Title

HOME ENERGY RATING SYSTEMS: SAMPLE APPROVAL METHODOLOGY FOR THREE TOOLS

Author

Huang, Y.J.

Publication Date

1985-03-01

LBL-18669

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

APPLIED SCIENCE
DIVISION

Presented at the American Council for an Energy-Efficient Economy (ACEEE) 1984 Summer Study, Santa Cruz, CA, August 14-22, 1984; and published in the Proceedings, Volume B

HOME ENERGY RATING SYSTEMS: SAMPLE APPROVAL METHODOLOGY FOR THREE TOOLS

Y.J. Huang, J.B. Dickinson, C. Hsui,
A.H. Rosenfeld, and B.S. Wagner

March 1985

APPLIED SCIENCE
DIVISION

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

DISCLAIMER

Published in the Proceedings of the
American Council for an Energy-Efficient
Economy (ACEEE) 1984 Summer Study on
Energy-Efficient Buildings, Volume B,
page 135 ff. Updated November, 1984,
to include comparisons for a third
calculational program.

LBL-18669
EEB 84-3

HOME ENERGY RATING SYSTEMS: SAMPLE APPROVAL METHODOLOGY FOR THREE TOOLS

Y. Joe Huang
J. Bruce Dickinson
Chean Hsui
Arthur H. Rosenfeld
Barbara S. Wagner

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

March 1985

HOME ENERGY RATING SYSTEMS :
SAMPLE APPROVAL METHODOLOGY FOR THREE TOOLS *

Y. Joe Huang, J. Bruce Dickinson, Chean Hsui,
Arthur H. Rosenfeld, and Barbara S. Wagner
Lawrence Berkeley Laboratory

I. INTRODUCTION

Over the past ten years a number of systems have been developed to rate the energy efficiency of single-family houses. These systems can be categorized as either calculational, prescriptive, or performance systems. Calculational systems range from simple degree-day methods to large computer simulation codes. Prescriptive systems are derived from calculations, but require only simple arithmetic to produce points, labels, and, in more elaborate ones, actual energy use. Performance systems are those that use past utility bills as a basis for assigning ratings. Of the 86 systems reviewed in a 1982 study, 59 are prescriptive, 24 are calculational, and only 3 are performance (Hendrickson, 1982).

At present, different rating systems are apt to give divergent values due to differences in their assumptions as well as calculational methods. If the public is to accept the validity of rating systems, there must be a method to assess their accuracy and to certify those that are technically reliable. The certification procedure can also diagnose those areas where rating systems need improvement, and suggest ways of bringing compatibility to the present chaos in rating system numbers.

II. TECHNICAL ISSUES IN CERTIFYING RATING SYSTEMS

An ideal method to certify rating systems would be to compare them to a set of carefully monitored energy consumption data for actual houses. Authors of rating systems would be furnished drawings and descriptions of these houses and asked to compare their energy use values or equivalent rating points to the actual measured usage of those houses. Unfortunately, the amount of measured data needed to reliably assess conservation measures covered in even the simplest rating systems would be very large. Moreover, questions would invariably arise about how typical

---

* Note: The tables and text in this March 1985 version differ slightly from those in the Proceedings of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings (Santa Cruz, Aug. 1984); comparisons for a third calculational program were added in November, 1984.

were the houses, their occupants' lifestyles, locations, or even the weather during the measuring period. Consequently, this ideal evaluation procedure is difficult to put into practice at the present, although it may be feasible in the future with reduced costs and improved reliability in monitoring houses.

Given present circumstances, a practical certification procedure for rating systems would be to compare their results to those produced by a comprehensive and validated computer simulation program. Candidates for serving as this secondary standard include hourly thermal load models such as DOE.2, BLAST or TARP.* The accuracy of these detailed building simulation programs will remain an issue due to the scarcity of reliable monitored data. One report notes that most "validation" studies have been inconclusive because incomplete or missing data have allowed the authors to "tune" input parameters to achieve agreement with measurements (Wagner,1984). However, indications from the most thorough validation efforts to date suggest that detailed programs such as DOE-2 and BLAST are within 10% for predicting energy use in typical residential houses over periods of several days or longer (Judkoff, 1983; A.D. Little, 1982). We recognize that further work is needed in validating and updating such hourly simulation programs, but we believe that, when used in a competent and well documented fashion, they provide the best available basis for assessing the accuracy of rating systems based on less detailed calculational techniques.

After a standard simulation program has been chosen, it is then used to calculate energy budgets for various conditions spanning the range of building types, locations, and conservation measures found in typical rating systems. These values then serve as the secondary standard against which different rating systems can be judged.

For rating systems covering detached houses, the test procedure should include at least three generic prototypes (one story, two story, and split-level houses). If the rating system also covers attached houses, one and preferably two, additional prototypes, either an average townhouse unit, or a townhouse separated into middle and end units, should be added. The reason for using several prototypes is to test the ability of a rating system to distinguish between variations in wall-to-floor ratio and building internal loads.

A rating system should be able to account for climate variations in the regions for which it is used. Calculational systems that encompass the entire U.S. should be tested for at least five

---

* This is similar to the procedure proposed by the California Energy Commission (CEC) in June 1984 for certifying programs for use in its Title 24 new building standards. For residential buildings, CEC relies on energy budgets for prototypical houses calculated by the CALPAS.1 computer program as a secondary standard against which other programs are compared (for example, see Micropas User's Manual, 1984). For new office buildings, CEC has proposed using DOE.2.1A as the secondary standard.

locations (cold, temperate, temperate with high solar gain, hot arid, and hot humid) and preferably more. Prescriptive systems that are divided into climate zones should be tested zone by zone.

For calculational systems, all assumptions used in setting the secondary standard, such as building operations, building design, construction details, equipment characteristics, modeling simplifications, as well as the climate data used (including hourly weather tapes, if necessary), must be documented in detail and publicly available so that authors of rating systems can match them as closely as possible when calculating their energy values for comparison.

For prescriptive or simpler calculational systems, there will be practical difficulties in matching assumptions since most if not all of these hidden assumptions are fixed and often different from system to system. There are two strategies that could be used for the certification process. The first is to modify the standard program inputs to match those of the rating system and make special sets of comparison data. The second is to ask that those systems be adjusted to the standard set of operating conditions and assumptions prior to certification. The first approach, while more accommodating, would require much more work, as well as permit continued incompatibility between rating systems, and, in the worse case, a loophole for rating systems with unreasonable assumptions. For these reasons, we recommend the second approach, although we realize that it requires the definition and acceptance by both industry and the public of a set of standard building operating conditions.

Another issue that must be considered in developing a certification process is that many prescriptive systems use qualitative terms to define building characteristics and express building energy use in normalized values such as points. In such cases, the authors are required to convert such terms to their equivalent thermodynamic value or conventional engineering units. For example, infiltration terms such as "average" or "loose" should be translated into effective leakage area or air changes per hour, and duct insulation or flue dampers into changes in system efficiency.

After building parameters, operating conditions, and climate data have been matched as closely as possible, an assessment can then be made of the technical accuracy of the rating system as compared to the standard program. We reviewed more than twenty existing or proposed prescriptive rating systems described in a PNL report (Hendrickson et.al.) to determine which conservation measures are generally considered in such home energy rating systems and need to be addressed in a certification procedure. The results are summarized in Table I, where the measures are grouped as those affecting the building shell, solar gain, equipment, and hot water system.

A detailed certification procedure could conceivably compare rating system predictions to those by the standard program for each measure covered in that rating system. Such an item-by-item check would be akin to reconstructing the entire rating system and is probably more

Table I. Conservation measures covered in 21 existing rating systems

Measure	Method of description used
Building Shell-	
(1) Ceiling	By R-value
(2) Wall	By R-value
(3) Foundation or Floor	By R-value and depth
(4) Infiltration	Qualitative (i.e., "loose") or descriptive (i.e.,are windows caulked?)
(5) Window layers	By number of panes
(6) Window sash type	Descriptive (with thermal break, etc)
(7) Window insulation	Descriptive (drapes, etc.) or by R-value
(8) Storm or insulated doors	Yes or no
(9) Attic vent	Type and area of vent
Solar Gain -	
(1) Window glass type	Descriptive (reflective, colored,etc.)
(2) Window overhangs	by amount of overhang projection *
(3) Window areas, esp. south	By area or percent of floor
(4) House orientation	Either N-S or E-W
Equipment -	
(1) Type	Points for heat pumps
(2) Efficiency	Numeric
(3) Sizing	Correct sizing by rough calculation
(4) HVAC location	Either in or out of living space
(5) Duct insulation	Yes or no
(6) Automatic setback thermostat	Yes or no
(7) Special controls	filter indicator, zonal controls
Domestic Hot Water Equipment -	
(1) Type	Descriptive (active solar, passive solar)
(2) Insulated tank	Yes or no
(3) Insulated pipes	Yes or no
(4) Location of tank	Either in or out of living space
(5) Low-flow showerhead	Yes or no
Other equipment -	
(1) Fireplace dampers	Yes or no
(2) Fireplace glass screen	Yes or no
(3) Appliances	Descriptive

* Note: The energy impact of a window overhang depends on its geometry, including both its width and height above the window. Rating systems consider only the width of a window overhang will give inaccurate values for its effect.

detailed than necessary or feasible. A more reasonable approach is to use the standard program only to check key parameters that reflect distinct thermodynamic processes. A minimum list of key parameters should include changes in (1) overall building conductance (UA), (2) infiltration (air changes per hour), (3) solar gain (windows orientation and shading coefficients), and (4) equipment efficiency (AFUE or SEER).

Other parameters that should be checked in a thorough certification procedure are (5) changes in conductance for a single building component (i.e., varying ceiling insulation while holding the rest of the house constant), (6) foundation heat losses, and (7) the effects of thermal mass, if they are included in a rating system.

Once the accuracy of the rating system for these key parameters have been determined (see IV for sample test), its accuracy for most other measures could be sufficiently verified using interpolated values from the key tests, or by simply comparing engineering inputs. For example, secondary standard values for different window sash types can be interpolated from the tests for overall building conductance. Comparison of engineering inputs involves comparing the assumed impacts of different conservation measures, expressed as changes in the building conductance, infiltration rate, etc. If a rating system uses engineeering values that differ substantially from most research information such as ASHRAE or DOE studies, the rating system authors must supply adequate documentation. For example, rating system authors who credit duct insulation with a 20% improvement in furnace efficiency must substantiate their claim.

III. CRITERIA FOR COMPARISION

The accuracy of a rating system can be expressed either in terms of percent or absolute differences from the the standard program. For this study, we chose the four criteria of dollar differences in annual heating, and cooling energy costs for any house, and dollar differences in annual heating and cooling energy savings between different houses. We distinguish between annual energy costs and annual energy savings because the latter allows houses and conservation measures to be compared and may be influential in affecting consumer decisions. In addition, we feel that the criteria for annual energy savings should be more stringent than that for annual energy costs. We rejected the concept of percent differences because they may equate to high dollar differences in one location or house and insignificant dollar differences in other locations or houses.

IV. A SAMPLE TESTING PROCEDURE FOR CERTIFYING RATING SYSTEMS

A sample testing procedure was developed and applied to three calculational rating system tools, CIRA, the Energy Slide Rule, and CALPAS3. CIRA is a simplified microcomputer program written for residential audits using a variable base degree day calculation method. The Energy Slide Rule is a mechanical device that computes home energy values by correlating a comprehensive data base of DOE.2 simulations for four prototype houses in 45 locations. CALPAS3 is a hourly simulation model developed by Berkeley Solar Group for residential and small commercial buildings. (for further details on the three tools, see EPB, 1983, Huang(2),1983, and BSG, 1983). DOE.2 (Version 2.1A) was selected as the standard program, and the testing procedure followed for a one-story prototype building in three locations - Washington, Minneapolis, and Miami. This testing procedure is included here only for illustrative purposes, and should not be regarded as definitive or comprehensive for any of the three tools.

The testing procedure consists of comparing heating and cooling energies predicted by the rating system tool to those from the standard program for twelve options of a prototype building. To avoid bias towards the Energy Slide Rule, we purposely selected a prototype house that differed in size, geometry, overhangs, and window distributions from those used in generating the Slide Rule data base. Summaries of the building description and assumed operating conditions are given in Table II. Descriptions of the twelve options are given at the beginning of Tables III and IV. These include six options to test whole-house conductances ranging from a super-insulated (House A) to a totally uninsulated house (House H); three to test infiltration rates from 0.4 to 1.0 ach (Houses C, D, and E); and three to test conductance changes in a single building component (ceiling R-value from R-0 to R-38, Houses F,G, and H).

In addition, six more options are used to test changes in solar gain due to increasing the amount of windows on a loose and a tight house from 10% equally distributed on four sides of the house to 20% glazing equally distributed, and to 20% glazing with 12.5% on the south (Table IV, Houses D, D1, D2, A, A1, and A2). These window options were tested only for the Energy Slide Rule and CIRA.

These 16 tests represent a skeletal series of comparisons covering the key building parameters mentioned earlier (equipment efficiency is implicitly covered, since each test was done with heating and cooling equipment). Thus, we believe the above procedure is adequate for testing the basic calculational accuracy of rating systems, with the exception of the hot water system, which is not a space conditioning measure. However, if a more detailed testing procedure is required for the individual items on Table I, the secondary standard would have to be expanded either by more test runs or by interpolations.

Table II. Description of Prototype House and Operating Assumptions

House type	1-Story Ranch House
House Geometry	L-shaped
Foundation Types	Basement in cold and temperate locations Slab on grade in hot locations
Floor Area (sq.ft.)	1080
Floor condition	Covered with rug furniture covering 20% of floor
Roof Area (sq.ft.)	1362
Net Wall Area (sq.ft.)	953
Perimeter Length (ft.)	141
Roof	20.8° pitch, 2 ft. south overhang
Wall Construction	Wood frame 2 x 4 18" O.C.
Window Area (pct. of floor area)	16.1 %
South	5.3 %
North	5.0 %
East	2.7 %
West	3.1 %
Window shading	0.6316 shading coefficient
Internal Loads	56,106 Btu/day sensible load, 12,156 Btu/day latent load
Thermostat settings	70°F heating, no setback 78°F cooling, no venting
Equipment efficiencies	77 Furnace AFUE, duct loss 10% 9.2 A/C SEER, duct loss 10%

The above procedure also does not test for passive solar measures such as increased thermal mass or south windows beyond 12.5% of the floor area. These measures are not typically found in conventional houses, and also have appeared on only a few of the rating systems reviewed.

V. RESULTS

Results of our interprogram comparisons are given in Table III. For *units* we have chosen annual dollars, which we believe are of most interest to home-buyers or lenders. In our earlier writings we had discussed percentage differences and a desired accuracy of ± 15-20% (Rosenfeld and Wagner, 1982). However, we found that using percentages tended to exaggerate the differences for superinsulated homes. Thus, our Tightness *A* home has, according to the secondary standard, a small heating bill of $144 in Washington, D.C.; CIRA overpredicts by 24%, but this is still only $35 a year.

Table III shows six steps of decreasing "tightness" (covering a heating cost range of 500% and a cooling range of 130%), and two more steps (C and E) where we vary the infiltration by ± 0.3 ach for a current-practice house and thus go from a Washington heating bill of $279 to $380.

Table III. Interprogram differences between DOE.2 (used as a secondary standard) and the Slide Rule (SR), CALPAS3 or CIRA, for 8 "tightnesses" of a 1080 ft^2 Prototype House in 3 cities: Washington, D.C., Minneapolis, and Miami.

Units are annual dollars. For heating the fuel is assumed to be gas at $6/Mbtu; for cooling, electricity at $0.07/kWh.

House Type		Superinsulated							Uninsulated
		A	B	C	D	E	F	G	H
Ceiling (R-value)		49	30	-	19	-	**38**	**19**	**0**
Wall (R-value)		27	11	-	11	-	-	0	-
Foundation (R-value & depth)		10-8'	5-8'	-	5-8'	-	-	0	-
Infiltration (ach)		0.7	0.7	**0.4**	**0.7**	**1.0**	-	0.7	-
Glazing (panes)		3	2	-	1	-	-	1	-
Washington Annual Gas Heating									
DOE.2	($)	**144**	**233**	**279**	**329**	**380**	**453**	**479**	**712**
SR - DOE.2	($)	+6	+2	+3	+5	+7	-3	-5	-18
CIRA - DOE.2	($)	+35	+19	+48	+50	+56	+64	+58	+29
CALPAS3 - DOE.2	($)	+11	+15	+1	0	-8	+15	+10	-45
Washington Annual Cooling									
DOE.2	($)	**200**	**210**	**214**	**218**	**222**	**231**	**236**	**255**
SR - DOE.2	($)	+4	-6	-1	-3	-4	-3	-2	+11
CIRA - DOE.2	($)	-43	-42	-41	-41	-42	-45	-44	-7
CALPAS3 - DOE.2	($)	-86	-82	-67	-72	-77	-83	-76	-80
DOE.2 (sensible)	($)	**163**	**174**	**186**	**183**	**181**	**195**	**200**	**224**
CALPAS3 - DOE.2 (sens)	($)	-49	-46	-39	-37	-36	-47	-40	-39
Minneapolis Annual Gas Heating									
DOE.2	($)	**350**	**527**	**627**	**716**	**805**	**955**	**1004**	**1393**
SR - DOE.2	($)	+8	-2	-5	-2	-2	-37	-40	-109
CIRA - DOE.2	($)	+64	+37	+53	+79	+90	+99	+92	+78
CALPAS3 - DOE.2	($)	+29	+40	+12	+14	+4	+64	+37	+10
Miami Annual Cooling									
Slab Foundation	($)	5-4'	5-2'	5-2'	5-2'	5-2'	0	0	0
DOE.2	($)	**493**	**528**	**515**	**557**	**590**	**620**	**630**	**721**
SR - DOE.2	($)	—	-13	-2	-7	-2	-6	-4	+12
CIRA - DOE.2	($)	-12	+24	-10	-23	-44	-61	-60	-41
CALPAS3 - DOE.2	($)	-159	-159	-119	-160	-191	-79	-64	38
DOE.2 (sensible)	($)	**335**	**369**	**396**	**397**	**399**	**452**	**466**	**555**
CALPAS3 - DOE.2 (sens)	($)	-2	+19	+35	+35	+33	+89	+98	+204

Note: Foundations (or slabs) have perimeter insulation. Thus, 5/4' means R-5 vertical insulation to a depth of 4 feet. Washington and Minneapolis have heated basements; Miami, as indicated, has a slab.

The Slide Rule compares extremely well to DOE.2 in the middle of the table (Columns C,D,and E) and exceeds the ± $100 threshold only for a completely uninsulated, single-glazed home in Minneapolis. CIRA typically overpredicts heating and underpredicts cooling by ± $50 in the middle columns of the table. CIRA's combined heating-plus-cooling predictions agree with DOE.2 to within a few dollars/year. CALPAS3 shows negligible differences in heating (except for the totally uninsulated house), but lower cooling budgets by $60 to $80, due in large part because the CALPAS3 version used does not calculate latent loads. If we compare only cooling energies due to sensible loads, the differences between the secondary standard and CALPAS3 drops by a half.

For Minneapolis heating, CIRA typically predicted higher energies than the secondary standard, but still within the ± $100 criteria. For CALPAS3, the differences are again negligible, between $4 and $60. For Miami cooling, CIRA again underpredicts by the same amount as for Washington, while CALPAS3 significantly underpredicts when compared to total cooling, but overpredicts slightly when compared to sensible cooling energies, and exceeds the $100 threshold for the totally uninsulated house.

We return to the smooth sidewise variation of CIRA. Thus, for Washington heating, it is $50 high for Col. D, but never varies from this $50 offset by more than $15 (except for $29 for the totally uninsulated house H). This suggests that the sponsors of a rating tool be allowed and encouraged to calibrate or "offset" their tool for a given city or state. In any case, those responsible for certification must recognize that a single offset of $50 or $100 is easily fixed, whereas a random sidewise variation of the same magnitude is disconcerting to the buyer.

Table IV shows additional Washington results for the Energy Slide Rule and CIRA as we explore the sensitivity of a 1540 ft^2 prototype house to changes in window area and orientation. The numbers shown are the differences in predicted heating and cooling energy savings, thus revealing whether there is agreement in the effectiveness of added conservation measures. As mentioned earlier, the criteria in predicting trends should be more strict than that for predicting total energy use. In Table IV, we see that the Energy Slide Rule shows negligible errors in predicting changes in heating bills, but underpredicts cooling increases by as much as $21 (out of $60). The discrepancies between CIRA and DOE.2 are similarly in the the neighborhood of $20.

Although this sample test procedure is not complete, the indications from the results is that there seems to be good agreement for the Energy Slide Rule and acceptable agreement for CIRA in both heating and cooling, very good agreement for CALPAS3 in heating, and acceptable agreement in cooling in areas with low to medium latent loads. However, some work is needed for CALPA3 for areas with high latent cooling loads.

Table IV. Sensitivity of heating and cooling costs to differing solar gain in 1540 sq.ft. prototype ranch house. Units are annual dollars, as in Table III, but the entries indicated by Δ's are the **differences** between base cases A and D of Table III and the increased window conditions shown here as A',A",D',and D".

	Superinsulated (3-pane windows)			Conventional (1-pane windows)		
House Types	A'		A"	D'		D"
Increase in window area	**+ 10% eq. distrib.**		**+ 10% south**	**+ 10% eq. distrib.**		**+ 10% south**
Ceiling (R-value)	-	49	-	-	19	-
Wall (R-value)	-	27	-	-	11	-
Foundation (R-value & depth)	-	10/8'	-	-	5/8'	-
Infiltration (ach)	-	0.7	-	-	0.7	-
Glazing (panes)	-	3	-	-	1	-
Washington Annual Gas Heating						
Δ DOE.2 ($)	**-13**		**-48**	**+75**		**+42**
Δ SR - Δ DOE.2 ($)	0		-7	-1		-6
Δ CIRA - Δ DOE.2 ($)	+2		+1	+31		+25
Washington Annual Cooling						
Δ DOE.2 ($)	**+57**		**+52**	**+66**		**+60**
Δ SR - Δ DOE.2 ($)	-2		+15	+14		+21
Δ CIRA - Δ DOE.2 ($)	+2		+4	-4		-7

We have not tested extremes of passive solar design thermal mass, but we conclude that for conventional housing all three tools we tested are acceptable over a broad domain. This covers heating and cooling only. In our opinion, any rating system should also cover hot water and appliances (Rosenfeld and Wagner, 1982), as does CIRA.

VI. CONCLUSIONS

Our experiment suggests that it is possible to assess the technical accuracy of different rating systems using a large simulation program as a standard yardstick, provided that the assumptions, as well as the modeling techniques used in developing the secondary standard, are fully documented. This is particularly important when working with rating system tools such as CALPAS3 that have very flexible inputs. For these simulation programs, the documentation must include not only the conditions being modeled, but if necessary, also the algorithms used. Based on our experience, for most calculational systems the certification procedure will require direct and close interaction between the certifying body and the rating system authors.

If this certification procedure is to be workable, there needs to be sufficient general agreement on building operations assumptions, selection of a standard program, and the modeling techniques for generating the secondary standard. Thus, some national consortium of agencies and trade associations must define standard building operating conditions such as indoor thermostat setting and setback amount and duration, internal loads, window venting and shading schedules. It might also address the question of default values for furnace efficiencies and the COP for heat pumps and air conditioners at full and part load.

The choice of the standard simulation program and the modeling methodology should be carefully scrutinized, and will no doubt generate some controversy. However, we feel that this approach will at least provide a benchmark for comparing various rating systems and is preferable to the current incompatibility of different systems or ad-hoc comparisons that are difficult for others to evaluate. The certifying body must also decide what comprises an acceptable level of accuracy (e.g., good to ± $100). One possible alternative is that, in addition to merely accepting a tool as "satisfactory" extra credit can be given to those tools that are more accurate by stating that they are good to within so many dollars for typical local homes.

IX. ACKNOWLEDGEMENTS

We thank Jim Bull and Peter Cleary of LBL, and Bruce Wilcox and Robin Mitchell of the Berkeley Solar Group. This work was done with partial support from the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

X. REFERENCES

Berkeley Solar Group (BSG), "CALPAS.3 User's Guide", 1983, Berkeley CA.

Energy Performance of Buildings Group (EPB), "Computerized Instrumented Residential Audit (CIRA-1.0) Reference Manual, Lawrence Berkeley Laboratory Pub-442, 1982 (rev. Feb. '83), Berkeley, CA.

Hendrickson, P. L., Garrett-Price, B. A., and . Williams, T., "Overview of Existing Residential Energy-Efficiency Rating Systems and Measuring Tools", Pacific Northwest Laboratory, 1982, Richland, WA.

Huang, Y. Joe, et.al., "Affordable Housing Through Energy Conservation, Technical Support Document", Lawrence Berkeley Laboratory Report 16342, Nov. 1983 (draft), Berkeley, CA.

Huang, Y. Joe, et.al., "Affordable Housing Through Energy Conservation, Data Base for Simplified Energy Analysis", Lawrence Berkeley Laboratory Report 16343, June 1983 (draft), Berkeley, CA.

Judkoff, R., Wortman, D., and Burch, J., "Empirical Validation Using Data from the SERI Class-A Validation House", Solar Energy Research Institute Report SERI/TP-254-1928, 1983, Golden, CO.

Arthur D. Little, Inc., "Evaluation of Existing Programs for Simulation of Residential Building Energy Use", Electric Power Research Institute Report EA-2575, 1982, Palo Alto, CA.

Micropas User's Manual, Appendix D: Comparing Micropas with Calpas-1; Figs. D-2, 3, 4. Office of Appropriate Technology, State of California, Sacramento, CA 95814, or Enercomp, 2655 Portage Bay, Suite 4, Davis, CA 95616.

Rosenfeld A. H., and Wagner, B. S., "Technical Issues for Building Energy Ratings", Lawrence Berkeley Laboratory Report 14914, 1982, Berkeley, CA.

Wagner, B. S., "Verification of Building Energy Use Models: An Update of BECA-Validation", HERS Panel, this Proceedings, or Lawrence Berkeley Laboratory Report 17884, 1984, Berkeley, CA.

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