ENERGY SAVINGS DUE TO MODEL CONSERVATION STANDARDS IN MULTIFAMILY BUILDINGS*

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ABSTRACT

In the past several years, the Bonneville Power Administration and utilities in the U.S. Pacific Northwest have invested significant amounts of money in retrofitting existing dwellings with energy conservation measures. In 1983, regionwide Model Conservation Standards (MCS) were developed to guide the construction of energy efficient dwellings in order to preclude the more expensive retrofitting process. This paper evaluates energy savings attributable to MCS in the multifamily sector.

The sample of buildings used in this study is located in Tacoma, Washington. Forty-seven buildings, with a total of 602 units, comprise the MCS or study sample. Thirty buildings, with a total of 158 units, built before 1984 under current practice energy and building codes, comprise the control sample. Billing histories were collected for each unit in all buildings for the period of January 1985 to December 1987. Data on unit size and spatial orientation were drawn from building plans and on-site inspections. Occupants of the buildings were surveyed about energy use, demographic characteristics, and characteristics about their apartment units (e.g., rent, location).

This paper presents the differences in electricity use between the MCS and non-MCS samples and estimates differences in multifamily household electricity use (with a focus on space heating) according to significant demographic and unit descriptors. It is estimated that between 0.8 kWh/Ft2/year and 1.8 kWh/Ft2/year of space heating electricity savings are attributable to the MCS for multifamily buildings.

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INTRODUCTION

The Bonneville Power Administration and utilities in the Pacific Northwest region of the United States have invested heavily in energy conservation, especially in the residential sector. Most programs have focused on retrofitting existing buildings. In 1983, the Northwest Power Planning Council developed Model Conservation Standards (MCS) to support building codes in the effort to save energy in newly constructed buildings.

This paper analyzes energy savings attributable to MCS in the multifamily building sector. The first section provides details about the MCS program. The second section describes the data base, which contains various unit, occupant, and building characteristics for 47 buildings built to the MCS code and 30 buildings built to 1983 current practice code; all are located within the city limits of Tacoma, Washington. The third section presents: (1) statistical descriptions of the buildings and the occupants; and (2) estimates of space heating electricity savings attributable to MCS.

BACKGROUND ON MCS

The Bonneville Power Administration has developed and implemented numerous programs designed to conserve residential energy in existing buildings. Together with the Northwest Power Planning Council (NPPC), Bonneville determined that costs for conserving energy could be decreased if <u>new</u> buildings were constructed to be more energy efficient. In part, this determination was reached based upon the operations and evaluations of several major residential retrofit programs, particularly the pilot, interim, and long-term Residential Weatherization Programs, all of which were sponsored by Bonneville.

In 1983, the NPPC developed Model Conservation Standards (aka, the Northwest Energy Code or NWEC [1]) to complement building codes in order to guide construction of energy efficient buildings. In the multifamily sector (three or more dwelling units in a single building) for weather zone 1, in which Tacoma, Washington is located, the NPPC estimated that units in buildings built to MCS would consume 1.2 kWh/Ft2/year of space heating electricity versus the estimated 3.4 kWh/Ft2/year consumed by units in buildings built to 1983 current practice [2].

The City of Tacoma, Washington, adopted the MCS code in 1984 to replace the 1980 Washington State Energy Code (WSEC), as amended in 1983, where the WSEC related to electrically heated buildings. Tacoma was then responsible for the enforcement of three codes: the existing building code; the WSEC as it related to buildings heated by fuel oil or natural gas; and the MCS for buildings heated by electricity. With respect to the multifamily sector, the major differences between the codes--as the differences existed in 1984--are listed in Table I. MCS requires more insulation and tighter units. The builders of multifamily complexes have the option of meeting a bottom-line component performance standard or following a prescriptive path as provided in the code. For example, builders could provide more insulation in the floors and ceilings than required while providing less in the walls. Builders were subsidized by Bonneville at $1 (one dollar) per square foot per unit and $360 for each air-to-air heat exchanger (AAHX) per unit for building to the MCS code. The AAHX does not save electricity; it contributes to the demand of electrical appliances.

DATA

The sample of MCS buildings contains all multifamily buildings, built to MCS, that are heated with electricity and that were available for occupancy in the City of Tacoma by September 1986. This allowed the collection of billing histories for each unit for one entire year, from September 1986 to September 1987. Investigation of building permit records and Tacoma City Light (TCL) utility records from June 1984 (the start of MCS enforcement in Tacoma) to September 1987 resulted in the identification of 47 buildings, which include 602 units.

Table I. Major differences between MCS and Washington State Energy Code, June 1984

	MCS*	WSEC*
Allowable Air Infiltration Rates		
Windows (cfm/lineal foot of operable sash crack)	0.3	0.5
Doors (cfm/square feet of door area)		
-swinging	0.2	1.00
-sliding glass	0.2	0.50
Thermal resistance (minimum allowable R-values)†		
Walls	8.50	4.00
Roof/ceiling	29.00	20.00
Floors		
-exposed	20.00	12.50
-enclosed	12.50	12.50
Slab-on-grade floors (@ perimeter)		
-unheated	5.00	4.25
-heated	10.00	6.25

*As applied to electric resistance space heating for R-1 building classification (i.e., multifamily) for weather zone 1 (less than 6,000 heating degree days, base 65°F).

†U-values are reported in the codes. The R-value is the inverse of the U-value.

The control group sample was identified in a similar fashion. Building permit records were examined for the period January 1983 to May 1984, when the amended WSEC code was in effect. This investigation resulted in the identification of 30 buildings, which include 158 units. Buildings approved for permits between 1980, when the WSEC was first implemented, and 1983 would have been constructed in accordance with energy and building codes that no longer applied to new construction. Thus, buildings approved for permits before 1983 were not included in the control group sample since the construction of them did not reflect current practice just prior to the adoption and implementation of MCS.

All units in both MCS and 1983 current practice buildings are individually metered. Each unit is primarily heated with electric baseboard equipment that is thermostatically controlled in the unit.

Table II shows the dwelling unit configurations for all MCS and 1983 current practice buildings. These configurations are discussed in the next section. For now it is important to recall that these buildings make up the base sample from which data are drawn for all analyses.

Billing histories were collected for all units in each building for the period January 1985 through December 1987. (However, when the data permitted, the billing histories not actually used in the following analyses were examined to determine the extent of apartment turnover and vacancy over time.) Only the TCL electric utility bills from October 1986 through September 1987 were retained to conduct energy savings analyses. Weather data for use in the billing history analysis were also collected for this time period. Building plans for all buildings were reviewed to collect data on building size, unit size, building orientation, and other building characteristics. From the billing histories, a sampling frame for an occupant survey was created. Occupant surveys were mailed to all members of the sampling frame in January 1988, with two follow-up mailings during the next two months. Table III shows the number of buildings and units in each sample, and shows the number of units with complete billing histories and surveys.

Table II. Dwelling unit configurations for buildings in the MCS and 1983 current practice samples.

Units in Building	Number of Buildings		Units in Building	Number of Buildings	
	MCS	Current Practice 1983		MCS	Current Practice 1983
3	2	0	12	11	1
4	12	20	14	2	0
6	1	3	18	7	0
8	2	6	24	10	0

Table III. MCS and 1983 current practice building samples.

	MCS	Current Practice 1983
Number of buildings	47	30
Total number of units	602	158
Occupants sent surveys*	521	155
Occupants responding to survey	279	101
Occupants with bills and survey	278	92

*Active utility accounts; i.e., 86.5% of MCS units were occupied when the survey sampling frame was developed in November 1987, and 98.1% of the 1983 current practice units were occupied.

RESULTS

Before presenting estimates of energy savings, it is important to recognize that MCS and 1983 current practice buildings and the occupants of them are different in ways that could affect space heating electricity use (Table IV). Most striking are the differences in the MCS and 1983 current practice building characteristics. The MCS *buildings* are much larger, but the *units* are much smaller. These differences are not attributed to MCS, but to changing local economic conditions [3]. Units were downsized between 1983 and 1984 to maintain rent levels; complexes were enlarged to supply revenue to support amenities such as pools and common rooms. On the other hand, the reduction in window area is directly attributable to MCS. In meeting bottom-line performance standards, builders determined that it would cost less to increase the energy performance of the floors and ceilings/roofs and to install less energy

Table IV. Major differences between MCS and 1983 current practice buildings and occupants.

Characteristics*	MCS	Current Practice 1983
Buildings (N=77 buildings, 760 units)		
No. units/building	12.9	5.3
Size of unit (Ft2)	763	980
Window area unit (Ft2)	84.6	159.4
Occupants (N=380)		
Age of respondent (years)	30.5	48.5
Income of household ($, 1987)	20,500	25,000
Believe that unit is optimally efficient (%)	28.0	45.3
Very informed about conservation (%)	19.4	30.9

*Data are mean values unless otherwise indicated.

efficient and fewer windows. There is insufficient evidence to conclude that these events will signal the onset of trends, or that they are the products of trends.

The occupant characteristics also differed between samples. The MCS occupants are younger and earned less income in 1987. That might be expected for occupants living in smaller units in larger complexes with more socially-oriented amenities. Interestingly, the occupants did differ in their beliefs about the energy efficiency of their apartments. In fact, a greater proportion of the 1983 current practice households responded that their units are as energy efficient as possible. Apparently, the MCS buildings were not advertised as being any more energy efficient than other apartment buildings in the Tacoma area. (Of course, energy efficiency is only one feature of new, MCS apartments.) Additionally, occupants of 1983 current practice buildings consider themselves more informed about energy conservation than do their MCS counterparts. These findings indicate that it is very unlikely a self-selection bias based on attitudes toward energy use would distort the energy savings analyses.

Energy savings were conducted at the unit level and at the building (or aggregate) level. Billing histories were weather-adjusted using the Princeton Scorekeeping Method (PRISM). (See Fels, 1986, for a detailed discussion of PRISM [4].)

The basic assumption of PRISM is that residential energy consumption and outdoor temperature are linearly related. PRISM uses average daily consumption and average daily outdoor temperatures to fit the following linear model:

$$F = a + bH(t) + e, \tag{1}$$

<u>where</u>

- F = average daily consumption,
- H = the heating degree-days computed to reference temperature t,
- a = the fixed amount of daily consumption (base load),
- b = the proportional constant amount of consumption (heating slope) relative to H,
- e = the random error term.

Normalized annual consumption (NAC) is calculated as follows:

$$NAC = 365a + bH(t), \tag{2}$$

<u>where</u>

- 365a = the fixed amount of fuel used by a household in one year,
- H(t) = the heating degree-days (base t) in a typical year, so that
- bH(t) = the proportional constant amount of heating fuel relative to the outdoor temperature, relative to long-term outdoor temperatures.

Model conservation standards are expected to reduce the amount of electricity used for space heating in new buildings. Thus, the PRISM estimate of space heating consumption (bH(t) from Equation 2), is the parameter estimate that should be relatively smaller on average for MCS units than for 1983 current practice units.

Usually, only NAC is modeled as the response variable. This is because the parameter estimates from PRISM, including the estimate for heating, are not as robust as the NAC estimate [5]. A validation of PRISM is currently being conducted at Oak Ridge National Laboratory using submetered data on single family electricity use collected as part of the Hood River Conservation Project. Preliminary analysis indicates that the heating component of NAC as estimated by PRISM could be overestimated by as much as 19% [6]. Fels et al. [5] hypothesizes that hidden nonheating factors cause the overestimates.

Given the available data, it was not possible to determine the extent of PRISM's overestimation of the space heating component. Also, it is not readily apparent that specific results found in the single family sector can be directly transferred to the multifamily sector. The hidden nonheating component may be a larger proportion of the space heating estimate, because space heating is a smaller component of total NAC. Apartments and houses contain similar appliance portfolios, but houses have much larger space heating requirements. On the other hand, vacant apartments draw heat from occupied units, thereby increasing occupied units' space heating loads and decreasing the proportion of the hidden component. Given these factors, the space heating component provided by PRISM is not adjusted in analyses reported below, although the results are appropriately qualified.

A summary of unit-level PRISM parameter estimates is presented in Table V. NAC and space heating estimates have been standardized by unit size (measured in square feet of heated living space) to reflect the design differences between MCS and 1983 current practice multifamily buildings and units. Standardization of electricity use by floor area is consistent with resource

Table V. Summary (means) of unit-level electricity use for (1986-1987).

(N)*	MCS (298)	Current Practice 1983 (121)
NAC (kWh/year)	10,660	13,310
Space heating (kWh/year)	6,310	6,890
Reference temperature (°F)	58.2	58.5
PRISM model R-square	0.89	0.93
Electricity/Ft2(kWh/year)†	9.6	10.2
NAC/Ft2 (kWh/year)	13.9	13.4
Space heating/Ft2 (kWh/year)	8.3	7.1

*Of the original 760 units (see Table III), turnover and vacancy precluded the modeling of 32% of the units. Another 13% of the units were removed from analyses due to anomalous parameters estimated by PRISM (e.g., negative heating slope estimate or R-square below 0.50).

†Calculated as sum of electric utility bills for all units in a building for one year divided by the heated living space in the building.

planning and forecasting activities of the NPPC and Bonneville and with standards outlined in the NWEC.

These results appear to suggest that the MCS did not result in energy savings. However, these can be deceiving because a large number of factors which may impact energy use have not been controlled. Table VI presents regression models which attempt to control for energy use preferences, energy use attitudes, idiosyncratic energy use behaviors, building orientation and construction, and appliance holdings.

After controlling for housing and demographic factors related to energy use, unit-level regression analysis indicates that occupants of MCS units saved 4.2 kWh/Ft2/year in total electricity use and 1.8 kWh/Ft2/year in space heating electricity consumption. The coefficients are highly significant and fall within a range expected by NPPC. Recall that MCS addresses only space

Table VI. Summary of unit-level multiple regression models of electricity consumption.

	Response variable			
	NAC/Ft2/year		Space heat/Ft2/year	
Predictor variable	Coefficient	Beta Weight	Coefficient	Beta Weight
Intercept	17.80***		10.5***	
MCS	-4.19***	-0.40	-1.81**	-0.19
Number of electrical appliances	0.57	0.15	-0.32	-0.09
Wood stove (1=yes, 0=no)			8.00**	0.12
Rent ($/Ft2)			8.33*	0.14
Closed rooms/vents (1=yes, 0-no)	-1.94**	-0.19	-1.81***	-0.20
Sun exposure (1=low, 4=high)	-0.52**	-0.13	-0.29	-0.08
Air vented to outside (1=yes,0=no)	-4.06***	-0.40	-1.97**	-0.22
Number children aged 6 or less	1.08	0.08	2.77***	0.24
Heat for comfort (1=v.imp, 5=v.unimp)	-1.03**	-0.15	-0.86**	-0.14
Use additional electrical space heaters (1=yes, 0=no)	-0.71	-0.07		
Hard to afford energy (1=no, 4=v.hard)	1.17**	0.20		
Window area (Ft2)	-0.02**	-0.19		
F statistic	5.57***		6.70***	
N=419 (298 MCS, 121 current practice 1983)				
R-square	0.22		0.24	

*,**,*** Indicates that coefficient is statistically significant at 0.10, 0.05, or 0.01.

heating. These findings, particularly the difference in savings between NAC/Ft2 and space heating/Ft2, suggest that there are major interpretation issues involved in measuring the electricity savings to be attributed to MCS.

Beta weights (standardized regression coefficients) are presented to show the relative importance of the independent variables. Among predictors that are associated with greater NAC savings, the MCS variable is the most important predictor in the NAC/Ft2/year equation and the third most important in the space heat equation. These findings add validity to the coefficient estimates.

Numerous other independent variables were found important in the regressions. For example, significant and substantial decreases in space heating are correlated with households closing off rooms and vents and using exhaust systems to vent air to the outside. The latter finding may result from households using exhaust fans instead of opening windows to provide fresh air. This interpretation would also apply more narrowly to MCS units because very few units use their AAHX (i.e., 13%). High exposure to the sun is significantly related to decreases in NAC and households that do not heat for comfort. Lastly, larger window area is significantly and negatively related to NAC, although the coefficient is very small in magnitude.

Positively and significantly related to space heating electricity use are the number of children in the household aged 6 or less. This is a reasonable finding because apartments with young children in residence are apt to be occupied a greater percentage of the time and kept warmer. Higher rent, which may be interpreted as a proxy for households' preferences for consuming versus saving, is also positively correlated to space heating. Those households that find it hard to afford energy expenses, do, in fact, consume more energy than other households.

Numerous other variables, both kept in the models and dropped from the models, were found insignificant. More notable variables dropped from the models include household income, education of respondent, and length of residence. Those variables kept in the model(s) but are insignificant include the number of appliances and the use of additional electrical space heaters.

Unit-level analysis features the attractive benefit of avoiding the issue that plagues analyses of energy savings in the multifamily sector, namely, vacancy. Vacant units draw heat from occupied units and serve as buffers between dwellings and outdoor temperatures. The extent of these indirect effects is unknown. Since vacant units have no billing histories to model, they only indirectly affect weather-adjustment of billing histories for other, occupied units. Since only occupied units are modeled in the unit-level analysis, the parameter estimates of base load and space heating--even when standardized by floor area--can be expected to be somewhat larger (in terms of absolute value) than parameter estimates derivable from a building-level analysis which assumes full occupancy of all units in the buildings. Thus, at the very least, building-level analysis should be conducted to triangulate energy savings attributable to MCS.

To conduct building-level analysis, the issue of vacancy needs to be explicitly addressed. The vacancy rate for all apartment buildings in Pierce County, Washington, in which Tacoma is located, has held fairly constant since 1984 at 6-7% [7]. The rate is based upon the number of units that are vacant during the first week of the month. However, this kind of vacancy rate, which corresponds to an occupancy rate of 93 to 94%, is misleading in its implication for effects on energy use, because units could be occupied and using energy at other times of the month or more units could be vacant and not using energy. Thus, for energy analysis, determining occupancy is more important.

Decicco et al.[8] adjusted monthly bills for one large multifamily complex by dividing the number of units occupied by total, master-metered monthly energy use, with occupancy determined from reports of building managers. The occupancy rate developed for this paper expressly accounts for all days of the month during which a unit was vacant. Since utility bills were collected for virtually all units in the MCS and 1983 current practice samples, a vacant unit could be identified by no or very low electricity use. That is, if the electricity use in a particular unit was much lower than expected (less than 50% of the lowest estimated *base load* for any unit in the same building) then the unit was probably vacant. Thus, occupancy in this paper refers to units that are definitely occupied. The occupancy rate is defined as the number of occupied unit-days divided by the total unit-days for each building for each month, where total unit-days is calculated as number of units in building times number of days in the month.

Billing histories for occupied units were then summed to create aggregate monthly building bills. Attempts to adjust the aggregate bills depending on the buildings' occupancy rates revealed that the relationship between NAC/Ft2 and occupancy rate is intrinsically linear. Transformations and nonlinear specifications were also tested and found less satisfactory. The best-fit relationship took the form of a segmented, linear model, best represented by an "L" turned 90^{0} to its left. Although all model coefficients were statistically significant, since the model could only explain less than 45% of the variation in NAC/Ft2, the original sum of unit billing histories was retained without adjustments due to occupancy. On the other hand, occupancy rate was retained as a predictor in the building-level regression.

By comparison, the occupancy rate of 94% developed for Tacoma [7] is substantially higher than occupancy rates developed for this paper. MCS units retained for the building-level analysis were occupied 77% of the time during 1986/1987 while 1983 current practice units were occupied 82%.

A summary of PRISM parameter estimates based upon aggregate building bills is presented in Table VII. Please note that the mean value for space heating per square foot (5.5 kWh/Ft2/year) for 1983 current practice buildings is much closer than the unit-level value (Table V) to the standard (3.4 kWh/Ft2/year) used by the NPPC to project savings due to MCS . Why, in this study, engineering estimates of energy use appear to be much lower than the actual use, with and without weather-adjustment is not precisely known. As mentioned above, hidden variables may result in PRISM overestimating the

Table VII. Summary (means) of building-level (aggregate) electricity use for 1986/1987.

(N)*	MCS (28)	Current Practice 1983 (26)
NAC (kWh/year)	90,400	58,600
Space heating (kWh/year)	34,200	26,300
Reference temperature (^{o}F)	60.0	62.1
PRISM model R-square	0.82	0.89
Electricity/Ft2(kWh/year)+	9.6	10.2
NAC/Ft2(kWh/year)	10.9	11.5
Space heating/Ft2(kWh/year)	4.1	5.5

*Buildings with occupancy rates consistently below 60% are not included.

+Calculated as sum of electric utility bills for all units in a building for one year divided by the heated living space in the building.

space heating component, which would bring the results in Table VII even more in-line with NPPC's engineering estimates. On the other hand, the engineering estimates made in 1983 may not have been rigorously validated, leaving the possibility of underestimates. It is also possible that energy-related occupant behavior has not been properly accounted for in the engineering estimates, although Stovall and Fuller [9] report that this factor is not sufficient to explain differences between audit estimates and actual savings of energy due to weatherization. Further research in all areas would be needed to better explore this issue.

As previously noted, MCS buildings and occupants are different from the 1983 current practice counterparts. It is important to control for these differences in order to obtain a more valid estimate of space heating electricity savings due to MCS. Table VIII presents the building-level regression models. After controlling for housing and demographic factors related to energy use, building-level regression analysis indicates that occupants of MCS buildings combined to save an average of 1.3 kWh/Ft2/year in total electricity use (NAC) and 0.8 kWh/Ft2/year in space heating electricity consumption.

As suspected, occupancy rate is also an important predictor in both models, as indicated by the beta weights. As expected, the sign of the coefficient is positive but, unexpectedly, the magnitude of the coefficient is small. Possibly, the occupancy effect in the multifamily sector has been overrated. Additional studies are recommended, however, to substantiate this observation.

Also positively related to energy use are rent ($/Ft2), lack of solar exposure, and laundry facilities. As discussed with respect to the unit-level models, the rent variable may act as a proxy for the tendency of households

Table VIII. Summary of building-level (aggregate) multiple regression models of electricity consumption.

Predictor variable	Response variable: NAC/Ft2/year Coefficient	NAC/Ft2/year Beta Weights	Space heat/Ft2/year Coefficient	Space heat/Ft2/year Beta Weights
Intercept	-3.88		-5.07*	
MCS	-1.30**	-0.26	-0.78*	-0.21
Occupancy rates	0.16***	0.72	0.06**	0.40
Rent ($/Ft2)	11.06**	0.26	10.55**	0.36
Units receiving no sun (%)	0.12***	0.34		
Age (typical) of occupant (years)	-0.07**	-0.44		
Floors in unit	-2.29**	-0.22		
Rent/occupants' incomes (%)	0.02	0.12		
Laundry facility in building (1=yes, 0=no)			2.07**	0.27
Glass (Ft2) receiving no sun(%)			0.44**	0.25
F statistic	13.17***		6.90***	
N=54 (28 MCS, 26 current practice 1983)				
R-square	0.69		0.43	

*,**,*** Indicate that coefficient is statistically significant at 0.10, 0.05, or 0.01.

to consume rather than save. Households consuming more housing may be apt to also consume more energy. It is also possible that the higher rent units have more energy-using appliances. Lack of sunshine is straight-forwardly related to increased energy use and the presence of laundry facilities may tend to displace the need for such appliances in the units and, thereby, reduce heat gained by the unit from washers and dryers.

Age of respondent and the number of floors are significantly and negatively related to NAC/Ft2. The latter finding indicates a stack effect (i.e., heat rising from lower to upper floors). The former result can be explained because households with older adults are less likely to have children and the associated increased energy needs.

DISCUSSION

The analyses presented above offer a wide range of estimates for energy savings due to MCS in multifamily buildings. A comparison of means based upon unit-level data indicated that occupants of MCS units actually used more space heating electricity than occupants of 1983 current practice units. However, residential energy use is not a univariate proposition. Multiple regression analysis at the unit-level indicated that model conservation standards resulted in a savings of 1.8 kWh/Ft2/year. In other words, MCS resulted in a 25% reduction of the space heating electricity used in units built to pre-MCS code. Building-level analysis indicated that MCS saved 0.8 kWh/Ft2/year, or 15% of the space heating electricity used in 1983 current practice buildings. These levels of savings are generally higher than savings in multifamily buildings due to retrofit, which range from 8% to 30%.[10,11,12]

In order to improve estimates of energy savings of MCS in the multifamily sector, there needs to be an improved understanding of why unit-level and building-level analyses yielded different estimates of space heating electricity savings due to model conservation standards and why the proportion of NAC/Ft2 that is used for electric space heating also varied according to unit- and building-level analyses (Table IX). These contrasting estimates could be attributed to the vacancy issue. Recall that vacancy was greater among MCS units and that unit-level analysis bypasses the direct effects of vacancy on weather-adjusted estimates of NAC and space heating. The higher space heating/NAC proportion at the unit-level suggests that heating is being distributed across vacant units, possibly giving the appearance that a greater space heat load is required for the occupied units. On the other hand, vacancies may adversely affect the correlation that PRISM finds between kWh and HDD, resulting in an over-estimate of baseload at the building-level. Under these conditions, the proper interpretations of PRISM parameters for base load and space heating are not clear.

The implications are great for energy conservation program design and evaluation. That is, if the costs and benefits of MCS are primarily judged on savings of space heating energy, then it is necessary to thoroughly understand this hidden baseload and measure it. Furthermore, it may be important to choose between unit-level and building-level analyses if resources are not available for both. Undoubtedly, the submetering of each unit's end-use loads would provide an exceptional opportunity to segment electricity into its various components and to assess the pluses and minuses associated with unit-level and building-level analyses.

More accurate and defensible estimates may be very difficult to develop. One reason is the nature of the multifamily sector. It is typified by frequent moves, which make it difficult to establish even one year's worth of consistent billing histories. A physically mobile population may also have fewer ties

Table IX. Estimates of the proportion of total electricity use that is used for space heating.

		MCS	Current Practice 1983
Proportion of space heating to NAC (kWh/Ft2/year)	Unit-level	.597	.530
	Building-level	.376	.478

to the community, which tend to reduce incentives for residents to respond to survey requests. In light of these problems, the number of billing histories and the response rate achieved in this study may be difficult to surpass.

A second reason is the difficulty in working with complex buildings that consume energy as the result of numerous human behaviors. Analyses presented above attempted to control for such factors as occupancy rate, building orientation, building practices, and weather. This was possible because all the buildings shared a common geographic location. However, with buildings across the Pacific Northwest, such factors may become impossible to control. Some consideration is needed with respect to defining prototypical multifamily units along a set of variables in order to better achieve a more rigorous definition and estimate of multifamily energy use.

Innovative programs would be needed to overcome many of the problems. Units could be submetered to supply more accurate data. Households could be given incentives not to move for one or more years. Research and analyses of housing subsidy programs indicate that the incentives, even in cash, would not be saved for purposes of relocating from or altering the condition of the apartment [13]. Long-term analysis would require collecting energy use and occupancy data from a sample of units for a number of years and determining how to adjust energy use for changes in unit occupancy.

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