Lawrence Berkeley Laboratory
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APPLIED SCIENCE DIVISION

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ENERGY USE AMONG THE LOW-INCOME ELDERLY: A CLOSER LOOK

R.C. Diamond

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Richard C. Diamond

Applied Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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ABSTRACT

An investigation of energy use in a public housing project for the elderly continues to turn up unexpected findings regarding the importance of occupant behavior in actual energy consumption. Detailed examination of eighteen months of utility bills for each unit in the project shows wide variation (on the order of 10-1) in both summer and winter. Because we found little correlation between individual energy use, construction quality, and reported thermostat settings, we examined additional behavioral and attitudinal data collected from interviews for clues to the large variations observed. Factors affecting the energy used by individual residents as well as by groups of high and low users are presented. Differences in the residents' health and comfort, the level of satisfaction with the heating/cooling system, the degree of understanding and control exercised, attitudes toward conserving, and income and status, all appear to be variables underlying the wide divergence in energy usage.

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INTRODUCTION

As part of our continuing study of energy use in public housing we have been studying how occupant behavior effects energy consumption. We initiated this study in 1982, specifically to find out how energy use is affected by actions taken during the design, construction, and occupancy of a building. (Diamond, 1983). The study site is a 60-unit public housing project for the elderly. The project, called Winston Gardens, is located in Oroville, California. The sixty units at Winston Gardens, which were completed and occupied in August 1982, are similar in size (58 m^2 or 625 ft^2), number of residents per unit (three couples, the rest all single), and type and number of appliances. Thirty five of the units have been continuously occupied by their original resident for eighteen months; these units constitute the main sample for most of the findings in this study. Each apartment has a gas water heater and a gas stove, a refrigerator, and an electric heat pump for heating and cooling. The residents are mostly single women (75%), between the ages of 55 and 85, whose individual monthly income is less than $300.

We selected this particular housing project for three reasons: its location (the area has an extended heating season and an extended cooling season), our previous collaboration with the project's architect, (who provided us with considerable information on its design and construction), and its resident population of low-income elderly (selected because they are particularly vulnerable to rising energy prices and because little is known about the energy and comfort needs of this group). Over the past year we have amassed considerable data, both factual and anecdotal, on weather conditions, structural building parameters, computer simulations, occupant behavior, and utility bills. Our initial examination of the monthly, individually metered utility bills showed a large variation in energy use among what we had assumed were identical apartments with similar residents. The variations in energy use among the residents, in summer as well as in winter, are on the order of 10-to-1. To account for these large variations, we examined two standard physical determinants of energy usage: climate and construction quality.

PHYSICAL DETERMINANTS OF ENERGY USE

Standard engineering models for determining energy consumption are based on two factors, a measure of the severity of the climate (given by the number of degree days), and a physical index for the thermal integrity of the building. Our earlier work (Lipschutz, 1983) presented evidence that the more severe the climate, the less variation in energy use among similar houses can be expected. Given that Oroville has a relatively mild climate--1,600 heating degree days ^{o}C (2800 ^{o}F) and 890 cooling degree days ^{o}C (1600 ^{o}F)--we would expect that there could be a large variation in individual energy consumption (which we observed) even though degree days were an accurate indicator of aggregate energy consumption (see Figure 1).

Figure 1 shows the correlation between the average monthly electricity consumption and heating degree days for the 35 continuously-occupied units at Winston Gardens. Electricity consumption figures recorded here include energy used for space heating (the electric heat pump) and baseload energy use (lighting and appliances). Because all units have identical appliances and are occupied by single residents whose lifestyles are similar, we assume that the baseload does not vary much from unit to unit.

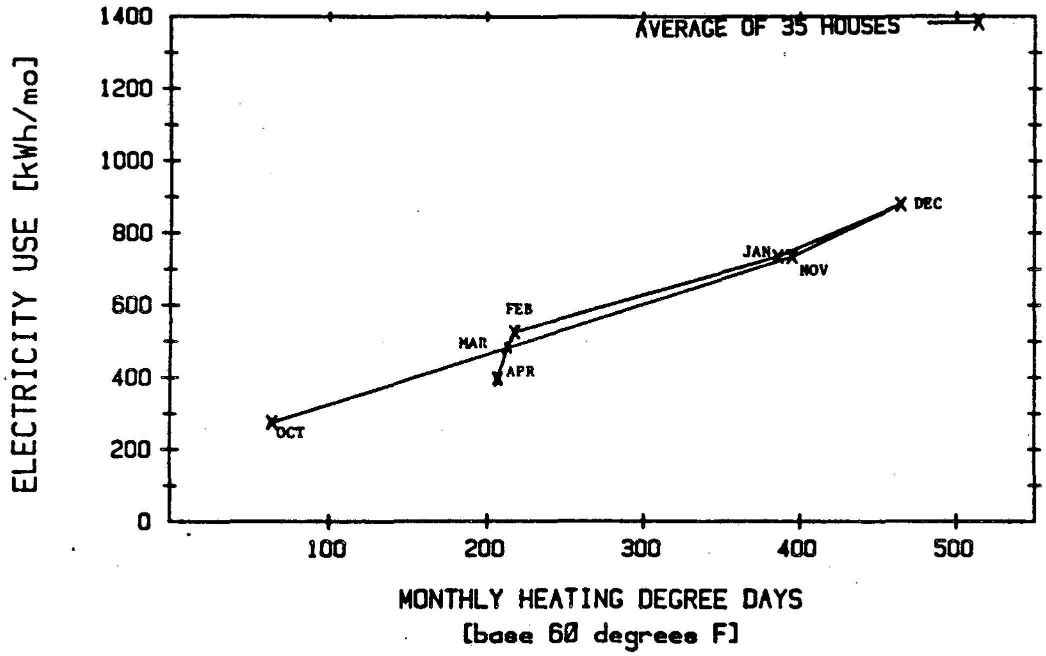

Figure 1. Heating season degree days (1982-83) and electricity use for 35 units at Winston Gardens, Oroville, California.

The second variable in the standard engineering model is the thermal integrity of the building shell, which is made up of two parts, the thermal characteristics of the building components, and the tightness of construction. Because all the units at Winston Gardens are built of similar materials, we chose to examine the tightness of the individual units to look for hidden variations in construction quality. All but three of the sixty units were pressurized and depressurized using a blower door to move air through the units. By measuring the air flows and pressures during the tests we could then calculate the total leakage area for each unit. Our hypothesis was that leakier units--having large leakage areas--would have greater energy consumption in both summer and winter, given that residents would have to run their heat pumps longer in order to heat and cool the rooms.

The distribution of leakage areas showed that the units, although quite leaky (mean = 566 cm^2), were uniformly leaky (standard deviation = 98 cm^2 or 17%), and thus could not account for the variation in electricity use during the heating season. Furthermore, the correlation between leakage areas and electricity consumption was near zero (see Figure 2).

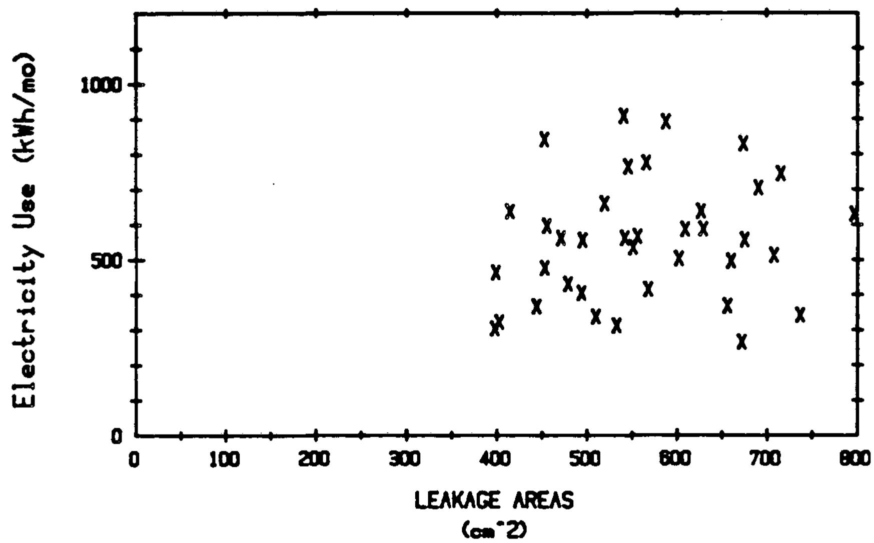

Figure 2. Leakage areas and average electricity use over the heating season (1982-83) for units at Winston Gardens.

BEHAVIORAL VARIABLES

Thermostat Settings

With the standard engineering indicators of building and climate parameters unable to explain the variation in energy consumption at Winston Gardens, we tested thermostat settings as a potential predictor for energy consumption. Occupant behavior regarding thermostat operation is rather complex (Kempton, 1983), and we had only limited data from our interviews on reported settings and usage patterns. (In addition to the survey data we had single readings of the summer air conditioning settings that were observed during the house air leakage tests.) Figures 3 and 4 show heating season (3) and cooling season (4) electricity use plotted against thermostat settings (occupant reported for winter, and observed for summer).
The low correlations between thermostat settings and energy used for space conditioning could be due to a number of factors: the unreliability of occupant-reported settings (either through ignorance or possible inclination of some occupants to give the impression of correct behavior), improper calibration or poor design of the thermostat, and/or the occupants poor understanding of thermostat operation, usage patterns in which the temperature setting is left unchanged but the thermostat is turned off for extended periods of time, and the use of supplementary heat sources, such as the kitchen stove. All of these situations were observed at Winston Gardens, and may well explain the poor correlation the data show between the thermostat settings and the electricity consumption.

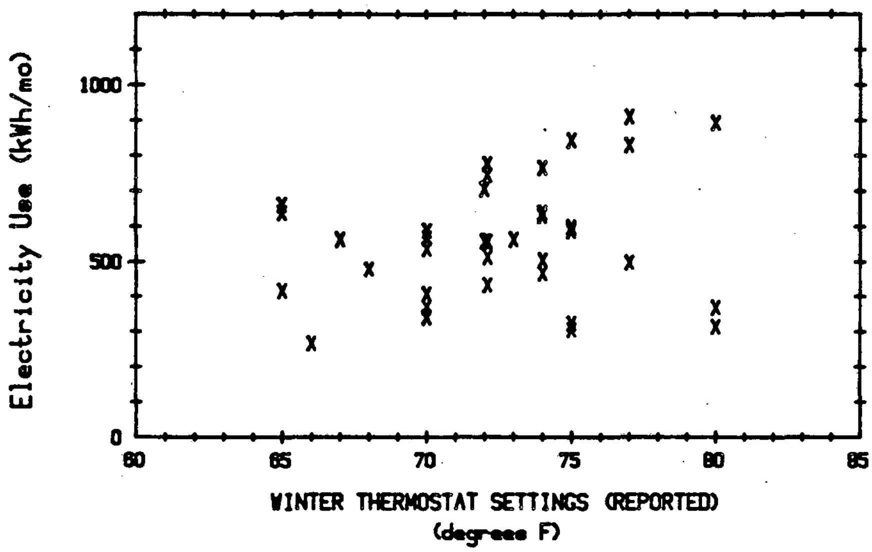

Figure 3. Winter thermostat settings (reported) and average electricity use, November 1982 -- April 1983, Winston Gardens.

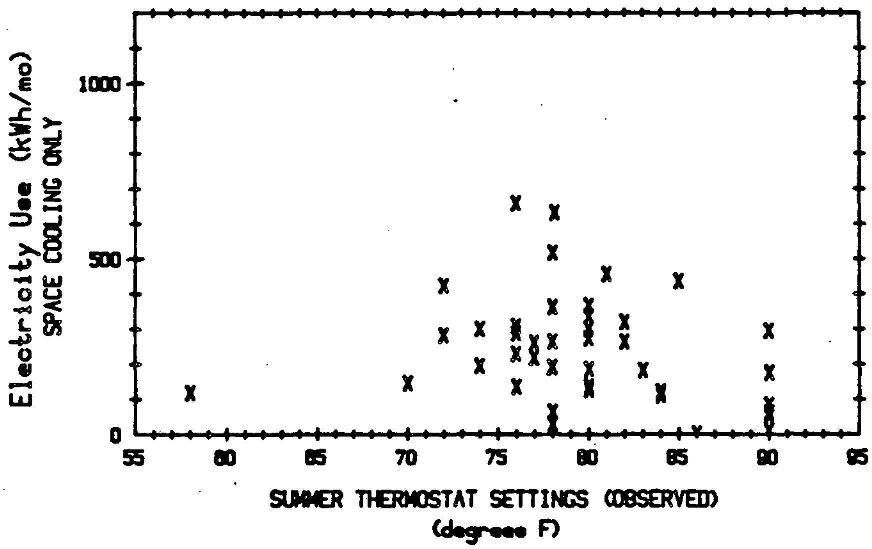

Figure 4. Summer thermostat settings (observed) and average space cooling electricity use, July 1983 -- September 1983, Winston Gardens.

A particular problem with the thermostats at Winston Gardens is that the heat pump can be easily overridden by the resident turning on the emergency back-up electric-resistance heaters. This behavior is a result of both accidental usage, where the resident incorrectly sets the thermostat, or through intentional design, by residents who prefer the heater strips to the heat pump because the air temperature is considerably higher, allowing the apartments to heat more quickly.

Patterns of Energy Use

Having eliminated construction quality and thermostat settings as explanatory variables, we looked more closely at patterns of individual energy use, taking the average usage for all the units and examining individual deviations from that average. Figure 5 shows the average monthly electricity use for the 35 continuously occupied units.

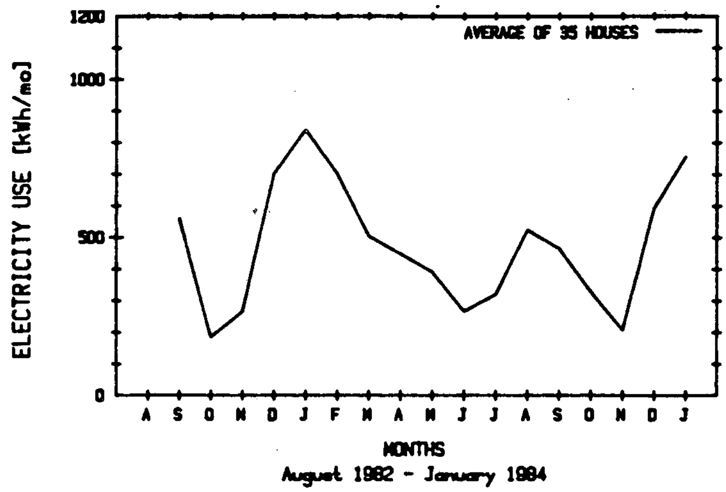

Figure 5. Average monthly electricity use at Winston Gardens.

The data shows two peaks, the first, between November and May represents the electricity used for space heating; the second, between June and October, represents energy used for space cooling. A baseload calculation of 220 kWh/month for the refrigerator, lights, and television corresponds to the lowest dips in the graph. When individuals units were plotted, (Figure 6), the large variation among the identical users appears dramatically.

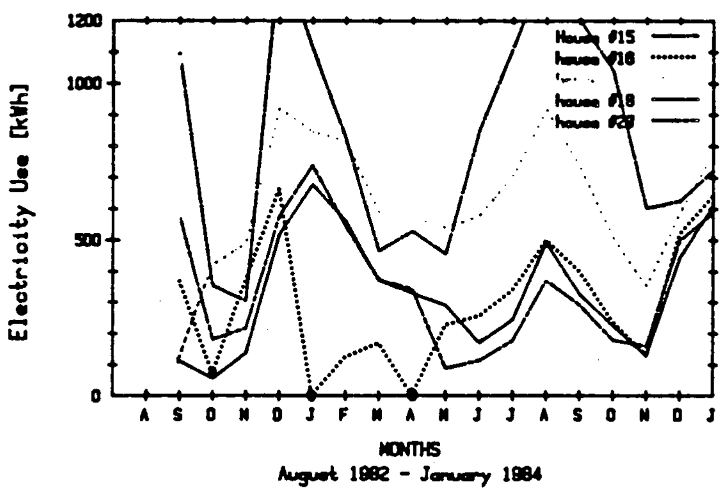

Figure 6. Individual monthly electricity use for five units at Winston Gardens.

Because the interview data showed little variation in the cooking and bathing practices among the residents, we expected a relatively constant yearly gas usage, and were consequently surprised by the seasonal variation in the average monthly gas consumption (see Figure 7).

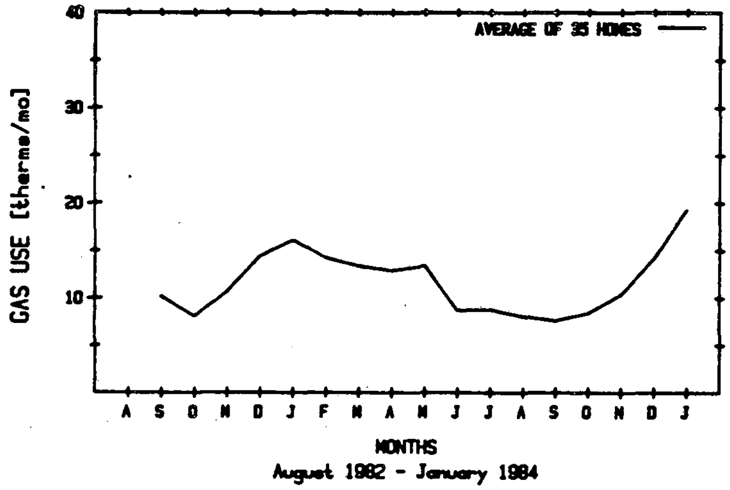

Figure 7. Average monthly gas use at Winston Gardens.

The baseload value calculated for bathing and cooking, 8 therms/month, corresponds well with actual usage over the five summer months. Unexpected, however, is the finding that gas usage increased 100% over summer usage for both winter periods. Possible explanations are: increased use of gas for cooking over the winter months; longer showers and baths in winter; colder incoming water at the water heater in wintertime, increasing gas consumption at the water heater; and the use of gas stoves for space heating. Plots of the individual units (Figure 8) support the last hypothesis, and interviews with the residents confirm it.

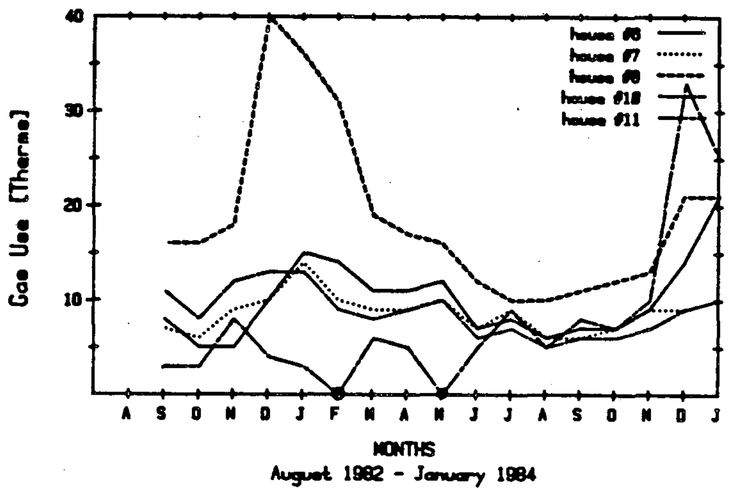

Figure 8. Individual monthly gas use for five units at Winston Gardens

Patterns of Individual Use: Case Studies

Following are case studies of four Winston Gardens residents based on interviews conducted with all residents in August 1983. The interviews were based on a one-hundred-item questionnaire that addressed several aspects of the residents' living patterns and housing. Accompanying each case study is a figure with eighteen months of electricity consumption plotted as ratios of their usage to the group average. The cases were selected to represent different categories: higher than average, lower than average, low winter/high summer, and a low user with gas stove used for additional heating.

Case 1 (Figure 9): An 87-year old widow who had moved to Winston Gardens from an apartment in another part of the county. She left because of the "poor ventilation in the room and the rowdyness of the neighbors".

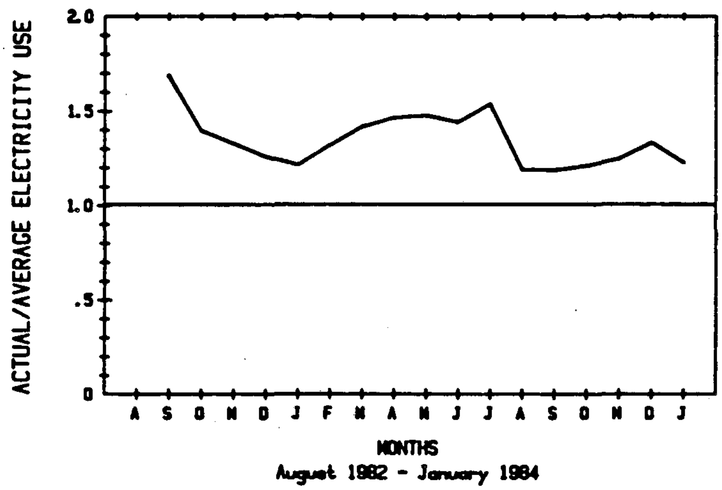

Figure 9. Case 1, actual/average electricity use.

She keeps the thermostat set at 23 °C (74 °F) all winter and never moves it ("I have to have it that warm"). She has carpeted over the hall and kitchen floor because the tile on the concrete slab floor was too cold. In summer she uses the air conditioner: "I can't open the windows, I'm too crippled". Unlike most other residents, she leaves the drapes open during the day in summer because she likes to look at her flowers. Her television is on every day from 5:00 a.m. to 12:00 p.m. Excluding the heat pump, the television is the single largest user of electricity (2.3 kWh/day), consuming more than the refrigerator (2.0 kWh/day). She attributes her high energy usage--36% higher than the average at Winston Gardens--to the air conditioner, which she claims to use more than the others, and to her toaster oven and microwave.

Case 2 (Figure 10): A 71-year-old, who had moved to Winston Gardens from her apartment in town when the rent was raised. Unlike Case 1, she uses 42% less energy than the group average.
In winter she keeps the house at 19 °C (66 °F) during the day, and shuts it off at night. "My friends say, 'My, aren't you freezing to death?', and I say, 'No, I'm comfortable." In summer she keeps drapes closed and windows open all

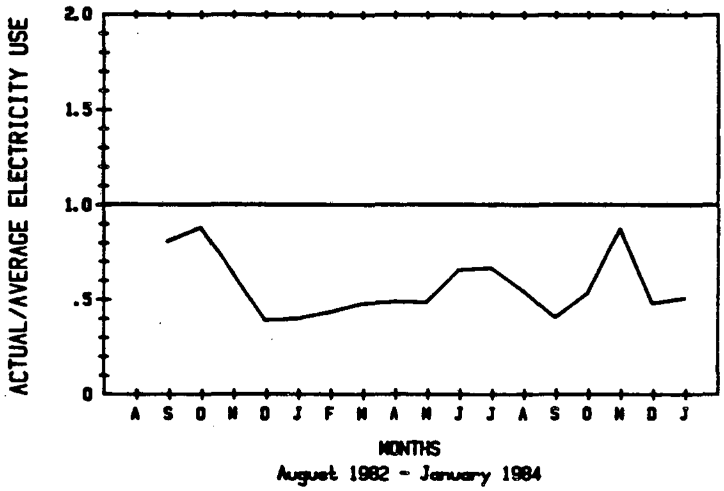

Figure 10. Case 2, actual/average electricity use.

the time, "I hardly ever use the air conditioner." She has also rigged up a blind on her west-facing porch to provide shade from the hot afternoon sun. The baseload usage (as indicated by the two peaks occurring in the fall) is (10% less than average.

Case 3 (Figure 11): A 74-year old woman, she is also a low consumer of electricity--17% less than the average.

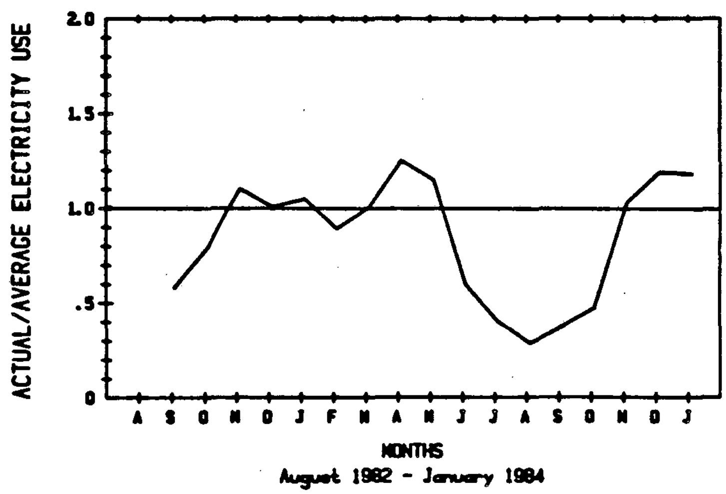

Figure 11. Case 3, actual/average electricity use.

Her winter usage is right on average, but her summer use is substantially lower than average, as she says, "I never use the air conditioner. I can't stand that thing blowing down on me." In summer she keeps the windows open as well as the drapes because "I like the view." While the electricity data here suggest a low energy user, the gas data tells a different story: her gas consumption in winter is three times the average for the group. Because she says she has no change in bathing or cooking practice throughout the year, we assume the gas use is the gas stove used for space heating. She admitted that although she does no baking, she dislikes the stove because "you can't light a burner when the oven is on."

Case 4 (Figure 12): A 72-year-old man who says he turns on the kitchen burners for warmth. The elevated gas use in the winter season is clearly seen in the figure.

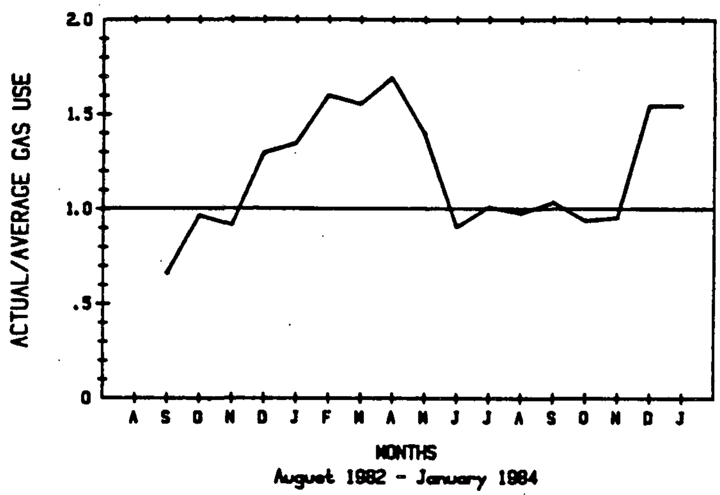

Figure 12. Case 4, actual/average gas use.

As he explains, the electric heating is too noisy and expensive. He adds: "I don't need as much [heat] as those women." In summer he uses four floor fans, opens windows, and closes the drapes, using the air conditioner only in the evenings. His electric use (not shown) is 45% less than the average.

Patterns of Individual Use: High Users vs Low Users

To look for overall behavioral patterns, we split the plots of the actual/average data into two groups: high users and low users. We then looked at characteristics of each group for explanatory indicators. The characteristics we identified are summarized in Table 1.
Both high and low users were fairly accurate in guessing their relative usage, even though there is little socializing among the residents, and as one woman put it, "We never talk about things like that".

Asked to give reasons for why their usage differed from those of their neighbors, high users cited health reasons, frequent use of the air conditioner, and not caring about conserving. Low users usually said they did not need as much air conditioning and that, generally, they were more conservative than the high users. The responses of these two groups to the questions, "What do you do when you are too hot?" and "What do you do when you are too cold?" are given in Table 2.

Table 1: Characteristics of low and high energy users at Winston Gardens.

	LOW USERS (n=22)	HIGH USERS (n=13)
male	31%	27%
female	69%	73%
Age		
mean	71.4 years	68.3 years
st. deviation	7.2 years	8.7 years
Perceived energy use compared to neighbors		
more	5%	46%
about the same	27%	15%
less	59%	0%
not sure	9%	39%
Use gas stove for heating	45%	25%

Table 2: Behavioral responses for heating and cooling for high and low users at Winston Gardens.

	LOW USERS (n=22)	HIGH USERS (n=13)
Heating		
use furnace	68%	69%
wear more clothes	45%	23%
use space heaters	5%	23%
Cooling		
use air conditioning	73%	69%
open windows	91%	31%
close drapes	50%	30%
use floor fans	32%	15%

Differences between the two groups are that low users say they are more likely to wear additional clothes in winter, and to open windows, close drapes, and use floor fans in summer rather than the air conditioning. Several women in the high-user group mentioned not being able to open the windows because of arthritis, as the reason for using the air conditioning. High users gave as reasons for not pulling drapes in summer: liking the natural light, preferring to be able to see out, and not knowing how to operate the blinds.

Explanatory variables

Based on the interviews with the residents of Winston Gardens, we have identified five categories of variables to explain the variation in energy consumption. The categories are: 1) The residents' health and comfort, 2) the level of satisfaction with the heating/cooling system, 3) the degree of understanding and control exercised, 4) attitudes toward conserving, and 5) income and status.

Health and comfort. Part of our initial impetus for studying this particular population was to find out something about the thermally-related health and comfort aspects of the elderly. Only four of the residents said they required heating or air conditioning for their health. Some residents who said they didn't mind the heat, or that they were never cold, would comment on their neighbors' wasteful behavior. The wide range of interior temperatures recorded during the summer interviews, 22 to 35 ^{o}C (72 to 95 ^{o}F), may be more indicative of relative income, however, than of temperature preference and comfort.

Fanger has shown in his studies of thermal comfort that there are no general differences in temperature preference for individuals based on age or sex, and that comfort for a given environment is determined by activity level and type of clothing (Fanger, 1970). According to residents at Winston Gardens, daily activities are chiefly reading, sewing, and watching television, all sedentary activities. Typically the women wear thin cotton dresses with either a light sweater or robe in winter. Under these conditions their temperature preferences in winter should be higher than the reported mean winter thermostat setting of 22 ^{o}C (71 ^{o}F). One way to increase thermal comfort is to use supplementary space heaters, and we believe that their high use of these heaters is linked to their dissatisfaction with their heat pumps.

Satisfaction/dissatisfaction with the heating/cooling system. Only 55% of the residents say they are satisfied with the heating system, and 63% with the cooling system. The problems cited are the noise, the drafty air, the cost, and the system's slowness in heating up. A British survey on the heating preferences of the elderly concluded that radiators and floor systems were the most preferred and ducted warm-air systems the least--too drafty and too noisy, and the controls were considered difficult to understand (Page and Muir, 1971). In addition to these factors is the particular characteristic of heat pumps that the warm air coming out of the registers, because it is only a few degrees warmer than room temperature, feels cool. As a local, radiant, familiar, easily controlled heat source, and one that is considerably cheaper to operate than the electric heat pump, the gas stoves' use for space heating is not surprising. We estimate 40% of the residents use their stove for some space heating. Because the use of these stoves for space heating represents a potential health and safety hazard, we have initiated a pilot retrofit project with the Housing Authority to modify the heat pumps and bring heat to the kitchen directly.

One unusual and disturbing finding at Winston Gardens has been the high number of residents (30%) who have moved away in the first year. Several reasons were given by the manager and neighbors for the cause of their leaving, chief among these being dissatisfaction with the heating and cooling system. Previous studies have shown that residents of public housing often singled out mechanical systems for blame, not only because of real deficiencies in their operation but also because they are easily identifiable objects to criticize and find fault with (Cranz, 1977). According to other studies, residents who feel stigmatized by living in public housing and whose general life satisfaction is low, will target mechanical systems rather than step out and criticize management or their own situation (Becker, 1977). Actually, at Winston Gardens, residents rate their life satisfaction as fairly high, and, with few exceptions, think well of the management. Because there are valid criticisms of the mechanical performance of the heating/cooling system at Winston Gardens, we haven't determined to what degree other confounding variables might explain the high user dissatisfaction. Contacting residents who have moved out may prove useful in this regard.

Understanding and control. One factor that emerged from the interviews was the degree to which the residents abandoned control over their situation. Several mentioned never touching the thermostat: "...my son-in-law sets it for me"; or "I get the manager to move it". In many cases, these same residents never moved or adjusted their mini-venetian blinds: "I don't know how to adjust them"; "I never touch anything I don't understand"; or "I just leave them the way they are, I like 'em just fine." One woman said, "There's nothing wrong with the thermostat, only the dummy who tries to use it."

Several of the residents expressed dissatisfaction with their showers, especially the hand held shower head and the inability to control the water flow. One woman had been taking baths simply because she didn't know how to work the shower, which only required a knob to be pulled up. In most of these cases, tenants were willing to do something--if only one knew what to do; afraid of doing the wrong thing, many simply lived with the problem.

Attitudes towards conserving. The elderly, much like the rest of the population, have mixed feelings about energy conservation. Often these sentiments differ with age and income (Minnesota Department of Energy and Economic Development). Younger seniors (ages 60-70) are more aware of conservation and more receptive to conservation messages. Like many of their younger counterparts, seniors with sufficient income to meet their living expenses often don't want to be bothered by conservation actions. One fairly well off respondent reported during the interview, "I don't mind PG&E telling me to save energy, they can do what they want. I just ignore them." The main concerns voiced by residents were: general uncertainty about technology, personal health, financial solvency, and the length of time they will be able to live independently.

Many residents believe they are doing everything they can to keep energy costs down, to the point where they are miserably cold in winter, and uncomfortably hot in summer. The goal of energy conservation work here should be to ensure that comfortable temperatures are maintained, not the amount of energy that can be saved. Residents pay their utility bills directly to the utility, with the Housing Authority providing a minimum utility allowance as a reduction in the rent. Another factor in the residents' attitudes towards conserving is the difference in the summer and winter allowances for the cheaper life-line rates. One reason residents think they use more energy for cooling than for heating is that they have a smaller quota for summer life-line usage, and consequently, end up paying more.

Income and Status. Income has been mentioned previously as a possible factor underlying differences in temperature preferences. Being able to heat and air condition the house for long periods of time has become a status indicator for many residents. Residents can hear the frequency and duration of their neighbors' heat-pump operation, and, as mentioned previously, commented on the high and low users during the interviews. Knowing that all residents must be below a certain income level to be eligible for Winston Gardens, we did not think that income would constitute an important variable in this research. However, residents are allowed to have up to sixteen thousand dollars in savings in addition to their income, and it is possible that differences in financial security are behind the behavioral variations we noted.

CONCLUSIONS

Our study of energy use among the low-income elderly at Winston Gardens continues to perplex and astonish. We have found that simple indicators such as reported thermostat settings and measured air leakage areas were not able to explain the variations in energy use observed in the utility bills. By examining the energy use of individual residents and of categories of high and low energy users, we identified characteristics of each group that help explain their different usage patterns. Differences in the residents' health and comfort, the level of satisfaction with the heating/cooling system, the degree of understanding and control exercised, attitudes toward conserving, and income and status, all appear to be variables underlying the wide divergence in energy usage. A next step will be to use these variables in developing a model that can characterize behavioral effects on energy consumption. Given our experience with the data from the residents at Winston Gardens, this will be no small task.

ACKNOWLEDGEMENTS

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