, 660 KwH in Complex *C*, and 380 KwH in Complex *D*.

DISCUSSION

The consistently significant differences in energy consumption between master meter and individual meter conditions indicate that energy consumption decreases when consumers are switched from an indirect energy billing system (i.e., where utilities are included in the rent) to a direct energy billing system (i.e., standard monthly billing). This appears to be true immediately after conversion, as in Complex *D*, and continues to be the case as long as two years post-conversion, as in Complex *C*. This finding, across a variety of apartment complexes and calendar periods, suggests that direct contingencies and monthly feedback may serve to decrease energy consumption without the necessity of more frequent feedback, direct educational efforts, or extra incentives not already wholly contained within the context of the monthly electric bill. It might be argued that the reduction in energy consumption following conversion from master to individual metering was due not to the introduction of feedback and incentives but instead was a result of publicity regarding energy conservation in general. This is unlikely, however, because available evidence indicates that residential, commercial and industrial electricity consumption has either remained stable or actually increased during the years of this study [16, 17]. This, in turn, suggests that educational efforts may be ineffective without the presence of other contingencies such as those found in the individual meter condition and is consistent with the results of earlier efforts to induce energy conservation through education [18, 19].

The data support the conclusion that the presence of a direct fee contingency and monthly consumption feedback within the context of standard individual metering procedures contributes to a decrease in energy consumption among individuals previously not exposed to such procedures. This finding, based upon less variable data than that to which McLelland had access [13], replicates and confirms his general finding. In addition, this finding is consistent with the work of previous investigators who have manipulated incentive and feedback variables [2, 4, 6, 7, 9-11]. The results are not confounded by the presence of volunteers [4, 11], the reactivity of formal self-monitoring procedures [5], special instructions [2, 4-8], persuasive communications [6], or the elaborate procedures which characterize much of the earlier work involving conservation as a function of feedback [6, 7, 9, 10]. In an era of generally declining energy resources, the results of the present study indicate that converting from master meter to individual billing procedures promotes energy conservation by inducing individuals to reduce electricity consumption.

In addition, the results of the correlational and regression analyses indicate energy consumption does not conform as closely to temperature fluctuations in the individual metering condition as is found in the master meter condition. Perhaps one effect of the individual billing contingency is to increase the discomfort tolerance of consumers thus making them less likely to respond to small changes in weather conditions with increased energy demand in the form of air conditioning or heat.

Finally, the summation of the absolute values of heat days and cool days yielded consistently higher correlations with energy consumption than any other degree day statistic. This finding suggests an increase in predictive accuracy may result when the degree day statistic reflects the effects of both heat (i.e., air conditioning) and cold (i.e., heat) on energy consumption. Further evaluation of the degree day statistic might result in additional clarification of the relationship between temperature and energy consumption.

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