Title
COMPARISONS OF PREDICTED AMD MEASURED ENERGY USE IN OCCUPIED BUILDINGS

Author
Wagner, B.S.

Publication Date
1984-05-01

LBL-17364

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

APPLIED SCIENCE DIVISION

Presented at the ASHRAE Conference, Kansas City, MO,
June 17-20, 1984; and published in ASHRAE Transactions,
V. 90, Pt. 2

COMPARISONS OF PREDICTED AND MEASURED ENERGY USE IN OCCUPIED BUILDINGS

B.S. Wagner

May 1984

APPLIED SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-17364
EEB-BED-84-02

Presented at the ASHRAE Conference in Kansas City, MO, June 17-20, 1984, ASHRAE Transactions 1984, V. 90, Pt. 2.

COMPARISONS OF PREDICTED AND MEASURED ENERGY USE IN OCCUPIED BUILDINGS*

Barbara Shohl Wagner

Buildings Energy Data Group
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

May 1984

---

*The work described in this report was funded by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Buildings Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

COMPARISONS OF PREDICTED AND MEASURED ENERGY USE IN OCCUPIED BUILDINGS

Barbara Shohl Wagner

Buildings Energy Data Group
Lawrence Berkeley Laboratory

ABSTRACT

During the past decade, a number of studies have reported comparisons of building energy simulations to measured building performance. Over two dozen studies, comprising about 100 simulations of building energy use, have been compiled and categorized by quality of input and energy consumption data, type of study, model used, quality of input and consumption data, expertise of input preparer, and control and monitoring of occupancy. This paper summarizes results of studies of occupied buildings in which monitoring varied from very detailed to nonexistent, the comparison interval from hourly to yearly, and the number of buildings from one to 200-plus. These results are briefly compared to results from unoccupied buildings and preliminary conclusions are presented about the use of building energy models for different types of field applications. This is an ongoing compilation to which contributions both of data and methodological suggestions are invited.

INTRODUCTION

Use of building energy-analysis models fills a wide range of needs, from residential and commercial audit programs to design of new buildings and calculation of energy ratings, from policy studies to theoretical investigation of new retrofits and innovative building materials. The increasing use of the models has also increased the motivation to measure their accuracy which has, in turn, precipitated an increasing number of verification studies. Because the verification studies likewise span a wide range of model complexity, quality of input and consumption data, and type of verification intended, over two dozen studies have been compiled and categorized comprising about 100 simulations of building energy use, performed by a variety of users with 18 models, each using anywhere from 1 to 243 buildings. The purpose was to investigate model accuracy given varying levels of detail in input data, varying skills of input preparer, degree to which input is revised following an initial comparison, and time scale of the comparison.

Of particular interest, from both a theoretical and practical standpoint, is the ability of models to accurately account for the effect of occupancy on building energy use. Variations of 2:1 in energy use among nearly identical buildings have been reported by Sonderegger (1) and Wilson, et al. (2); Lipschutz, et al. (3) found a 40:1 variation in space heating use among units in the same apartment building. Obviously, the ability to model an empty building does not necessarily imply an ability to model the same building when occupied. For applications requiring predictions of energy use for particular occupants (or a particular group of

B.S. Wagner, Staff Scientist, Buildings energy Data Group, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720.

occupants) the key questions are:

- --are currently available models capable of accurately predicting the energy use of a particular occupant?
- --what key characteristics about the occupant(s) must be known for accurate predictions?
- --how accurately must those characteristics be known?

The compilation presented here, directly addresses the first question and can provide some preliminary insights into the other two.

A Philosophical Note

The agreement between model predictions and actual measurements is affected by

- --quality of data available on building characteristics and weather
- --quality of data available on occupant lifestyle
- --absence of errors in inputting the above data
- --ability of model algorithms to correctly model physical processes and accurately account for effect of occupant lifestyle.

A verification may be performed with the effects of any of the first three factors minimized, in order to test the model's ability to accurately account for the other factors. For example:

- --With chance of input errors minimized by having expert users prepare input from detailed, accurate measurements. (This may be easier said than done; see, for instance, Jones [4].)
- --With effects of occupants, or even weather, removed (unoccupied building) or controlled (simulated occupancy or weather).
- --Under normal field conditions, e.g. utility auditor or engineer with access to previous utility bills but not to detailed measurements.

But results of verifications under controlled conditions do not necessarily apply when the controls are removed. Likewise, it can be misleading to uncritically use results of a comparison based on data which was corrected after discovery of errors in a first round if the present situation does not allow such a check. Yet testing the model with varying degrees of control over errors can check that its individual components are all working correctly and that a correct prediction is not merely a fortuitous cancelling of errors. It can also help indicate the types of applications for which the model is best suited (e.g., for use by utility auditors, and/or for engineering retrofit calculations and/or for theoretical research).

METHODOLOGY

The intent of this compilation is not only to summarize results of model verifications, but to investigate the limitations on use of the models by noting the conditions under which a given accuracy was achieved. Each study was categorized according to 15 characteristics likely to affect model accuracy. In addition, study results were tabulated using several measures of accuracy. The most important characteristics and measures of accuracy are described briefly below; a complete summary of the cataloging system is presented in table 1.

Characteristics Cataloged

The method used to verify model accuracy will affect the results. For instance, in some studies the comparisons were "blind," with no corrections to input made after comparison of predicted and actual results, while in others verifiable errors were corrected after an initial comparison. Obviously, agreement should be closer in the second case, but the difference reflects different uses of the model as well as the accuracy of its algorithms. In order to distinguish among levels or types of verifications, studies are divided into the following groups:

1. Noniterative (N): results were obtained from blind simulations with input preparers not knowing measured energy use and with no subsequent adjustments to the model or input data based on initial comparison. This is a combined test of model and input accuracy and skill of the user. It represents such real-life situations as: designing a new building, where actual energy records do not exist; use of models for policy research or energy ratings requiring the energy use of buildings given an "average" or "typical" occupant (since energy records for individual buildings with such occupants do not exist).

2. Verifiable measurement or input errors corrected (M or E): studies in which verifiable input errors were corrected after comparison of predicted and measured energy consumption. "Verifiable" means that changes to input are only made if they are justified independently of their effects on model predictions, e.g., by actual measurement, or by discovery of errors in conversion units or similar input errors. These studies correspond to real-life situations such as utility audit programs or design of retrofits for an existing building for which energy-use records exist. In both cases, the utility auditor or engineer who finds a significant difference between actual and predicted energy use for the building "as is" will be well advised to check for verifiable mistakes in measurements or input before concluding that the model is at fault.

3. Verification based, in part, on test buildings used in developing the model (T). Models are often developed using empirical data from test buildings, occupied or unoccupied. A verification of the final model based entirely, or in part, on predicting energy use of the same buildings is a useful check on model accuracy, but does not necessarily imply that the model is sufficiently general to apply to a range of building types. These studies are useful when considered along with tests of the model on buildings not used in its development.

In addition, some studies were classed as Iterative (I), if their results were based on adjusting input data until predictions match measured energy use, usually by changing assumed values of unmeasured inputs. At the worst, such studies amount only to fiddling with the model. At the best, however, they document cases where lack of data causes inaccurate predictions and provide clear and useful demonstrations of model limitations. Since iterative studies are not verifications, they are listed only in the descriptive summary tables, and their results are not included in the plots of model accuracy.

Accuracy of input data and of measured energy consumption obviously have a large effect on the results of the verification. We were usually able to determine the input and consumption data actually monitored, along with the frequency of data collection. It would be useful to characterize the accuracy of the data, but since this information is not usually available, we categorize data by completeness, as follows:

--Class A: detailed on-site monitoring in addition to that specified for Class B, e.g. onsite solar and wind data, multiple indoor temperatures, heat fluxes, door and window openings, continuous infiltration measurement

--Class B: submetering of HVAC equipment, indoor temperature, total appliance load, onsite outdoor temperature

--Class B-: submetering, but off-site weather measurements or lacking indoor temperature or appliance load

--Class C: no submetering (typically, utility bills only), weather either on or off site

--Class X: comparison based on average characteristics or energy use of a group of buildings, on normalized weather, or on other averaging techniques

--Class D: major required inputs unknown, e.g., weather data for the actual comparison period (these are listed in tables but not shown on plots of accuracy)

Since occupancy can have a large effect on model accuracy, we note whether the buildings were occupied and the detail with which occupants were monitored. We also note the number and types of buildings compared, their HVAC system types, and their location. This information is included because some building and HVAC types are more difficult to model accurately than others. Note, also, that energy use in mild climates tends to be more difficult to predict within a given percentage error.*

Finally, we note the energy enduses compared, the size of intervals compared, the type of input preparers, and provide brief comments on each study to summarize important points not covered in the proceeding compilation.

Measuring Accuracy

Several different measures of program accuracy are described and listed for the compiled studies in reference 5. In this paper, results are summarized graphically (figures 1-3) only for average rate of measured auxiliary energy use versus predicted energy use, per unit floor area. On this basis, trends in the ability of programs to model very efficient buildings or buildings in mild climates can be seen graphically. Controlling for floor area reduces confusion in comparing energy use between a small inefficient building and a large efficient one; taking the average rate of energy use (total auxiliary energy use divided by total monitoring time) allows comparison between a building monitored for a month and one monitored for a year. However, this latter comparison is also of interest and is discussed at more length in reference 5; here the discussion focuses on the effect of occupancy on model accuracy.

RESULTS AND DISCUSSION

General Results

Summary descriptions of the verification studies appear in tables 2 and 3, which include occupied, individual buildings and averages of groups of buildings and/or studies, using normalized weather. Figures 1 and 2 present the predicted vs. measured energy use for the same studies, with the exception of iterative comparisons or those based on Class D data, as noted above. Table 4 and figure 3 show results for unoccupied buildings. On all figures, the solid line represents perfect agreement between predicted and measured energy use; the dashed lines represent ±20% difference.**

In all three figures, the overall agreement between actual and predicted energy use is within about 20%; the scatter for the individually monitored unoccupied buildings (figure 3) is somewhat smaller than for either individual buildings or groups of occupied buildings (fig-

---

* That is, the closer the average outdoor temperature to the building balance point (in a mild climate during a swing season, or in a well-insulated house) the more difficult the accounting for degree days, or for hourly variations above and below the balance point, and for effects of thermal mass. In addition, if the house is occupied, there will be a greater tendency to use varying natural ventilation and shading strategies and the perceived "comfortable" indoor dry bulb temperature may change. Thus, even though total energy use and absolute error may be lower, the percentage error will tend to be higher than when the outdoor temperature is well below the balance point.

** Where percentage difference is calculated as:

$$100 \times \frac{\text{(Predicted energy use - Measured energy use)}}{\text{Measured energy use}}$$

ure 1 and 2). Given that the unoccupied buildings were not only free of the effects of variable lifestyles, but also tended to be monitored in greater detail than the individual occupied buildings of figure 1 (indicated by their higher proportion of Class A buildings), the fact that the overall error is not much larger for the occupied buildings is surprising. A check of the summary tables, however, reveals that the unoccupied buildings were usually compared over a fairly short time period--hours to days--(table 4) while comparisons in occupied buildings were often made over several months to a year (table 2 and 3). Since predicting energy use on an hourly or daily basis is more difficult than monthly or annual predictions, the small decrease in accuracy of predictions for occupied buildings is less surprising. The effect on accuracy of predicting energy use over shorter time periods can be seen clearly in several studies of occupied and unoccupied buildings (e.g., references T17, T35, T3*) and is discussed at greater length in reference 5.

The fact that scatter does not increase when going from predictions for individual, occupied building (figure 1) to groups of occupied building (figure 2), most of which are monitored in considerably less detail, suggests that varying lifestyle effects among houses in a group average out to values near the assumptions used in the model, an important point for, say, utility audit programs. It should be emphasized that the scatter in actual vs. predicted data for the individual building can be far greater than that for the groups as a whole. A good illustration is given by Crenshaw (T13) for a group of houses in which average error was about 20% but individual errors were greater than 100%. It should also be noted that errors in inputs and measurements will tend to average out over a large sample of buildings, and that these errors also contribute to the scatter in predictions for individual buildings.

A look at the outlying points in figures 1 and 2 shows that most of the farthest outliers come from predictions of cooling energy use (shaded points) or predictions of energy savings after retrofits (X's in figure 2). (The non-cooling outlier in figure 1 labelled "N" is a building which was first modeled "blind" then modeled again after a significant input error was corrected; the corrected point "M" is indicated by the arrow, and lies at about 20%).

Cooling energy is frequently a more complicated modeling problem than heating, even in unoccupied buildings, since humidity and solar gain play larger roles as driving forces compared to temperature differences.** In occupied buildings, the problem is exacerbated by variable occupant use of shades and ventilation in addition to variations in occupant tolerances of higher indoor temperatures. The number of data points for cooling in this compilation is presently small, but they support the expected trends of greater scatter than in heating predictions and greater scatter for occupied buildings. The next section includes further discussion of cooling predictions, using detailed computer programs.

The scatter in predictions of energy savings (X's in figure 2) is not surprising since predictions of savings involves separate "before" and "after" retrofit predictions. A modest error, on a percentage basis, in total heating use will cause a very large percentage error in energy savings. Note, however, that there are very few comparisons of savings estimates in the compilation, and other calculative procedures may perform better.

Estimates of Energy Use in Occupied Buildings Using Detailed Models

A logical way to improve predictions of energy use in occupied buildings is to use a model that is sufficiently detailed to account for relatively complex variations in lifestyle, including different hourly patterns in thermostat setback and appliance use; and different approaches to use of natural ventilation and window shading. Efforts to do so have met with mixed success, and it is worth investigating them to gain a better understanding of limitations on uses of the models.

In 1974-75 Sepsy, et al. (T4, T5, T6) monitored in detail nine dwellings in Columbus, Ohio, and several dozen around the country in less detail, to support development of Ohio State University's hour-by-hour Residential Energy Analysis Program (REAP). When tested

---

* Reference numbers preceded by "T" are listed under "References to Tables."

** Except for buildings in low heating degree-day climates.

against the Columbus houses, REAP weekly and monthly predictions were within 10% of measured values for all but a heat-pump house, for which error was within 20%. However, in a follow-up project by Talbert, et al. (T3) testing REAP against the houses in other cities, which had less detailed data, weekly errors ranged as high as 60%. (Note that this latter simulation was performed "blind," and represents a "worst case" in that it was not possible to go back and collect data to correct input errors, with the one exception shown with an arrow in figure. 1). Most of the simulations for these two studies were performed for occupied houses. In another set of blind simulations, Merriam and Rancatore (T17) used four hourly models to predict heating use in one of the Columbus houses, which was unoccupied, with resulting monthly and weekly errors less than 10% (three of the models, DOE-2, ENCORE-CANADA, and TRNSYS 10.1 were developed completely independently of data from the test house).

In comparisons of DOE-2 predictions to annual energy use of two houses for which only utility bills and basic audit (plus spot infiltration) information were available, Hall (T21) found, after correction of input data, errors less than 10% in heating but up to 40% in cooling for the weather of Windsor, Ontario. Goldenberg, et al. (T18) and Stovall (T31) both found substantial errors in DOE-2 predictions of heating and cooling for houses in which information was lacking on infiltration, extent of basement heating, shading, and ventilation; the differences could be accounted for by varying those parameters within reasonable limits. For groups of houses, Colborne, et al. (T2) found reasonably good agreement between DOE-2 predictions and average heating use of 75 similar houses for which audit level information (including extent of basement heating) was available. Vine, et al. (T9) found differences up to 26% and 23% for summer electricity use for a group of 22 and 74 homes, respectively, using DOE2 predictions of cooling and relatively detailed audit data.

A Seattle utility (T25) found an average 52% error in predictions of savings for a large group of homes, using a simplified method based on BLAST; however, as noted above, savings estimates are prone to high percentage errors, and BLAST itself was not run for the specific houses audited. In occupied commercial buildings (with HVAC systems far more complex than residential systems), Yuill and Phillips (TII) found agreement within 20% for BLAST predictions. Also in occupied commercial buildings, Herron, et al. (T12) initially found BLAST predictions in error by as much as 40%--but after correction of errors in occupancy data found differences up to only 12%.

CONCLUSIONS

Energy analysis models can be effectively used on occupied buildings. Differences between predictions and measurements in most of the studies compiled were within a range of ±20% on average for the monitoring period for simulations of individual occupied buildings or groups of occupied buildings. Cooling energy use and energy savings tended to be more difficult to predict than heating consumption. For all end-uses, the availability of accurate and sufficiently complete input data, especially on occupant behavior, limits the ability of even detailed models to accurately predict energy use, in some cases, severely so. Two methods that successfully reduced errors were: (1) comparison of predicted and actual use for buildings with existing prior utility information, and correction of verifiable input errors; and (2) for groups of buildings with limited building-by-building data, restricting predictions to the average of the group. The first should be standard practice for engineers or auditors recommending retrofits for individual buildings; the second is useful for utility programs for large numbers of buildings. For new building, or prototypical (hypothetical) buildings used in policy studies, when the energy use need not be predicted for a particular, actual occupant,`the situation is similar to predictions for an unoccupied building or building with controlled (well-characterized) occupancy, for which predictions were generally less than 20% in error.

This compilation is an ongoing project, and contributions from readers both of data and of methodological suggestions are welcomed.

REFERENCES

1. R.C. Sonderegger, "Movers and Stayers: The Resident's Contribution to Variation Across Houses in Energy Consumption for Space Heating," R.H. Socolow, ed., in *Saving Energy in the Home: Princeton's Experiments at Twin Rivers*, (Cambridge, MA; Princeton Univ., Ballinger Publishing Co.), 1978.

2. N.W. Wilson; W.G. Colborne; T. Hoffman; E. Fretz; and A. Niec, "Occupant Effects on Residential Energy Consumption," presented at ENERGEX '82, Regina, Saskatchewan, Canada.

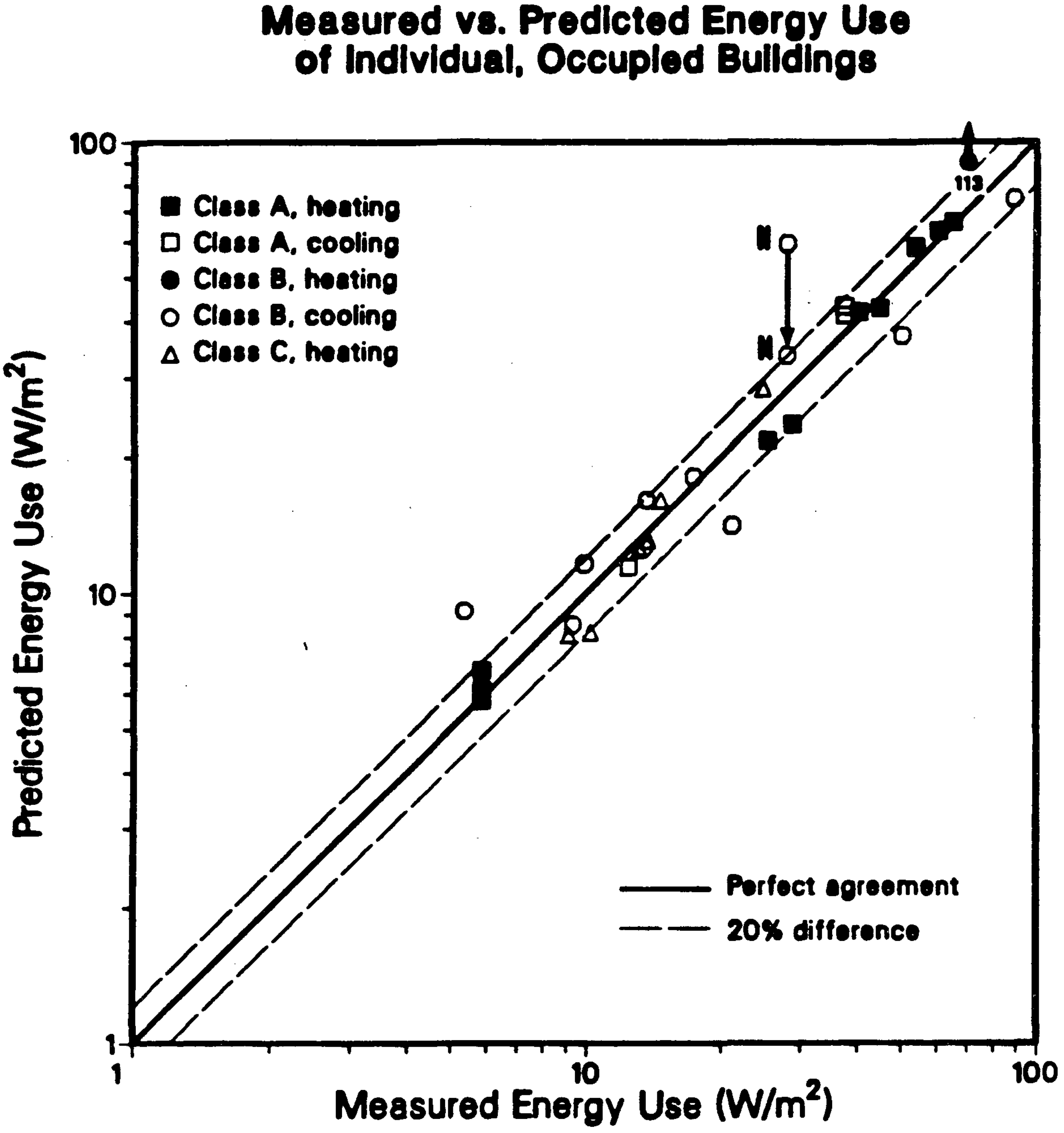
3. R.D. Lipschutz; R.C. Diamond; and R.C. Sonderegger, "Some Technical and Behavioral Aspects of Energy Use in a High-Rise Apartment Building," presented at Families and Energy: Coping with Uncertainty, Michigan State University, 1983.

4. L. Jones, "The Analyst as a Factor in the Prediction of Energy Consumption," DBR Paper No. 920, Division of Building Research, NRCC 18488 National Research Council Canada, Ottawa, Canada, 1979.

5. B.S. Wagner, "Verification Studies of Building Energy Analysis Models; Building Energy Use Compilation and Analysis, Part V," Lawrence Berkeley Laboratory (in preparation).

ACKNOWLEDGEMENT

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Buildings Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. The author also extends special thanks to Jeana Traynor and Chuck Goldman for their considerable efforts and excellent results on the Tables and Figures.



XCG 843-13023

Figure 1. "Energy use" is the average use of individual occupied buildings measured and predicted over the monitoring period. All simulations used weather data for the actual monitoring period. Varying levels of detail in audit and consumption data (Class A = most detailed, Class C = least detailed) are indicated, as well as enduse modeled. The points joined by an arrow represent a house modeled initially with incorrect occupancy data (point "N"); error was verified and corrected (point "M"). All other buildings were either modeled "blind" or with corrections made to input only if verifiable mistakes were discovered. Note log-log scale.

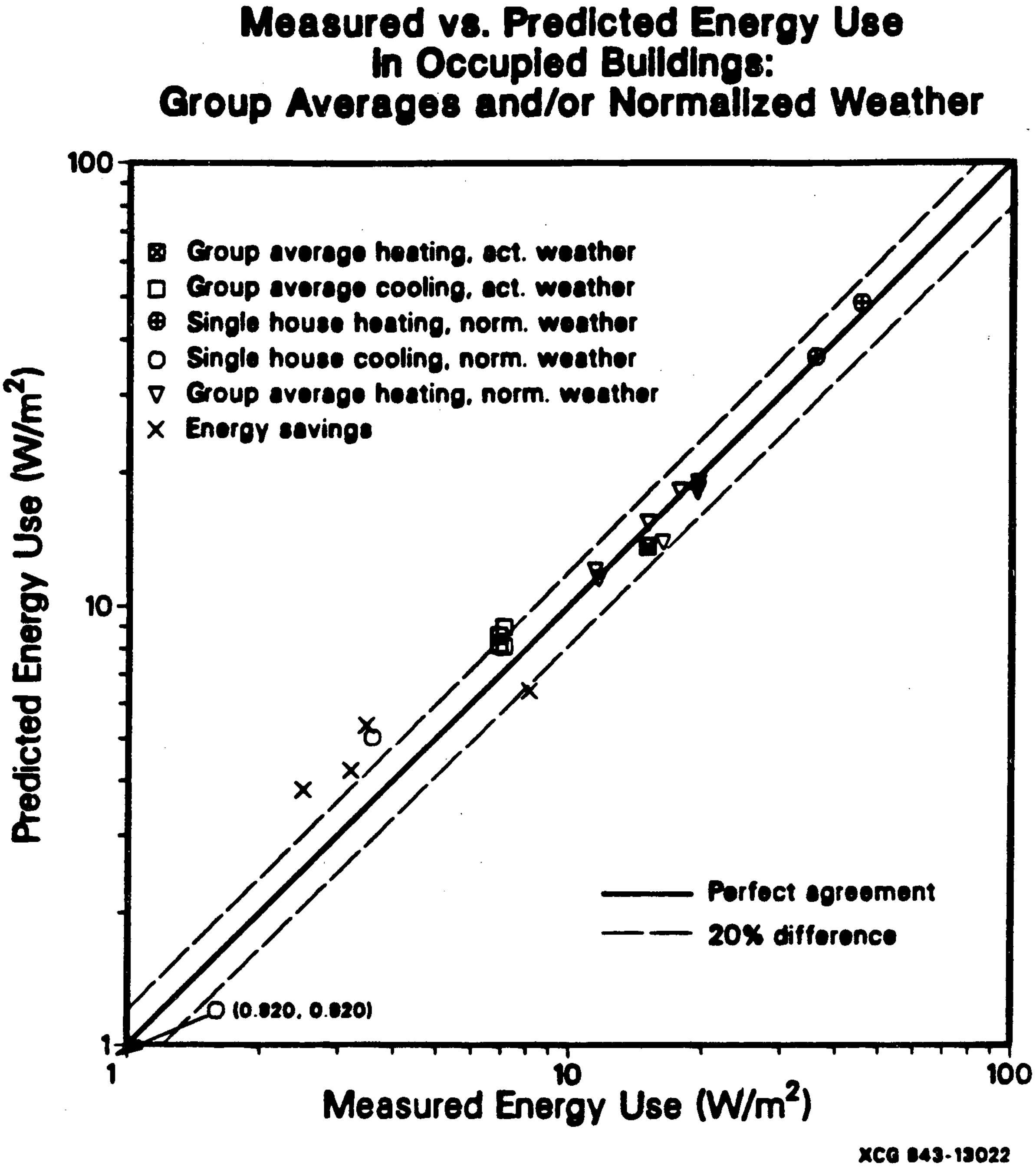


Figure 2. As in figure 1, all buildings were occupied and energy use is the average over the monitoring period. Comparison of predicted and measured energy use is based on the average use of a group of buildings and/or on use of normalized weather data, as indicated ("act." means actual weather data for monitoring period was used). Detail of audit data is generally equivalent to Class B or C of figures 1 and 3. All simulations were either "blind" or with only verifiable errors corrected. Note log-log scale.

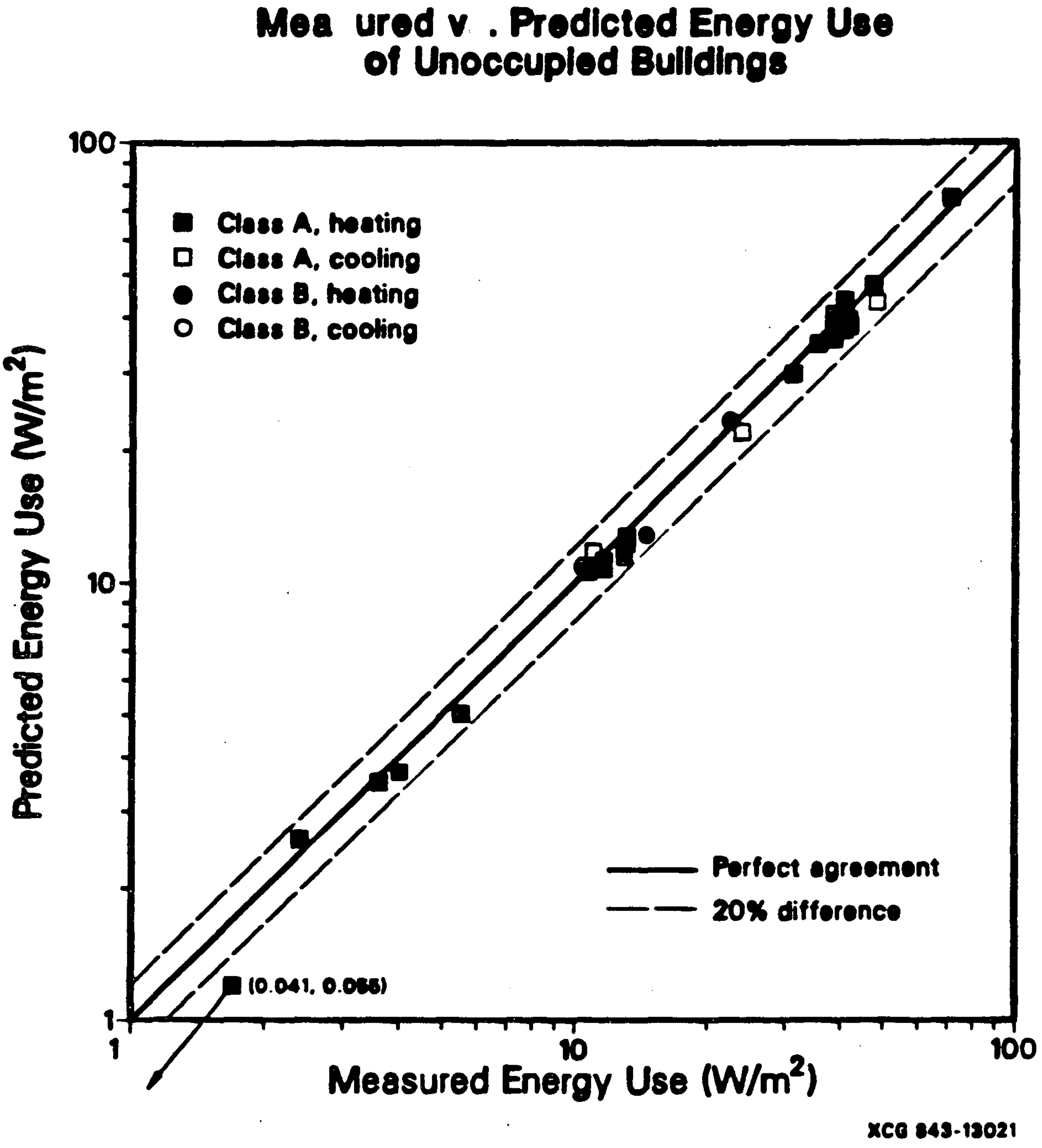


Figure 3. Average energy use over monitoring period for individual, unoccupied buildings. Detail of audit and consumption data (Class A = most detail, Class B = less detailed. None of these were Class C, least detailed) and enduses are indicated in symbol key. All simulations used weather data from the actual monitoring period, and were "blind" or with only verifiable errors corrected. Note log-log scale.

TABLE 1
Key to Headings and Symbols Used in Summary Tables

Program Name: name of building energy model
Analysts/Affiliation: person(s) who performed the verification study and their affiliation
Sponsor: institution funding the study
Reference Number: identification number for study, keyed to the references listed in "References to Tables"
Run Number: for studies in which more than one comparison was performed, this identifies the individual comparisons. Note: In entry of a study with multiple comparisons, the number of runs (column 2) is given either as a list, with each run given corresponding entries in following columns, or as a total number of runs. In either case, if only one entry appears in any descriptive column, that information applies to all the houses and runs listed.
Type: type of verification performed, coded as:
N= noniterative, "blind" comparison
I= iterative adjustments to input after comparison of predicted and measured data, to make model match measurements
E= verifiable input errors corrected only
M= verifiable measurement errors corrected only
T= test site data includes data used in developing model
S= sensitivity analysis performed
Data: class of input and energy consumption data
A= detailed on-site monitoring in addition to B-level data, e.g. onsite solar and wind data, multiple indoor temperatures, heat fluxes, door and window openings, continuous infiltration measurement
B= submetering, indoor temperature, total appliance use, and on-site outdoor temperature
B-= submeter but lacking one or more of B-level data above
C= no submeter
X= comparison based on averaged characteristics and/or energy use of a group of buildings and/or on use of normalized weather
D= major required inputs missing
Number and Types of Buildings: number of individual buildings used in comparisons, described as
R= residential
C= commercial
T= test cell
Building Description: short narrative description of buildings, including floor area
Location: location of buildings
Date Monitored and Reported: date of building monitoring and date of report
Fuel type: coded as:
E= electric
G= gas
O= oil
P= passive solar
A= active solar
R= remote plant
HVAC type: coded as
F= forced air
W= hot water
St= steam
R= resistance heat other than forced air)
Hp= heat pump
Ev= evaporative cooler
Ch= chiller (water assumed)
T= cooling tower
X= residential air-to-air heat exchanger
Z= other
Cm= compressor-type air-conditioner
V= various
Parameters Monitored: building, occupant, and weather characteristics
W= weather, with n=on-site, f=off-site, a=adjusted/normalized
S= solar with n=on-site, f=off-site
T= indoor air temperature, with a=audit/thermostat setting, s=spot measurement, e=envelope surface measurement in addition to air
I= infiltration, with c=continuous, s=spot measurement, b=blower door
Hu= indoor humidity
B= detailed building characteristics, E= HVAC efficiency
Z= other
Submetering: energy uses submetered:
H= heat
C= cooling
A= appliances
W= water heating
N= none
Simulations Reported: quantities predicted by model, used in verification:
H= heating
C= cooling
Tot= total of several enduses
()S= savings of (), where () is one of the first three enduses

TABLE 1 (continued)

()L= load of ()
()P= peak use of ()
T= indoor temperatures

Occupancy: whether building was occupied, and if so, how monitored
U= unoccupied
O= occupied, with a=audited parameters in addition to those already noted, m=monitored parameters in addition to those already noted, u=unmonitored except as already noted; c=check made of major changes in occupancy, pre- and post-retrofit
S= simulated occupancy

Monitoring Interval: smallest interval for which most data were recorded, coded as:

m= minutes	H= hours	D= days
W= weeks	M= months	Y= years

and numerical prefix indicates how many of each unit was used, e.g, 2M means the smallest monitoring interval was two months

Intervals Compared: monitoring period on which verification was based. Code is the same as for "Monitoring interval."

Input Preparer: coded as

C= code (model) author	K= user familiar with model algorithms
U= utility auditor or equivalent	O= other or unknown

Comments: a narrative summary of the unique aspects of each particular study or important points not covered in previous entries.

TABLE 2

Individual Occupied Buildings -Page 1A-

Program Name Analyst/Affiliation (Sponsor)	Run #	Type Data	# Bldgs. & Type	Building Description	Location	Date Monit. Date Rept.	Fuel HVAC	Parameters Monit.
BLAST 2.0 Herron, Windingland, Hittle CERL (US DOD) Ref. #12	1	N, M/A	2 C	1) 10-zone dental clinic, 872 m^2,	Fort Hood, TX	78-79/80	E/Ch G/W	(Wn, Sn, T, H, B, ventilation airflow)
	2			2) Battalion headquarters and classroom, 1757 m^2 floor + 310 m^2 basement. 10 zones. Both monitored as part of U.S. Army energy monitoring project.	Fort Carson, CO		R/Ch R/W	
INSOL, SVS Faber, Nikken, LASL, TRNSYS Hedstrom and Freeman (IEA) Ref. #33	6	E/A	1 C	Los Alamos Study Center, an active solar space heated building, 5500 m^2.	Los Alamos, NM	77-78/80	A/W, St	(Wn, Sn, load)
REAP Sepsy, McBride, Blancett, Jones @ OSU (EPRI) Ref. #4,5,6	1	T/A	3 R	Occupied house, actual internal gains;	Columbus, OH	74-75/78	G/F	(Wn, Hu, Sn, T, Is, wind, dew point, door and window openings, water flow, duct airflow)
	2			Same house, average gains;			G/F	
	3			Second occupied house, average gains;			G/F	
	4			Unoccupied house;			E/F	
	5			House of run 3, HVAC changed;			E/F	
	6			Same house, HVAC again changed;			E/R	
	7			Same house, HVAC again changed;			E/Hp	
	8			Same as run 7, different week;			E/Hp	
	9			Unoccupied house of run 4;			E/Cm	
	10			House of run 3; area 1, 2 = 161.6 m^2*; area 3, 5-8, 10 = 151.8 m^2*; area 4, 9 = 151.8 m^2*; *without basement			E/Hp	
REAP Talbert, Jakob, Fisher, @ BCL Ref. #3, 4, 5	1	N/B-	6 R	Six conventional buildings, monitored during development of REAP by OSU (Ref. #6). Data not used during program development. Monitoring was less detailed than for houses in Columbus, OH	Milwaukee, WI	71-75/80	G/F	(Wf, Sn, T, wind, humidity)
	2	N/B-			St. Louis, MO		G/F	
	3a	N/B-			Fresno, CA		G/F	
	3b	M/B-			Same House		G/F	
	4	N/B-			E. Greenwich, RI		E/F	
	5	N/B-			Milwaukee, WI		E/Hp	
	6	N/B-			St. Louis, MO		E/Hp	
	7	N/B-			Milwaukee, WI		E/Cm	
	8	N/B-			Milwaukee, WI		E/Hp	
	9	N/D			St. Louis, MO		E/Cm	
	10	N/B-			St. Louis, MO		E/Hp	

Table 2
Individual Occupied Buildings -Page 1B-

Ref. #	Run #	Sub-meter	Simulation Rept.	Occupancy	Monitoring Intvl.	Intvls. Compared	Input Prep.	Comments
#12	1	H, C, W, A	C, A, Tot	Oa	H	H	C	Simulation was initially performed blind; errors were subsequently found and corrected in subcontracter-supplied internal load and occupancy schedule.
	2							
#33	6	H, W	H	0	na	D, 2W	C, 0	This is primarily a test of the solar system simulation, (although auxiliary energy requirements are calculated) since the building load was given as an input.
#4, #5, #6	1	H, C, W, A	H	Om	15m	W	C	As part of a project to develop a new building energy-analysis program (REAP), the authors monitored 9 dwellings in Columbus, Ohio, in detail. One house was unoccupied; two houses had different HVAC systems installed and operated during the monitoring period. Some components of the model were developed using measured data from some or all of the houses, but the bulk of the model was based on general, theoretical algorithms. A verification of the final model was performed using three houses in various operating conditions and using various HVAC systems.
	2		H	Om		M		
	3		H	Om		W		
	4		H	U		M		
	5		H	Om		W		
	6		H	Om		W		
	7		H	Om		W		
	8		H	Om		W		
	9		C	U		M		
	10		C	Om		W		
#3, #4, #5	1	H, C, W, A	H	Oa	15m	H, D, W	0	Study designed as "blind" verification of REAP, using houses previously instrumented by OSU but not used in code development. Exceptions to the class B- points are: 3) M/B- = a house in which night temperature setback occurred but was not modeled initially. 9) N/D = house in which the characteristics of the air-conditioning equipment was unknown.
	2		H					
	3		H					
	3a		H					
	3b		H					
	4		H					
	5		H					
	6		C					
	7		C					
	8		C					
	9		C					
	10		H, C					

TABLE 2
Individual Occupied Buildings -Page 2A-

Program Name Analyst/Affiliation (Sponsor)	Run #	Type Data	# Bldgs. & Type	Building Description	Location	Date Monit. Date Rept.	Fuel HVAC	Parameters Monit.
BLAST 2.0 Yuill, Phillips @ Yuill and Associates Ref. #11	1	E/C	1 C	Office, classroom, and lab building, terminal reheat and variable air volume using purchased steam and purchased chilled water. 20,900m^2	Canada	76/81	S, E, chilled water	Wf
	2	E/C	1 C	Office, 1115 m^2, two multizone systems, two chillers.	Canada		G/W, G/Ch, E/Ch	Wf
DOE-2.0A Diamond, Hunn, Cappiello @ LANL (US DOE) Ref. #15	1	I/C	1 C	1-story bank, 624.6 m^2	Santa Clara, CA	78*	G/W, E/Ch	W
	2	I/C	1 C	3-story office, 6503 m^2	Dayton, OH	77*	O/W, E/W, E/Ch, E/Cm	W
	3	I/C	1 C	Retail store, 3066 m^2	Albuquerque, NM	75*	E/Ch, T	W
	4	I/C	1 C	Restaurant, 2052 m^2	Downers Grove, IL	77*	G/W, E/Ch	W
	5	I/C	1 C	Hospital, 46,452 m^2	Chattanooga, TN	76*	G, O, E	W
	6	I/C	1 C	School, 3728 m^2	Kennewick, WA	75*	G/W, E	W
	7	I/B	1 C	Study center @ LANL 5969 m^2	Los Alamos, NM	78* *all reported in 81	A, Er, E/Ch, S, T	Sn, W
DOE-2.1A + appliance, model Vine, et al. LBL (DOE, UCD, PG&E, CEC) Ref. #9	1	NS/C	22 R	The 22-house sample is a subset of the 74-house group. Conventional houses-prototype was wood-frame, 183.5 m^2, air conditioners, EER = 7.1	Davis, CA	80/82	E/Cm	Wf, Sf, T, Ta, Z
	2	NS/C	74 R					Wf, Sf, Ta, Z

TABLE 2

Individual-Occupied Buildings -Page 2B-

Ref. #	Run #	Sub-meter	Simulation Rept.	Occupancy	Monitoring Intvl.	Intvls. Compared	Input Prep.	Comments
#11	1	N	Tot (E, S, Z)	Oa	M	Y	K	The 20% error in the second building was attributed to an unconventional air-handling system operated with a large degree of manual control. Since it was due for elimination during retrofits, no further modeling work was undertaken.
	2	N	Tot (E, G)	Oa	M	Y	K	
#15	1	N	Tot (G,E)	Ou	M	M, Y	O	Simulations conducted as first phase of DOE-2 verification project. Each building simulated using actual billing data as reference. These runs intended to serve as reference for later runs by different users.
	2	N	Tot (O,E)	Ou	M	M, Y	O	
	3	N	Tot (E)	Ou	M	M, Y	O	
	4	N	Tot (G+E)	Ou	M	M, Y	O	
	5	N	Tot (G+O+E)	Ou	Y	Y	O	
	6	N	Tot (G+E)	Ou	M	M, Y	C	
	7	H, C, A	Tot (G+E)	Ou	M	M, Y	C	
#9	1	N	Tot	Oa	(W	3M	U	DOE 2.1A simulations of cooling energy use and two different models of appliance energy use were combined to predict total summer electricity use for houses in Davis, CA. Actual weather data were used; a subset of both groups of houses had blower door measurements.
	2			Oa	W	3M	U	

TABLE 3
Groups of Buildings and/or Normalized Weather -Page 1A-

Program Name Analyst/Affiliation (Sponsor)	Run #	Type Data	# Bldgs. & Type	Building Description	Location	Date Monit. Date Rept.	Fuel HVAC	Parameters Monit.
DOE-2 C-factor DD Colborne, Wilson, Hall @ U. of Windsor (NSERC), Ref. #2	1 2	NS/X N/X	75 R	75 houses of same design and construction, all located in one subdivision. 1^{st} plus 2^{nd} story floor area = 89.32 m^2.	Windsor, Ontario, Canada	80-81/82	E/R	Wa
CIRA Dickinson, Grimsrud, Krinkel, Lipschutz @ LBL, (DOE and BPA) Ref. #1	1	E/X	18 R	A group of similar, conventional houses, wood-frame single-family detached, 1,110 to 1,329 ft^2, built 1943 to 1968.	Midway, WA	78-81/82	E/R	Ib, Wna, Sn
SHLM Balance point degree hour, Crenshaw, LBL (NBS and DOE) Ref. #13a,b	1 2	N/X N/X	110 R	NBS/CSA Optimal Weatherization (low income) homes.	US (varied)	78-80/82	Varied Varied	Wfa (Wfa, Is, Ts, E)
DOE-2.1A Hall @ Univ. of Windsor, Canada (National Science & Engineering Research Council) Ref. #21	1 2	E/X E/X	1 R 1 R	Single-story 93.55 m^2 house with basement. Single-story 93.83 m^2 house on slab.	Windsor, Ontario Canada Windsor, Ontario Canada	81-82 78-79	G/F, E/Cm	Wa, Ta, Ib Wa, Ta, Isb
BPA - audit Hirst, White, Goeltz @ Oak Ridge (Bonneville Power Administration) Ref. #32		T/X	243 R	Recipients of audit and loans in BPA's pilot weatherization program.	Pacific NW	80-82/83	E/V	Wfa

TABLE 3

Groups of Buildings and/or Normalized Weather -Page 1B-

Ref. #	Run #	Sub-meter !	Simulation Rept.	Occupancy	Monitoring Intvl.	Intvls. Compared	Input Prep.	Comments
#2	1	N	H	Oa	2M	Y	K	Average space heating use of 75 similar, occupied houses compared to DOE-2 simulation using engineering estimates for unknown inputs. Actual space heat consumption was estimated by subtraction of summer baseload.
	2							2) Conventional C-factor degree-day calculation made for heated and unheated basement cases for the same house.
#1		H, C, W, A	H, HS	Ou	15m	Y	C	Energy use and savings calculated on average for three subgroups of houses, each receiving one or two different sets of retrofits. Actual and predicted use were normalized to typical weather conditions.
#13	1	H	H	Ou	M	Y	K	For SHLM assumed base 65°HDD and engineering estimates used instead of measured temperature and infiltration. For balance point method, spot measurements were used, plus furnace efficiency measurements. Balance point calculated from audit data.
	2	H						
#21	1	N	H, C	Oa	2M	2M, Y	0	Actual heating and cooling use estimated from utility bills by baseload subtraction. Heating use was normalized using ratio of degree days (65 F) for actual weather and TRY tape used in simulation.
	2	N	H, C	Oa	2M	2M, 12M	0	
#32		N	HS	Ou	M	Y	U	Heating savings estimated by calculating normalized annual consumption, base 60 F, for each house before and after retrofit. Data based on approximation to BPA revised audit calculations.

TABLE 4

Unoccupied Buildings -Page 8A-

Program Name Analyst/Affiliation (Sponsor)	Run #	Type Data	# Bldgs. & Type	Building Description	Location	Date Monit. Date Rept.	Fuel HVAC	Parameters Monit.
NBSLD Peavy, Burch, Powell, Hunt @ NBS, (HUD) Ref. #7	1 2 3 4 5 6	E/A	1 R	Four-bedroom townhouse inside a controlled environmental test chamber, 111.5 m^2	(Macon, GA and Kalamazoo, MI (both simulated), plus NBS defined day)		E/F G/F G/F E/F E/Cm E/Cm	Wn, Te, Hu, Is, B, (air-flow rate of furnace, CO_2, heat flow through envelope, room airflow rate).
DOE-2.1 ENCORE-CANADA, HEAP, REAP, TRNSYS 10.1, Merriam, Rancatore, @ ADL, (EPRI) Ref. #17	7	N/A	1 R	Unoccupied 2-story house monitored by Ohio State University and cited in Ref. #3-5. 1634 ft^2 conditioned.	Columbus, OH	74-75/82	E/FR	Wn, Sn, T, Ic
DOE-2.1 Hunn @ LANL (US DOE) Ref. #35	5	E/A	1 R	SERI Validation Test House. One-story passive solar home, crawlspace and attic, 93.5 m^2. Modeled as four zones.	Golden, CO	82/83	P, E/R	Wn, Sn, B, T, Ic, (Film coefficients, ground flux and temp., glazing transmission, ground albedo)
BLAST-3.0 Bauman, Anderson, Carroll, Kammerud, Friedman Ref. #22	1	M/A	1 R	NBS massive test building in environmental chamber, simulated desert conditions, 6.5 m x 5.3 m x 4.7 m, Floor area = 34.32 m^2.	Environmental chamber	79/83	E/Cm	Wn, Te, Ic, (wall heat fluxes)
NBSLD Steady-State Peavy, Powell, Burch, @ NBS (NBS, HUD) Ref. #16	20	/A	1 T	Massive masonry building inside controlled environmental test chamber, 37.2 m^2	Test chamber, temperature range from 10-100 F	73	E/R	(Is, B, Wn, Te, ground temperature, envelope heat flow)
DOE-2.1A Goldenberg, Kornitz, McClain @ Oak Ridge National Lab Ref. #18	1 2 3	E/B-	1 R	ACES control house. (1000 m^2 used in plotting)	Knoxville, TN	77-79/82	E/R, E/Hp E/Hp	Wf, T, I
	4	I/B-	4 R	Houses from U.S. DOE Electric Energy Systems Load Management demonstration, typical wood-frame construction.	Little Rock, AR	81/82	E/Cm	T,

TABLE 4
Unoccupied Buildings -Page 18-

Ref. #	Run #	Sub-meter	Simulation Rept.	Occupancy	Monitoring Intvl.	Intvls. Compared	Input Prep.	Comments
#7	1	H, C, W, A	H	S	0.5H	D	C	Intensively instrumented townhouse with simulated occupancy operated inside environmental chamber with artificial weather conditions simulating diurnal cycles in Macon, GA, and Kalamazoo, MI. No wind, precipitation, or direct solar gain were simulated; air temperatures matched "sol-air" temperatures.
	2		H					
	3		H					
	4		H					
	5		C					
	6		C					
#17	7	H, C, A, W	H	U	15 m	H, D, M	K	Blind simulations of unoccupied, well-monitored house in comparative study of five simulation programs.
#35	5	H, A	H, T	U	H	H, D, W	K	SERI test house modeled as four zones; comparisons reported for each zone.
#22	1	CL	CL	S	H	H, D	K	Severe desert climate simulated in environmental chamber. Error in room air measurement corrected.
#16		H	H, HP	U	0.5H	D	C	A simple, massive test building, unoccupied, was operated inside the NBS environmental chamber (same as ref. #7). No wind, precipitation, or direct solar gain effects imposed or modeled. Both NBSLD and steady-state methods were used to calculate daily average heating use and peak heating use.
#18	1	H, C	H	U	≤ D	M, 3M	K	House operated in three modes: (1) resistance heat, (2) HP cooling, (3) HP heating.
	2		C					
	3		H					
	4	C	C	Ou	≤ D	M, 5M	K	Based on preliminary results, ventilation rates and shading coefficientsn were modified to account for unknown occupant effects.

REFERENCES TO TABLES

1a. J.B. Dickinson; D.T. Grimsrud; D.L. Krinkel; and R.D. Lipschutz, Results of the Bonneville Power Administration Weatherization and Tightening Projects at the Midway Substation Residential Community, LBL-12742, UC-95d, Lawrence Berkeley Laboratory, Berkeley, CA, 1982.

1b. J.B. Dickinson, Lawrence Berkeley Laboratory, personal communication, 1982.

2. W.G. Colborne; N.W. Wilson; and J.D. Hall, "A Comparative Study of Methods to Determine Annual Energy Consumption for Space Heating," presented at Energex 82, Regina, Saskatchewan.

3. Analysis of Field Test Data on Residential Heating and Cooling, Battelle, Columbus Laboratory report to EPRI; PIs: S.G. Talbert, F.E. Jakcob, and R.D. Fisher, EA-1649, (EPRI, Palo Alto, CA) 1980.

4. R.S. Blancett; C.F. Sepsy; M.F. McBride; and C.D. Jones, "Energy Calculation Procedures for Residences with Field Validation," ASHRAE Transactions, Vol. 85, 1979, Pt. 1, pp. 695-704.

5. R.S. Blancett; M.F. McBride; C.F. Sepsy; and C.D. Jones, "Residential Thermal Load Analysis and Validation," ASHRAE Transactions, Vol. 85, 1979, Pt. 1, pp. 678-683.

6. C.F. Sepsy; M.F. McBride; R.S. Blancett; and C.D. Jones, Fuel Utilization in Residences, EA-894, prepared by The Ohio State University for Electric Power Research Institute, Palo Alto, CA, Sept. 1978.

7. B.A. Peavy; D.M. Burch; C.M. Hunt; and F.J. Powell, Comparison of Measured and Computer-Predicted Thermal Performance of a Four-Bedroom Wood-Frame Townhouse, Washington, D.C. National Bureau of Standards, NBS Building Science Series 57 1975.

8a. R.S. Dumont; H.W. Orr; and C.P. Hedlin, "Low-Energy Houses: Measured Energy-Consumption Figures," ASHRAE Transactions, 89, Pt. 1a, 1983.

8b. R.S. Dumont, National Research Council Canada, personal communication, 1981.

9. E.L. Vine; P.P. Craig; J.C. Cramer; T.M. Dietz; B. Hackett; D.J. Kowalczyk; and M.D. Levine, "The Applicability of Energy Models to Occupied Houses: Summer Electric Use in Davis," Energy, Vol. 7, 1982, No. 11, pp. 909-925.

10. J.F. Kerrisk; J.E. Moore; N.M. Schnurr; and B.D. Hunn, "Passive-Solar Design Calculations with the DOE-2 Computer Program," Proceedings of the 5th National Passive Solar Conference, Amherst, MA, Oct. 1980, pp. 116-120.

11. G.K. Yuill and E.G. Phillips, "Comparison of BLAST Program Predictions with the Energy Consumptions of Two Buildings," ASHRAE Transactions, Vol. 87, 1981, Pt. 1, pp. 1200-1206, 1981.

12. D. Herron; L. Windingland; and D. Hittle, Comparison of Building Loads Analysis and System Thermodynamics (BLAST) Computer Program Simulations and Measured Energy Use for Army Buildings, Construction Engineering Research Laboratory, U.S. Army Corps. of Engineers, Interim Report, CERI-IR-E-161 Champaign, IL, 1980.

13a. R. Crenshaw and R. Clark, Optimal Weatherization of Low-Income Housing in the U.S.: A Research Demonstration Project, NBSS 82-144, Washington, D.C., National Bureau of Standards, 1982.

13b. R. Crenshaw, Instrumented Residential Audits, LBL-14853, presented at 2d ACEEE Summer Study on Energy Efficient Buildings, Santa Cruz, CA, 1982 Lawrence Berkeley Laboratory, Berkeley, CA, 1982, p. 13.

14. R.S. Dumont; H.W. Orr; and M.E. Lux, "Comparison of Energy Consumption Calculations using HOTCAN with Measured Values from Unoccupied Test Huts," 9th Annual Conference, Solar Energy Society of Canada, Windsor, Ontario, 1983, pp. BEC 9.1-9.5.

15. S.C. Diamond; B.D. Hunn; and C.C. Cappiello, *DOE-2 Verification Project, Phase I, Interim Report*, Los Alamos Scientific Laboratory, (Los Alamos, NM) LA-8295-MS, UC-32 and UC-38, 1981.

16. B.A. Peavy; F.J. Powell; and D.M. Burch, *Dynamic Thermal Performance of an Experimental Masonry Building*, U.S. National Bureau of Standards, Building Science Series 45, Washington, D.C., 1973.

17. R.L. Merriam and R.J. Rancatore, *Evaluation of Existing Programs for Simulation of Residential Building Energy Use*, EA-2575, prepared by Arthur D. Little, Inc. for the Electric Power Research Institute (EPRI) and Gas Research Institute, EPRI, Palo Alto, CA, 1982.

18. D. Goldenberg; M.A. Karnitz; and H.A. McLain, memo to J.W. Michel, Oak Ridge National Laboratory, 22 Nov. 1982. Report forthcoming 2/84, ORNL-CON-113.

19. D. Clement; J.P. Hamon; J. Neppe; M. Raoust; L.M. Chounet; A. Lahellec; D. Picard; and F. Winkelmann, "Rehabilitation de la Cite du Lievre d'Or a Dreux," Office Public d'Habitations a Loyers Moderes de la Ville de Dreux; presented at the Conference de Cannes sur l'Architecture Solaire, Cannes, France, 13-16 December 1982.

20. National Association of Homebuilders Research Foundation, Inc., *The NAHB Energy Saver Homes, Design Energy Consumption Versus Measured Energy Consumption of the Ten NAHB Energy Saver Homes*, NAHB Research Foundation report to U.S. Department of Energy, Washington, D.C., 1983.

21. J.D. Hall, *A Retrofit Strategy for two Canadian Residential Dwellings Using the Building Energy Simulation Program DOE-2.1A*, Master's thesis, Dept. of Mechanical Engineering, University of Windsor, Windsor, Ontario, Canada, 1983.

22. F. Bauman; B. Andersson; W.L. Carroll; R. Kammerud; and N.E. Friedman, "Verification of BLAST by Comparison With Measurements of a Solar-Dominated Test Cell and a Thermally Massive Building," *Transactions of the ASME, Journal of Solar Energy Engineering*, Vol. 105, May 1983, pp. 207-216.

23. T. Kusuda; E.T. Pierce; and J.W. Bean, *Comparison of Calculated Hourly Cooling Load and Attic Temperature with Measured Data for a Houston Test House, ASHRAE Transactions*, Vol. 1981, 87 Pt. 1; No. 1, pp. 1185-1199.

24a. R. Judkoff; D.N. Wortman; and J. Burch, *Empirical Validation Using Data from the SERI Class-A Validation House*, Solar Energy Research Institute, SERI/TP-254-1928, Golden, CO, April 1983, for presentation at the ASES 1983 Annual Meeting, Minneapolis, MN, June 1-3, 1983.

24b. R. Judkoff; D. Wortman; and J. Burch, *Measured Versus Predicted Performance of the SERI Test House: A Validation Study*, SERI/TP-254-1953, presented at the National Heat Transfer Conference, Seattle, WA, July 1983, published by Solar Energy Research Institute, Golden, CO May 1983.

25. C.S. Weiss and T.M. Newcomb, "Home Energy Loan Program Energy Savings Analysis," report by Conservation and Solar Division, Seattle City Light, 1982.

26. Prepared Testimony of Thomas D. Dukich before the Idaho Public Utilities Commission Case # P-300-24; Case # U-1008-176.

27. Puget Power: J.J. Croft, Residential Weatherization Program Evaluation of Actual Savings 82-8-6.

28. S.R. Hanningan and P. King, *Residential Conservation Programs at Pacific Power and Light Company: Models Forecasts, and Assessments*, presented at EPRI Workshop on "Measuring the Effects of Utility Conservation Programs," at Columbus, OH, February 11, 1982.

29. B. Andersson; F. Bauman; and R. Kammerud, "Verification of BLAST by Comparison with Direct Gain Test Cell Measurements," LBL-10619, UC-95d, Lawrence Berkeley Laboratory, Berkeley, CA, Nov. 1980.

30. T. Kusuda and J.W. Bean, "Comparison of Calculated Hourly Cooling Load and Indoor Temperature with Measured Data for a High Mass Building Tested in an Environmental Chamber," *ASHRAE Transactions*, Vol. 87. 1981, Pt. 1, American Society of Heating, Refrigerating, pp. 1232-1240.

31. T.K. Stovall, *Verification of the DOE Model Audit*, *ORNL/CON-118*, Oak Ridge National Laboratory, Oak Ridge, TN, November 1983. (18pp.)

32. E. Hirst; D. White; and R. Goeltz, *Comparison of Actual Electricity Savings with Audit Predictions in the BPA Residential Weatherization Pilot Program*, *ORNL/CON-142*, Oak Ridge National Laboratory, Oak Ridge, TN, November 1983, p. 33.

33. J.C. Hedstrom, and T.L. Freeman, "Validation of Solar System Simulation Codes by the International Energy Agency," Proceedings of the *Systems Simulation and Economic Analysis Conferences*, *Second*, San Diego, Cal., 1980, pp. 85-90.

34. J.E. Moore; N.M. Schnurr; J.F. Kerrisk; and B.D. Hunn, "Thermal Storage Wall Model Development in the DOE-2 Computer Program," Proceedings of the 1981 Annual Meeting, Philadelphia, PA, *American Section of the International Solar Energy Society, Inc.* *Vol. 4.2* eds. Barbara H. Glenn and Gregory E. Franta, 1981, pp. 972-976.

35a. B.D. Hunn, "Analysis of Validation Data Sets in the Class A Performance Evaluation Program," *Progress in Passive Solar Energy Systems*, 8th National Passive Solar Conference, American Solar Energy Society, ed. Hayes and Andrejko, 1983, pp. 9-14.

35b. B.D. Hunn, University of Texas at Austin, personal communication, 1983.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720