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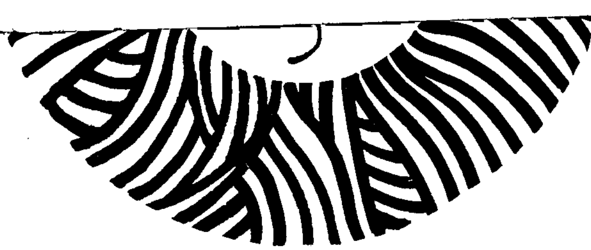

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ABSTRACT

Residential audit programs are successful only if they lead to a significant reduction in energy use. Therefore the first generation residential energy audit programs deserve careful evaluation. A small audit program is evaluated. Some of the factors complicating the analysis are discussed, including variations in weather, overlapping billing periods, poor selection of control groups and wide variation in individual energy use. No positive reduction in energy use was found.

INTRODUCTION

A residential energy conservation audit program is successful only if the audited homes use less energy. In addition, the energy savings must be large enough to justify the cost of the audit program. Thus, an analysis of an audit program's effectiveness must consist of two parts: first, the actual identification of energy savings and, second, the calculation of a return on investment, that is, energy saved per dollar invested in the audit program. In this paper, we focus on simply measuring the energy savings from a residential audit program using data from a small program completed last year.

The Energy Conservation Inspection Service (ECIS) originated from a need to compare computer estimates of conservation potentials with real houses. We used university students, trained in an experimental course, as the auditors. The auditors visited homes during the summer of 1977. In all, they inspected over 250 homes. (See Reference 1).

EXPERIMENT DESIGN

The audited homes can conserve energy in two ways:

(1) they can use less energy than in the past (after adjusting for weather differences)

(2) they can use less energy than a group of similar homes.

The first type, less energy used now relative to the past, may occur without an audit program. (Indeed, average residential gas consumption in California has been declining for several years.) This requires a second comparison with an unaudited control group; not only must the audited homes use less energy than last year but they must have used less than a group of similar, but unaudited homes.

To make this comparison, we followed the month-by-month energy use of four groups of homes:

(1) The Inspected (or audited) homes. When homeowners telephoned for an inspection, the even-numbered callers received an inspection.

(2) The Do-It-Yourself (DIY) homes. The odd-numbered callers requesting an inspection received instead a packet of conservation materials telling the resident how to conduct an audit alone.

(3) The Cohort (or neighbor) homes. The inspectors identified a home either next to or nearby to each inspected home similar in construction type and size.

(4) The Berkeley Average. The local utility company maintains statistics on the average electricity and gas use per residential meter in Berkeley.

The Inspected and DIY homes came from the same pool of applicants, that is, they <u>thought</u> they would receive an inspection. We expected the two groups to have essentially identical historical energy consumption patterns. Thus, we could compare the effectiveness of the labor-intensive energy audit to the relatively cheap Do-It-Yourself packet. Since ECIS performed audits only upon request we anticipated a self selection problem. Were those people who requested an audit significantly different than their neighbors? We constructed the Cohort group of homes to answer this question, as well as to indicate to what extent energy conservation occurred without any assistance. We included the Berkeley average because, even though it contains many apartments, it might reflect community trends in energy use.

The Audits

After a resident asked for an audit and returned a liability and utility release form, ECIS obtained the house's energy bill history from Pacific Gas and Electric (PG&E). Before visiting the house, the inspector plotted the last year's energy use, along with the Berkeley average for comparison. (In fact, this was a poor comparison because the Berkeley average contained many apartments and we inspected houses almost exclusively. Most houses' energy use lay above the average. Still, we found residents listened more closely to our suggestions after seeing that they used more energy than average.) Even before visiting, the inspector had a good sense of the house's energy use pattern.

The audit itself lasted anywhere from one to two hours. At the beginning, the inspector showed the residents the energy use graph. Together they would try to explain why it was so high or low. A walk-through inspection followed this discussion. The inspector made suggestions as the walk-through progressed. The inspectors brought samples or illustrations of many conservation measures. At the end, the inspector reiterated the most important recommendations. Later, back in the office, the inspector prepared and mailed to the resident a "conservation prescription" listing the measures, their cost, estimated savings and where to get the necessary materials or expertise.

THE TELEPHONE FOLLOW-UP

About nine months after the audits, we telephoned as many of the Inspected homes as possible - 192 homes - and 75 DIY homes to determine how many conservation measures had been done. In addition, we sought their impressions of the audit and any suggestions for improvement.

The follow-up indicated that the audited homes did not do substantially more conservation measures than the DIY homes. For only a few measures was there a statistically significant difference. Since each conservation measure had a low frequency of occurrence and we only sampled each group, the confidence in the difference between the two groups was often low. In other words, an absolute change of one in either group led to a large relative change between the two groups. Ideally, we should have also surveyed the Cohort homes to learn how many and which conservation measures they did. Unfortunately we lacked the staff and funds to make these inquiries.

Based on the response to the follow-up, should we expect to see any decrease in energy use? These calculations would show both how carefully and where to look in the energy use data for possible conservation. For example, about 8% of the Inspected homes installed a water heater insulation blanket, 22% set back their water heater thermostat, and 8% turned off their stove pilot lights. We estimate the respective natural gas savings from these measures are 3 therms/month, 2 therms/month, and 1.5 therms/month. These three measures would lower the average for <u>all</u> the Inspected homes [(.08 x 3) + (.22 x 2) + (.08 x 1.5) =] 0.8 therms/month. Such a change would be undetectable during the winter (about 0.5% of typical values), though possibly detectable during the summer (about 2% of typical values). Furthermore, in the summer, 9% of the residents turned off their furnace pilot lights for an additional (.09 x 7 =) 0.63 therms/month, for a total of 1.43 therms, or about 3% of typical summer values.

Similar calculations for heating and electricity savings can be done. In most cases the results of conservation measures will not be obvious until saturations are quite large.

RESULTS

We assembled energy use data for each group for a year prior and a year following the inspection. In theory, the analysis combined eight data sets (because the utilities only keep 13 months of utility records on the computer). In practice, however, collection problems in the Cohort sample led to nine data sets. We had considerable difficulty in combining the data sets since each came to us in a different format, and in some cases differing formats within the set.

There remain several sources of systematic and random error. Since billing periods are staggered through the city, a "January" bill may include a significant portion of December or February. We used the meter-reading date as the month indicator. For example, if the meter was read on January 15, then we assigned that month's consumption to January, even though it included half of December. Some bill histories were incomplete, owing to the occupants either moving in or leaving during the two year period. The start-up and shut-off months resulted in the reporting of a fraction of a month's energy use. As much as possible, we manually culled out the obvious fractional-use months. We found both systematic and typographical errors in the utility data. There are few estimated readings because most meters have been moved outside the houses.

Figure 1 shows the gas use for all four groups. The Berkeley Average consumption lies so much below the other three groups due to the large number of individually metered apartment units within this group. The audited houses are also larger than the average Berkeley house. We present it as one indication of the community trends in energy use. Virtually all Berkeley homes have gas heating. This accounts for the great seasonal variation in gas use, both in the Berkeley Average and the three other groups. Table 1 contains additional data for all four groups.

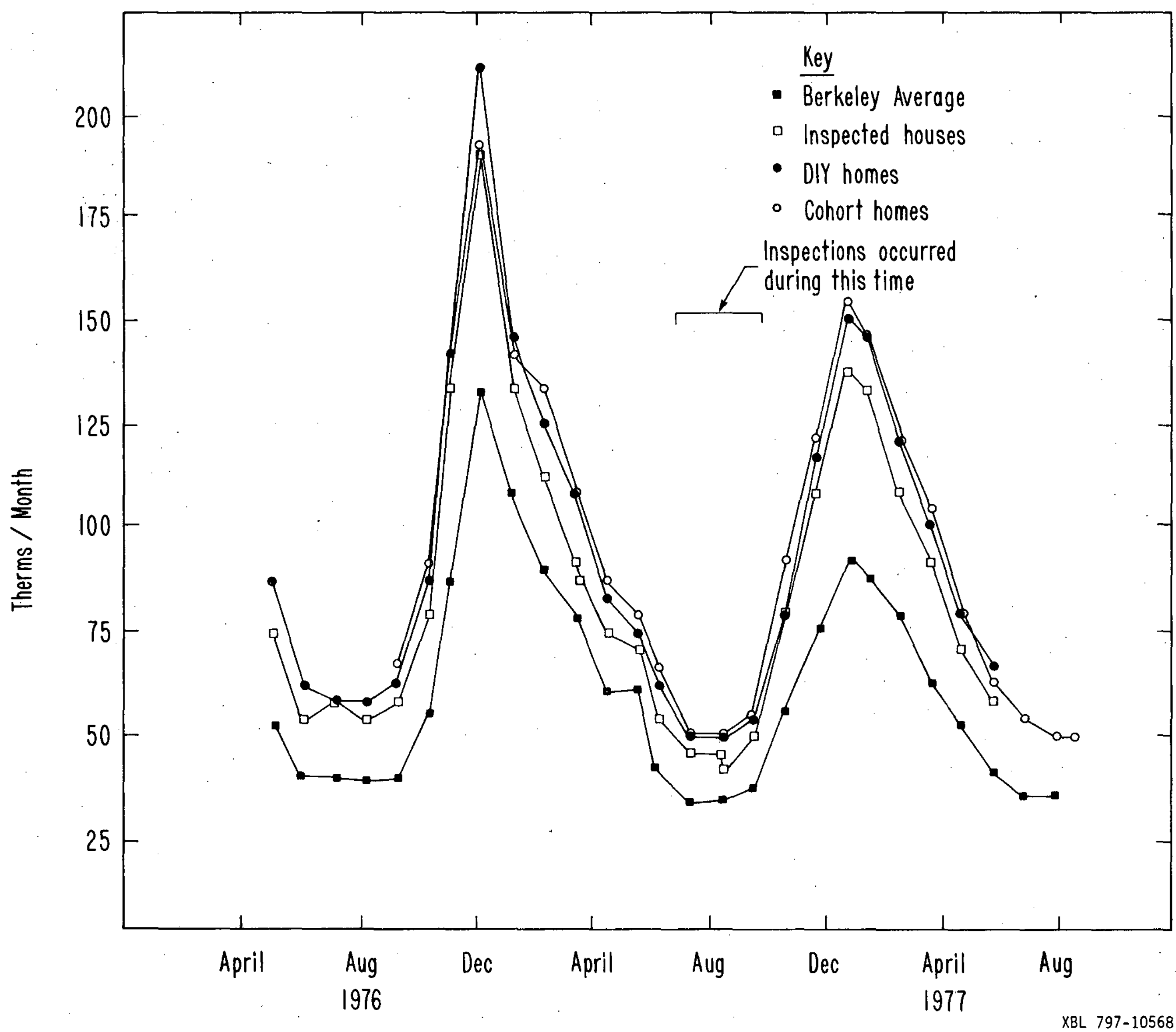

Figure 1.Natural gas use of the four groups over the two year period.

<u>Table 1 Summary of Energy Use Data</u>

	Inspected Year		DIY Year		Cohort Year		Berkeley Avg. Year	
	1	2	1	2	1	2	1	2
number in sample	233	168	250	204	202	189	37000	37000
avg. gas use (therms/yr)	1069	940	1196	1053	1178	1052	796	661
peak gas use (therms) (a)	189	137	212	149	191	153	129	91
baseline gas use(therms/mo)(b)	53	42	57	45		47	36	33
heating energy (therms) (c)	499	370	584	441	614	488	382	247
winter degree-days (d)	1593	1156	1593	1156	1593	1156	1593	1156
heating energy/degree-day (e)	0.31	0.32	0.37	0.38	0.39	0.42	0.24	0.21

(a) January use

(b) August use

(c) line 2 - 12x avg of line 4

(d) base 65 ^{o}F

(e) therms/degree-day

The natural gas use of the three other groups - the Inspected, DIY, and Cohort - all track very closely together. Recall that the DIY and Inspected homes consisted of people who requested audits. The even-numbered callers received audits and the odd-numbered callers received a DIY packet. A few homes assigned to the "to-be-audited" group were, for various reasons, never inspected; hence the DIY sample is 7% larger. Presumably these two groups should have an almost identical average energy use. Figure 1 shows that the DIY homes had a consistently higher gas consumption in the pre-inspection year. During the January peak, for example, the average DIY gas use exceeds the Inspected use by 23 therms. Since the standard error for the DIY and Inspected averages are 5.2 and 6.7 therms respectively, the difference is certainly significant. Careful scrutiny of the individual census tracts revealed that the census tracts where the average DIY consumption exceeds the Inspected homes are also those tracts where there are more DIY homes than Inspected homes.

For example, in Tract F the DIY average exceeds the Inspected average, 270 therms to 194 therms. At the same time, there are 27 DIY homes in the F tract but only 19 Inspected. The overall average is being excessively weighted by the census tracts where the DIY homes use significantly more gas than the Inspected homes. This accounts for a major part of the difference. We considered culling out the big DIY users in those high-use tracts to even out the two groups (with respect to both absolute numbers of homes in the samples and average energy use) but in the end, decided against it. Such measures are of dubious statistical validity.

The Cohort sample consists of the homes next to or near the Inspected homes that were similar in size and construction to the Inspected homes. In the year prior to the inspection, the Cohort homes used roughly 10% more gas as the Inspected homes. For typical winter months the standard errors in monthly gas use ranged around 4 therms. The monthly Cohort average exceeded the Inspected average by 0 - 24 therms, so the difference is statistically significant. Even during the summer of 1977 - the one summer we have overlapping data - the difference remains significant. This suggests that the residents who requested audits were slightly more energy- conserving than their neighbors who did not request an audit.

The relative positions of the three groups did not appreciably change after the inspection. Gas use dropped 12 - 17%. The milder winter (27% fewer degree-days) probably accounts for most of the change. Not surprisingly, the Berkeley Average, which includes many apartments where residents pay only for heating and cooking energy, is the most sensitive to weather changes. Following the inspection period, there appears to be a small change in the relative positions of the Cohort and DIY groups. At the January peak, for example, the Cohort average surpasses the DIY average by 4 therms. Standard errors range from 5 - 6 therms. One explanation is that the gas use patterns of the Cohort group remained constant while both the DIY and Inspected averages shifted downwards. This hypothesis is statistically unjustifiable; even though the changes in peak (January) gas use are quite clear, both groups cut their total heating consumption by the same proportion.

The unusually mild second winter forced us to construct a weather-adjusted indicator of heating use to compare the two heating seasons. This is in units of therms/degree-day and is presented in Table 1. We subtracted 12 months of average base demand - water heating, cooking, laundry, etc. - from the total gas consumed. (The base demand was taken as the average August use.) We assumed that the remainder was heating energy and possibly additional water heating, cooking, etc. which should be included as "free heat." Division by the number of heating season degree-days for the given year yields the measure, heating energy per degree-day. This is an admittedly crude measure of heating energy use, yet it shows the differences among the groups.

A successful insulation and weatherstripping program will lead to a drop in the ratio. (See Reference 2.) Precisely the opposite occured in the Inspected, DIY, and the Cohort groups. The increases were, however, quite small. On the other hand, the Berkeley Average ratio did decline. This may be an indication of heat conservation, but more likely a result of the sample's odd composition. The relative constancy, and possible increase, of the heating energy/degree- day ratio suggests that none of the three principle groups achieved any significant heating conservation compared to both their previous performance and comparable samples.

It appears that non-heating gas conservation did occur, although incomplete data preclude a statistical verification. August and September consumption for both the DIY and Inspected homes dropped 20 - 25%, that is, about 10 therms/month. Since the standard errors for the summer consumption levels range from 1.5 - 2.5 therms/month, the change is significant. There was no appreciable difference between the DIY and Inspected houses; the lower summer use of the Inspected homes continued through both years. The summer gas consumption for the Cohort homes remained virtually unchanged over the two summers. Unfortunately, the Cohort data do not cover the 1976 summer. For the summer where the samples do overlap (1977), the Cohort homes used roughly 12% more than the Inspected homes and 4% more than the DIY homes. The Cohort homes used the same amount the following summer. This suggests that little or no non-heating conservation occurred in the Cohort homes. Reference 3 discusses the results in greater detail.

CONCLUSIONS

These results are certainly disappointing! With the possible exception of a reduction in base gas demand, no significant energy conservation occurred. This conclusion holds for the comparison of a group with its own past energy use and with comparable groups over the same time. The audit made no detectable difference in energy use. In the one case where conservation may have occurred, in base gas demand, the DIY group cut their use by the same proportion as the Inspected homes.

The effects of an energy audit may appear years after the visit. The residents might not buy a stove with an electric pilot until the present one quits, insulate their attic until they replace the roof, install double windows until they renovate, and so on. Only an analysis spanning many years could catch these sorts of conservation measures. Still, it is reasonable to expect that the residents would attempt at least the simple measures during the first year while it is fresh in their minds. We can only conclude that even this did not occur.

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