ENERGY BILLING, CULTURAL VARIATION AND RESIDENTIAL ENERGY CONSUMPTION

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ABSTRACT

In the fall of 1985 the Housing Office on the University of California's Davis converted its two Student-Family apartment complexes from master- to individual-billing of gas and electricity. These 476 units were metered prior to the conversion, however, enabling us to make pre- and post-conversion comparisons at the level of the individual apartment. We report electricity consumption findings as part of a three-year study of the behavioral components of energy use in these complexes. Considerable variation in energy use between demographic subpopulations was observed prior to the conversion. Expected declines in consumption following the billing change are examined, along with persistent post-conversion subgroup differences in electricity use at fairly low absolute levels. Consumption differences between the two Parks (with appropriate controls for structural and household differences) suggest a possible ecological or institutional "Park Effect". Differences between cultural subgroups, family types, and households differing in length of residence, are also presented. Connections are reported between this study and ongoing survey and ethnographic research intended to interpret the group differences observed.

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We report on the first results of our second study of residential utility metering and specifically, the conversion from master to individual metering of apartments in Davis, California. The residences are apartments in two "student family" complexes located on the University of California's Davis campus. The special character of the population may limit our ability to generalize the findings of the research. However, these complexes had additional features that made this research site especially attractive: most notably, the fact that individual unit kilowatt-hour meters were operating and available for study prior to the use of these meters for billing purposes. We could study, then, the effects of master metering on energy consumption and of the conversion to individual metering at the level of the individual unit.

The meters were read monthly starting early in 1983 --originally as part of a study to determine the likely consequences, for the tenants and for the campus Housing Office, of using the meters for billing purposes. We used official records to supplement these data with information on move-in and move-out dates and some demographic features of each resident family. We recently (early 1986) conducted a social survey of all of the 476 currently resident families (the response rate was 84%, providing a sample size of 402) to obtain detailed information on household demographics, energy-related behaviors, attitudes, and appliance stocks. Analysis of these survey results, together with more qualitative ethnographic data, will enable us to specify, in some detail, divergent subpopulation consumption patterns. An additional attraction of this site lies in the fact that these apartment communities are ethnically diverse, housing students (mostly graduate students) and their families from many countries, thereby making it possible to study the possible impact of "cultural" variation on energy use.

The timing of the conversion to individual unit billing (in August of 1985) places severe limits on what can be reported here, since before-after comparisons will require meter data from the the summer of 1986. In addition, while some pre- and post-conversion winter gas consumption figures can be analyzed, pre-conversion gas meter readings are available only for buildings, not apartments.

I

It is now well-established that the change from master to individual metering of utilities results in a considerable drop in energy consumption, although the magnitude of the change varies considerably (McClelland, 1982; Nelson, 1981; Rosenberg, 1984). Our first study of such a conversion, in an all-electric apartment complex in Davis, showed a 36% reduction (with weather effects controlled) in energy used in the year following the change compared to the year that preceded it. (Hackett, 1984). The results of the present study seem to support those findings. Figure 1 shows average daily kilowatt-hour consumption for six months before and six months after the conversion for three groups: Orchard Park units, and Solano Park units with, and those without, air conditioners. Orchard Park, is a 200 unit complex whose two-bedroom apartments (with identical floor plans) are "furnished" and equipped with gas stoves, space and water heaters, refrigerators and wall-mounted air conditioners. Solano Park's 276 units are "unfurnished", equipped with similar space heaters, refrigerators, electric stoves and solar hot water. Air conditioners may be installed by Solano Park residents and, in the summer of 1985, 220 had done so.

The character of the drop in consumption between July and August makes it plain that what the residents were doing here was simply turning off the air conditioner. The continuing (into the winter months) difference between Orchard and Solano probably reflects the fact that Solano Park's stoves are electric.The continuation into the non-cooling months of a difference between apartments with air conditioners and those without may indicate that those without air conditioners are less likely than those who possess them to be at home, but it might also indicate their comparative dedication to energy conservation, their low incomes, their frugality, etc.

The August decline in electricity consumption might have been substantial without the conversion. In fact the weather was ideal for a conversion, from the

Figure 1. Pre/Post Billing Conversion
Electricity Consumption: Solano & Orchard Parks
Davis, California (1985-86)

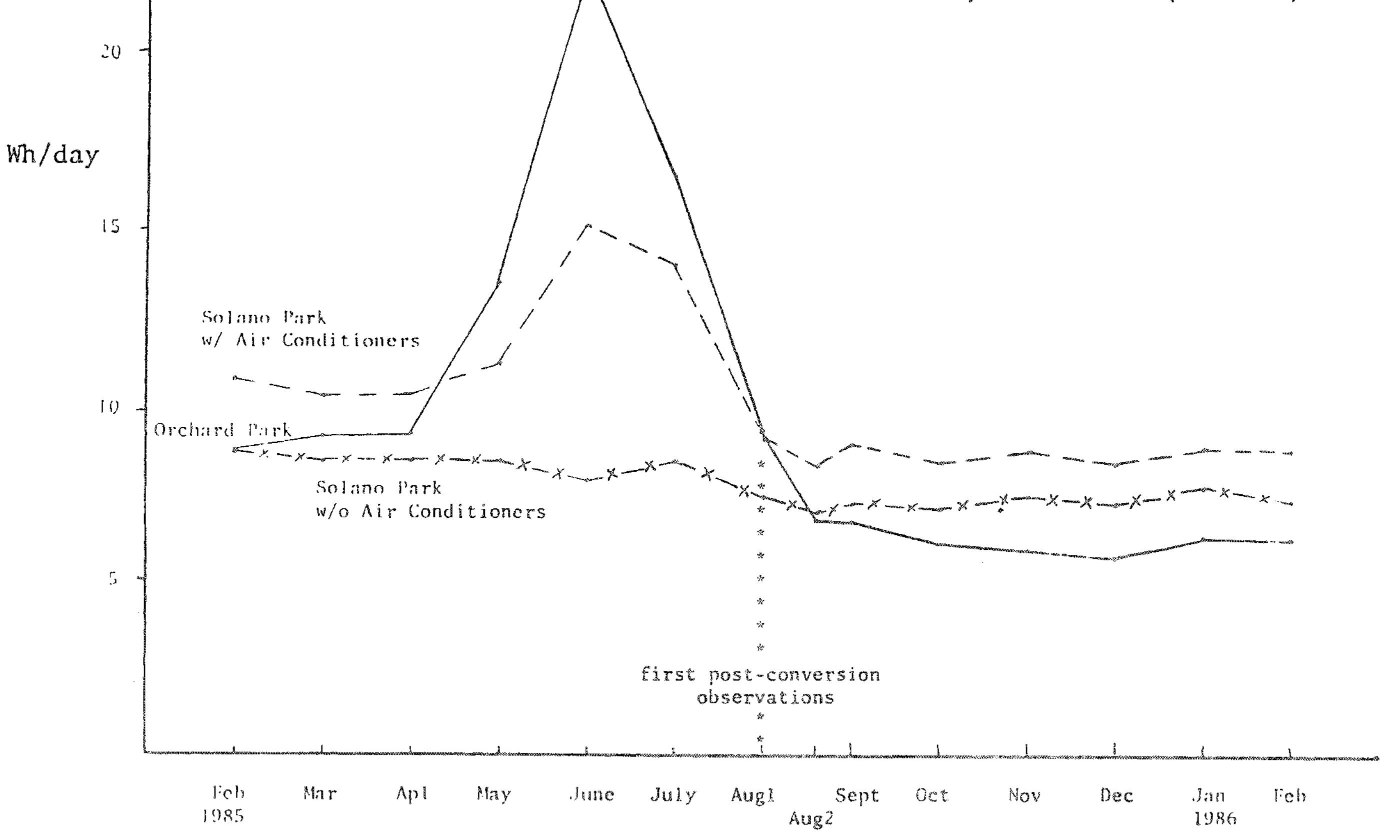
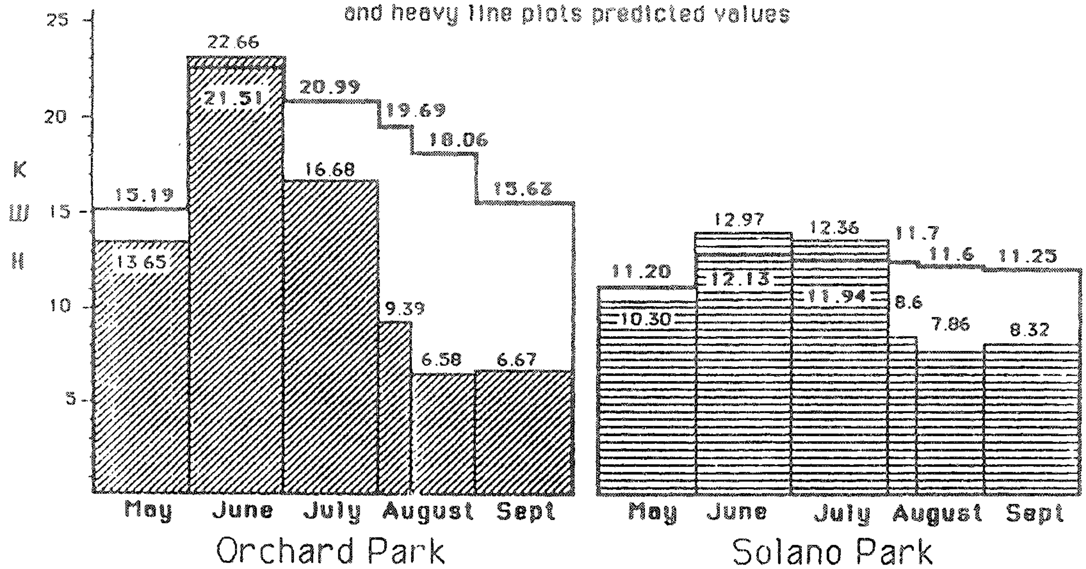


Figure 2. Predicted and Recorded Average Electricity Consumption: Summer 1985
KWH/day -- bars represent observed consumption and heavy line plots predicted values



perspective of an apartment complex owner fearful that conversion to individual billing during the hottest part of the summer might make the change a decidedly negative experience for many tenants. In August of 1985 air conditioning could be virtually foregone without a significant rise in indoor temperatures. However weather didn't account for the magnitude of the consumption drop observed. Using an equation which roughly approximates the Princeton Scorekeeping Method (PRISM) of temperature/demand modelling (Fels,1986), we regressed Orchard and Solano Park electricity consumption on recorded temperatures for the two summer cooling seasons (1983 and 1984) prior to the conversion year. Estimating a slope which expressed the relationship between average temperature and total electricity consumption for each Park for the previous two summers, we then calculated expected consumption levels for the 1985 cooling season (based on reported May through September temperatures), and report the contrast between the predicted and the observed values in Figure 2. This approach, while admittedly providing only the roughest grounds for estimating expected consumption levels, does have the advantage of making the best use of the only (nortoriously crude, at least for estimation purposes of the sort that concern us here) weather data available -- U.S. Weather Service daily hi/low recordings. This approach also makes more conservative assumptions about the relationship of measured median temperature to actual daily temperature distributions than does, for example, the expression of consumption in kWhrs per cooling degree-day.

A substantial consumption change unpredicted by the mild weather alone is indicated here. The decline observed in the July pre-conversion consumption suggests that conscious reductions in air conditioner use may be "in anticipation" of the conversion. Examination of the distributions of kWh use in June and July (in an effort to determine if this effect might be due to increased long-term vacations) revealed only a 3% increase in the lowest use category -- the level which is most likely to be correlated with long-term absence.

The differences in the profiles for the two Parks are in good measure a reflection of the fact that air conditioners are "optional equipment" in Solano, and that only in Solano are there one-bedroom apartments, but they may also reflect the demographic differences --to be noted below-- between the two settings. Orchard and Solano Parks do show quite different adjustments, but because air conditioner use is the major alteration being made they end in virtually the same place, Solano remaining slightly higher in energy use because of its electric stoves. It should also be noted, however, that the kWh consumption drop relative to the previous year continues on into the Fall and Winter months, when electricity is not used for space heating or cooling except, perhaps, for the use of portable heaters. The absolute size of this drop is small, of course, since electricity-use is minimal during this period in any case; but for just this reason --that the drop is small in terms of cost and large as a proportion of total electrical energy used-- suggests to us that it may well record the general adoption of new, and even perhaps somewhat severe, standards of conduct in the determination of situationally "appropriate" consumption levels.

II

We were especially interested in the impact of specific social variables on energy consumption and in the social dimensions of the behavioral response to the billing change. We assess the correlates of consumption using the demographic data gathered prior to the survey. In Table 1 we report bivariate relationships between electricity consumption and selected variables for June of 1985 --the final pre-conversion month. This table shows the percentages of each social category or type that fell into each of the bottom, middle and top thirds of the kWh consumption range.

We note a strong relationship between consumption and the sex of the "head of household" --meaning, in this case, the student who signed the lease. This variable is rather ambiguous, for it simply reflects, in many instances, the sex of the <u>student</u> adult whose status qualified the couple or family for the apartment. It also records, however, the fact that the parents in the relatively small, single-parent families (now a substantial category in these complexes) are almost always female.

The breakdown of consumption by "Family Type" indicates that couples without children have the lowest kWh consumption figures. The data also suggest the expected increase in consumption with larger family <u>size</u>; the size of the household, indirectly recorded by Family Type, is a good predictor of consumption, but there also may be a qualitative difference in consumption between childless couples or single-parent families, and "conventional" families. The length-of-residence ("tenure") variable also bears some relationship to family size, but it has

Table 1. Selected subgroup proportions in each of three equal electricity consumption ranges: June 1985

		Low	Medium	High	(N)
Total Population		.33	.33	.33	458
Sex of Head of Household:	Male	.31	.33	.36	373
	Female	.44	.37	.19	85
Family Type:	Couples	.40	.31	.29	205
	Single parent family	.50	.35	.15	34
	1 child family	.30	.35	.35	114
	2+ children	.20	.36	.44	103
Tenure:	< 1 yr	.40	.34	.26	149
	1-2 yrs	.32	.38	.30	151
	2-3 yrs	.31	.24	.44	70
	3 + yrs	.13	.34	.53	63
Continent of orgin:	North America	.40	.34	.26	199
	Latin America	.27	.16	.57	62
	Europe	.36	.07	.57	17
	Mid East & Africa	.18	.39	.43	57
	North Asia	.31	.46	.23	70
	South Asia	.17	.36	.47	29

Consumption range boundaries for the total population:

(kWh/day)			
2.2	11.6	18.6	53.0

its own consistent and sizeable bearing on consumption --higher consumption with longer tenure. Tenure may reflect an adjustment to higher consumption norms of a master-metered situation, an adjustment to air conditioning on the part of those unaccustomed to it, an increase in income, and/or an "accumulation" of energy-using appliances and activities.

One of the most interesting consumption-related variables may be the "cultural" background of the residents --recorded here as the tenant's "continent of origin." The variation within each of these categories is in some cases substantial, but the variation between them is also noteworthy, and additional refinement of the categories may yield a culture or ethnicity variable of some considerable value in the interpretation of energy use. These variations occur in spite of the fact that these complexes are in several other ways "culturally" homogeneous: these are all student households, they occupy a narrow band on the age spectrum, and the students are for the most part enrolled in scientific and technical programs of study, so that the variations shown here may likely be even more marked in less specialized populations. Figure 3 reports Multiple Classification Analysis (MCA) coefficients which present partial slopes (controlling for the effects of social and structural covariates) for cultural subgroups in kWhr/day units. The figure displays this variation in June of 1985 and its virtual collapse in the ensuing two months. and we indicate on the right-hand axis the previously-noted lower overall winter electricity consumption for 1986 as compared to 1985 values for the same subgroups. Figure 4 presents a more detailed MCA plot of cultural subgroup deviations from the overall population means during the June, 1985 to February, 1986 period. Appendix Table 1 provides the deviation coefficients and group means used to plot these profiles. We also note that, while the pre-conversion differences in groups' consumption levels "collapse" in the post-conversion period, interesting differences persist 6 months later.

In Table 2 we present two regression equations that clarify the contribution of these several variables to the estimation of monthly kWh use for June and October, 1985 --comparing pre- and post-conversion months. The data are generally consistent with and refine the bivariate relationships noted above. Female-headed households, on average, used less electricity in both months, controlling for family size (a factor which, expectedly, also had a strong effect). South Asian, Latin American and Mid-East/African families used somewhat more than North Asians

Figure 3. Multiple Classification Analysis (MCA) of cultural subgroup consumption profiles.

(controlling for wall surface, solar exposure, floor & length of residence)

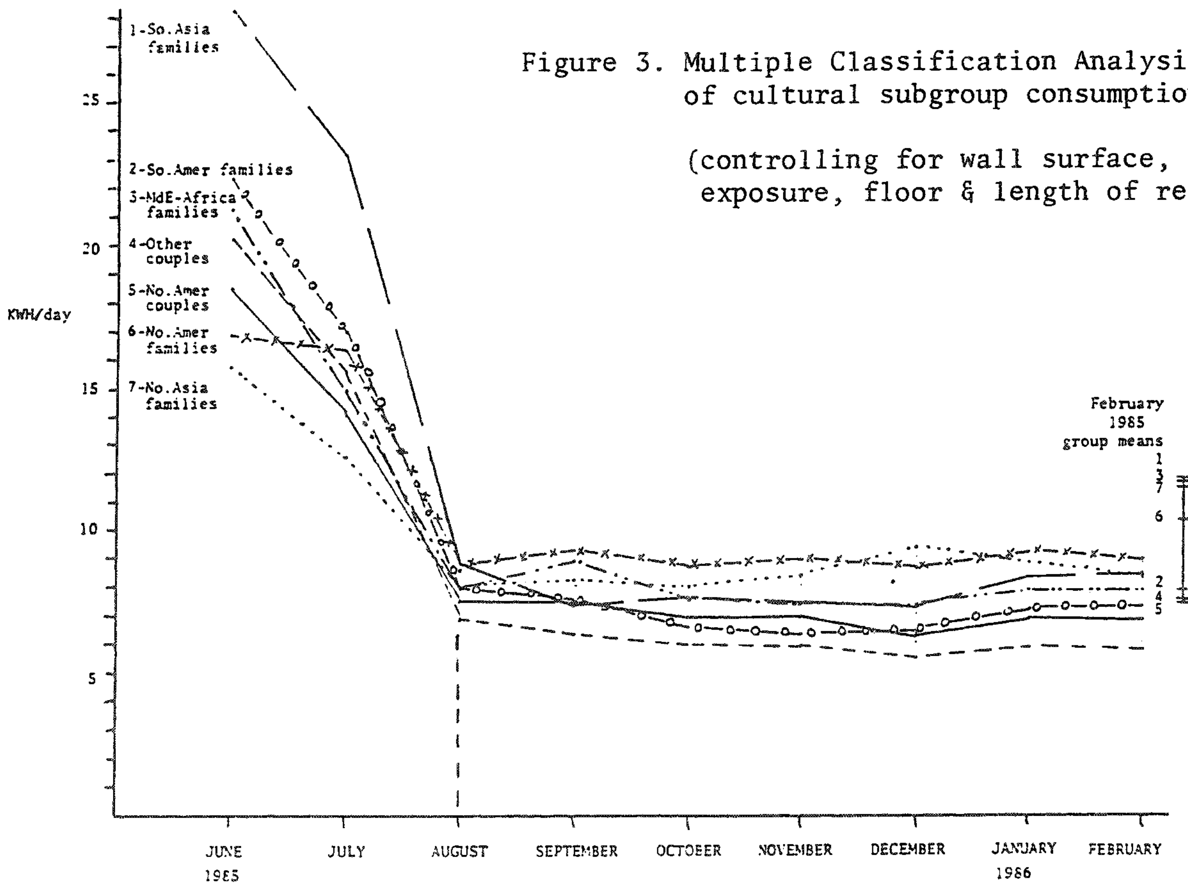


Figure 4. MCA coefficient deviations from monthly consumption means.

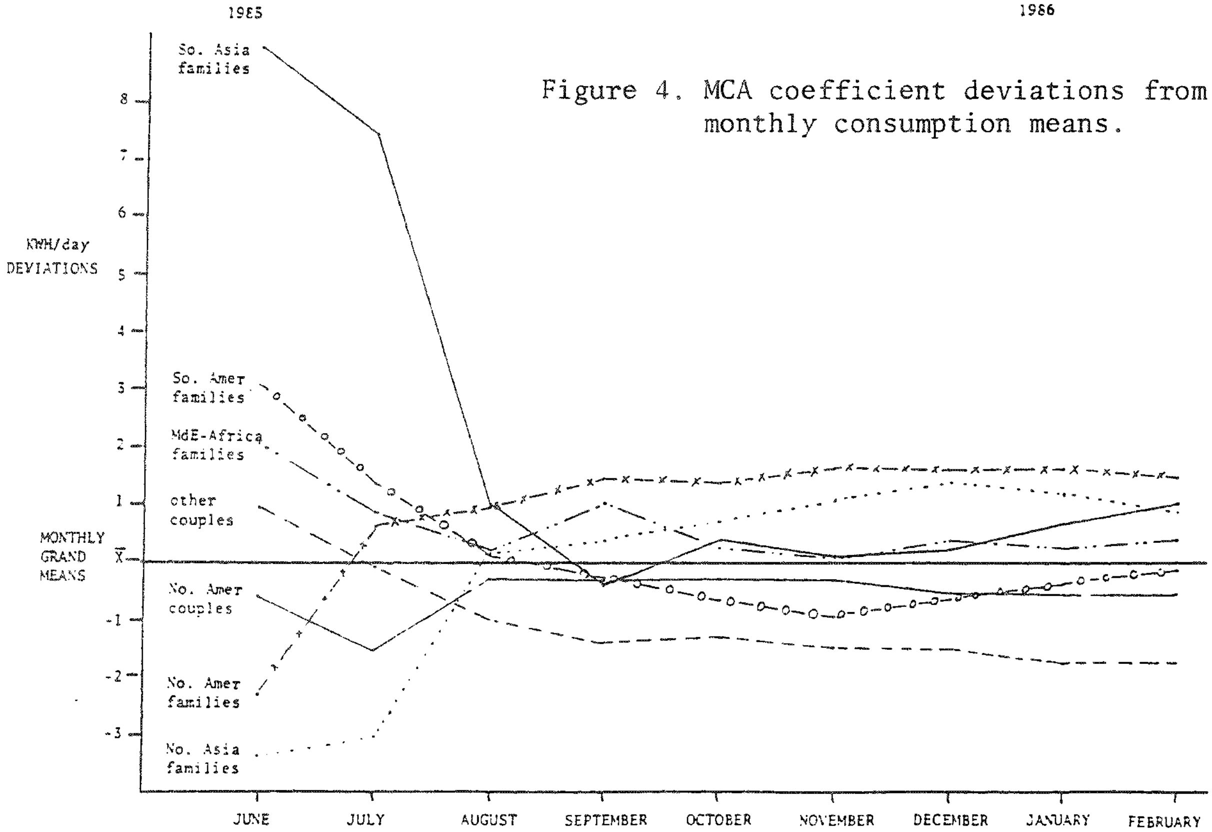


Table 2.
Regression Estimates of Subpopulation Effects on Electricity Consumption:

(KWH per Month - June and October 1985)

	JUNE		OCTOBER	
	slope	SE *	slope	SE *
intercept	276.70		229.90	
Tenure (months of residence)	**3.28**	.6	**.72**	.2
SMFam	**53.56**	24.5	**28.83**	7.6
LGFam (2+ children)	**107.60**	28.5	**54.36**	7.6
Female Head **	**-55.59**	30.7	**-12.89**	9.6
Latin Amer **	**64.81**	31.8	**-19.20**	9.3
MdE-Africa **	**71.52**	32.0	**- 8.40**	10.0
North Asia **	**- 3.29**	29.5	**-12.87**	9.1
South Asia **	**137.80**	42.6	**- 9.97**	12.8
Upstairs **	**86.26**	21.8	**-10.53**	6.8
No A-C **	**-155.58**	23.2	**-24.81**	9.2
Orchard Park **	**219.69**	23.2	**-61.39**	7.4
	R^2=.42		R^2=.32	

* standard errors (population data, no significance levels reported)

** gender, culture, location, A-C and Park variables are dummy coded dichotomies.

Reference Group: North American couple, male-head, ground floor apartment, Solano Park residence, with air conditioner and North Americans, however this difference is reversed after the conversion. Upstairs apartments had slightly higher consumption, but not as much as expected. The October A-C (air conditioning) coefficient suggests that the A-C variable is likely to be as much a proxy for frugality or voluntary simplicity ethics (and/or non-occupancy lifestyles), as it is a measure of the absence of the air conditioner as a load component.

Another particularly interesting suggestion in these data is that of a possible "Park effect." For these equations the residents of the two complexes were combined, and a dummy variable ("Orchard Park") created to examine the energy-consumption significance of residence in either of the two Parks per se. Most Orchard Park residents come from countries other than the U.S., their apartments are furnished, and all have two bedrooms. In contrast, Solano Park is unfurnished, most of its residents come from the U.S., and there are a number of one-bedroom units. We suspect that the demographic "character" of these complexes exerts its own influence on energy consumption --ecologically constraining so that it conforms with the standards of normality which have developed in each Park's social setting. Long-term observation at both Parks suggests, in fact, an ongoing effort to guage or assess the appropriateness of behavior (especially among newer residents) with reference to community standards. Learning "how to live" in present-day California is a not-inconsequential problem for persons arriving in Davis from throughout the U.S. and the rest of the world. Matters such as when and how much to open windows, how often to run air conditioners, how and when to cook outside are "solved" by families in part by observing the conduct of those already living in the complex. To some considerable extent energy-use is implicated in each person's or family's discovery and implementation of community standards, accounting for at least a portion of the "Park effect" observed here.

III

There are a number of other variables missing from these equations that may affect energy consumption, including such social variables as income, appliance stocks, and appliance-using routines that will be examined in the analysis of our social survey. While we control for some structural variables (e.g. number of outside walls, and upstairs vs. downstairs location), we are continuing our effort to specify the sources of variation in thermal performance within the complexes (including building orientation, air infiltration rates, and landscaping factors). We are also working on the somewhat perplexing problem of constructing an accurate "shade" variable. A separate engineering analysis of the expected energy consumption in these apartments using a modified version of the Department of Energy's (DOE 2.1a) building energy consumption model (CIRA,1982), suggests a substantial role for shading in this setting, but we are still in the process of developing adequate methods for measuring shade in the Parks.

During the next several months data on winter gas consumption and kWh-use during the first post-conversion (1986) summer will be collected. We will also undertake a second social survey, during the cooling season, with a sample of residents in order to confirm the results of the first survey and to provide additional information on the energy-using activities that constitute the various consumption "profiles" displayed by the meter data. The material obtained from the first survey includes a detailed appliance inventory and information on the use of particular appliances and the manner of their procurement. The analysis of these data, using factor-analytic and scaling techniques, should yield a reasonably accurate appliance index or typology useful for specifying and interpreting variations in consumption. We are also employing additional data-gathering techniques that can provide more detailed information about these end-use profiles, including diaries, ethnographic interviews, participant observation and instrumented end-use monitoring.

Additional work on the engineering model will also provide an opportunity for further comparative study of energy-use research methods themselves, especially helping to clarify the strengths and the limitations of our demographic and our more qualitative ethnographic procedures. Finally, we also draw attention to a message that seems to us apparent in the data examined thus far, namely the importance of gathering longitudinal or "panel" data on energy use, since a good deal of energy-use behavior may be "accumulated," may involve the procurement of appliances in a manner which indicates (indeed constructs) "upward social mobility" over the lifecourse , and may importantly involve the process of "adaptation" to a larger social settings or contexts.

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Appendix Table 1.

Cultural & Family Type Subpopulation Group Consumption Means
(with Multiple Classification Analysis Coefficients adjusted for covariates)
KWH/day -- June 1985 thru **February 1985**

	June'85	July	Aug	Sept	Oct	Nov	Dec	Jan'86	Feb	Feb'85
Grand Mean	19.11	15.58	7.80	7.81	7.27	7.32	7.02	7.57	7.46	9.60
NoAmer couples	**18.45**	**14.03**	**7.50**	**7.50**	**6.99**	**6.07**	**6.23**	**6.90**	**6.79**	**8.36**
	-.66	-1.55	-.30	-.31	-.28	-.23	-.79	-.67	-.67	-1.24
Other couples	**20.09**	**15.51**	**6.79**	**6.39**	**5.99**	**5.82**	**5.49**	**5.81**	**5.70**	**8.45**
	.98	-.07	-1.01	-1.42	-1.28	-1.47	-1.53	-1.76	-1.76	-1.15
NoAmer families	**16.76**	**16.25**	**8.76**	**9.28**	**8.66**	**8.91**	**8.59**	**9.17**	**8.93**	**10.31**
	-2.35	.67	.96	1.47	1.39	1.60	1.57	1.60	1.47	.71
SoAmer families	**22.21**	**16.92**	**7.90**	**7.52**	**6.56**	**6.39**	**6.30**	**7.13**	**7.28**	**8.84**
	3.10	1.34	.10	-.29	-.71	-1.03	-.72	-.44	-.18	-.76
ME-Afro families	**21.12**	**14.81**	**7.98**	**8.81**	**7.51**	**7.41**	**7.33**	**7.81**	**7.78**	**11.62**
	2.01	-.77	.18	1.00	.24	.30	.31	.24	.32	2.02
NoAsia families	**15.67**	**12.55**	**7.98**	**8.15**	**7.98**	**8.39**	**8.37**	**8.75**	**8.25**	**11.39**
	-3.44	-3.03	.18	.34	.71	.81	1.35	1.18	.81	1.79
SoAsia families	**28.03**	**23.06**	**8.60**	**7.46**	**7.59**	**7.43**	**7.23**	**8.25**	**8.46**	**11.57**
	8.92	7.48	.80	-.35	.32	-.14	.21	.68	1.00	1.97