HOME ENERGY RATING SYSTEMS : SAMPLE APPROVAL METHODOLOGY FOR TWO TOOLS

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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 exhaustive. Moreover, questions would invariably arise about how typical were the house, its occupants' lifestyles, location, or even the weather during the measuring period. Consequently, this ideal evaluation procedure is very 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 NBSLD *. Questions still remain concerning the technical accuracy of these and other building simulation programs, but the general indication is that they are accurate to within 10% for predicting residential energy use (Wagner, 1984; Judkoff, 1983; A.D. Little, 1982).

Once the standard program has been selected, it can be used to simulate a number of prototypical houses through a series of conservation measures and climates designed to test the accuracy of rating systems. From our experience, at least three prototypes are necessary to cover detached housing (one story, two story, and split-level houses), along with one, and preferably two, prototypes to cover attached housing (either an average townhouse unit, or a townhouse separated into middle and end units). This number of prototypes is needed to test the ability of a rating system to account for variations in the wall-to-floor ratio and the ratio of internal gains to shell conductance. The operating assumptions, construction details, and building design used for the standard simulation must be described in detail so that authors of rating systems can duplicate them closely in deriving their energy values for comparison to those from the standard program.

There will be problems in certifying prescriptive systems that have operating conditions different from the standard conditions selected for the secondary standard. In those cases, the certifying body can either demand that those systems be modified prior to certification, or accommodate them by making special simulations with the standard program. The second alternative is not recommended since it would lead to a proliferation of rating systems with differing assumptions about thermostat settings, window operations, etc., that would be extremely confusing to the general public.

III. TESTING PROCEDURE FOR CERTIFYING RATING SYSTEMS

Once operating conditions and building parameters have been standardized as much as possible, an assessment can be made of the technical accuracy of the rating system as compared to the standard program. We reviewed more than twenty existing or proposed rating systems to determine which conservation measures are considered in typical home energy rating systems. These are summarized in Table I, where the measures are grouped as those affecting the building shell, solar gain, equipment, and hot water system.

A testing procedure was devised comparing heating and cooling energies predicted by the rating system tool with energies from the standard program for twelve options of each prototype building (see 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

* This is similar to the procedure adopted by the California Energy Commission (CEC) in June 1984 to certify programs for use in its Title 24 new building standards. For residential buildings, CEC relies on 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 uses DOE.2.1A as the secondary standard.

Table I. Conservation measures covered in twenty 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) Exterior window shading	Yes or no
(4) Window areas, esp. south	By area or percent of floor
(5) 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) Pipe insulation	Either in or out of living space
(6) Duct insulation	Either in or out of living space
(7) Automatic setback thermostat	Yes or no
Domestic Hot Water Equipment -	
(1) Insulated tank	Yes or no
(2) Insulated pipes	Yes or no
(3) Location of tank	Either in or out of living space
(4) Low-flow showerhead	Yes or no
Other equipment -	
(1) Fireplace dampers	Yes or no
(2) Fireplace glass screen	Yes or no

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

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).

Since these tests cover the most critical conservation measures, 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 extrapolations. Minor measures such as different window sash types generally do not require additional simulations since their impacts can be extrapolated using wall values. There is a further check necessary prior to certifying a rating system. Authors of rating systems that use qualitative terms must convert such terms to the equivalent thermodynamic value. For example, infiltration terms such as "average" or "loose" must be translated into effective leakage area or air changes per hour, and duct insulation or flue dampers translated into changes in equipment efficiency. If the assumed translation differ substantially from research information available to the certifying body, the rating system authors must supply adequate documentation. For example, a rating system that credits duct insulation with a 20% improvement in equipment efficiency will be considered in error unless the claim can be substantiated.

The above procedure does not test passive solar measures such as adding thermal mass or increasing south windows beyond 12.5% of the floor area. These measures are not typically found in conventional houses, and also do not appear on most of the rating systems reviewed to date.

IV. CRITERIA FOR CERTIFICATION

Since rating system are aimed ultimately at home-buyers, the criteria for certification should relate to what consumers are most concerned about, the projected total energy bills for the house. 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. 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.

V. DEMONSTRATION OF TESTING PROCEDURE

Our testing procedure was applied to two rating system tools with which LBL is quite familiar, CIRA and the Energy Slide Rule. 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 (for further details, see EPB, 1983 and Huang(2), 1983). DOE.2 was selected as the standard program, and the testing procedure followed for a one-story prototype building in three locations - Washington, Minneapolis, and Miami. For the test simulations, we used the same building operating conditions as in the Energy Slide Rule DOE.2 data base.

When we first used the same prototype house as in the Energy Slide Rule, there was virtually no difference in energy values between the Slide Rule and the test cases. This shows that the Slide Rule accurately replicates its DOE.2 data base, but raises questions about the fairness of the tests. To make the comparison less biased in favor of the Slide Rule, we chose a new one-story prototype that differed from the original in size, geometry, overhangs, and window distribution (see Table II).

We encountered some difficulties in matching building operating conditions between the two tools and DOE.2. The Energy Slide Rule is based on a six-hour night setback, while CIRA models either no setback or a 12-hour setback. DOE.2 can simulate setbacks of any length or amount. To avoid bias towards either tool, we made two sets of simulations, one with a 6-hour setback for testing the Slide Rule, and another with no setback for testing CIRA. However, only the 6-hour setback values are shown in Tables III and IV to avoid unnecessary clutter.

VI. 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. In our earlier writings we have tended to use percentage differences and compare them with a desired accuracy of ± 15-20%, but percentages blow up for superinsulated homes. Thus, our Tightness A home has a heat bill as small as $131 in Washington, D.C.; CIRA predicts $35 more (30% too high), yet we do not believe that a home-buyer will be concerned unless he feels that the predictions are off by more than about $100/year. [Note that $100/year is 20% of the combined heating and air conditioning bill of $500/year for a typical house in Washington D.C. (Table IV, Houses C,D, or E).]

Table III shows six steps of decreasing "tightness" (covering a heating cost range of 400% and a cooling range of 150%), 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 $251 to $342.

The Slide Rule fits DOE.2 embarrassingly well at the middle of the table (Columns C, D, E) and exceed our ± $100 threshold of concern only for a completely uninsulated, single-glazed home in Minneapolis.

CIRA acts more like an independent computer program. It typically overpredicts heating and underpredicts cooling by ± $50 in the middle columns of the table, and it exceeds our ± $100 threshold for cooling in Miami. CIRA's combined heating-plus-cooling predictions agree with DOE.2 to within a few

Table II. Description of Prototype Houses

Building Characteristics	Original DOE.2 Prototype	Test Prototype
Geometry	rectangular	L-shaped
Construction	wood frame	wood frame
Floor Area (sq.ft.)	1540	1080
Roof Area (sq.ft.)	1754	1362
Net Wall Area (sq.ft.)	1154	953
Perimeter Length (ft.)	166	141
Window Area		
(% of floor area)	10.0	16.1
South	2.5	5.3
North	2.5	5.0
East	2.5	2.7
West	2.5	3.1

Table IV. Changes in heating and cooling costs for differing solar gain in 1540 sq.ft. prototype ranch house. Units are annual dollars, as in Table III, but the entries indicated by △'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			Conventional		
House Types	A'		A"	D'		D"
Increase in window area	+ 10% eq. distrib.		+ 10% south	+ 10% eq. distrib.		+ 10% south
Ceiling (R-)	-	49	-	-	19	-
Wall (R-)	-	27	-	-	11	-
Foundation (R-)	-	10-8'	-	-	5-8'	-
Infiltration (ach)	-	0.7	-	-	0.7	-
Glazing (panes)	-	3	-	-	1	-
Washington Annual Gas Heating						
△DOE.2	-9		-34	60		28
△SR - △DOE.2	-4		-7	-1		-6
△CIRA - △DOE.2	4		9	18		14
Washington Annual Cooling						
△DOE.2	57		52	66		60
△SR - △DOE.2	-9		-15	-15		-21
△CIRA - △DOE.2	20		6	18		20

Table III. Interprogram differences between DOE.2 (used as a secondary standard) and the Slide Rule (SR) or CIRA, for 8 "tightnesses" of the Test 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 A	B	C	D	E	F	G	Uninsulated H
Ceiling (R-)	49	30	-	19	-	38	19	0
Wall (R-)	27	11	-	11	-	-	0	-
Foundation (R-)	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	131	211	251	297	342	405	428	632
SR - DOE.2	6	2	3	5	7	-3	-5	-18
CIRA - DOE.2	35	19	48	50	56	64	58	29
Washington Annual Cooling								
DOE.2	149	167	176	182	187	200	205	254
SR - DOE.2	4	-6	-1	-3	-4	-3	-2	11
CIRA - DOE.2	-41	-35	-41	-41	-46	-44	-44	-44
Minneapolis Annual Gas Heating								
DOE.2	332	497	591	673	755	893	939	1299
SR - DOE.2	8	-2	-5	-2	2	-37	-40	-109
CIRA - DOE.2	64	37	53	79	90	99	92	78
Miami Annual Cooling								
Slab Foundation	5-4'	5-2'	5-2'	5-2'	5-2'	0	0	0
DOE.2	507	507	499	541	573	606	618	711
SR - DOE.2	--	-13	-2	-7	-2	-6	-4	12
CIRA - DOE.2	-108	-81	-27	-92	-134	-106	-106	-88

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.

dollars/year, and it easily handles the non-linear effects as building integrity changes going across the table. The large discrepancy in Miami cooling energies indicate, however, that additional work will be required before CIRA can be accepted as a Miami HERS tool. Our preliminary investigation suggests that this $100 offset is due to differing assumptions about window operations between the DOE.2 standard and CIRA, and may be easily correctable.

We return to the smooth sidewise variation of CIRA. Thus, for Washington heating, it is $50 high for Col. E, but never varies from this $50 offset by more than $15 (except for $21 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 results for one city (Washington) as we explore the "sideways" sensitivity of the prototype house to changes in window area and orientation. The Slide Rule showed negligible errors in predicting changes in heating bills, but underpredicted cooling increases by as much as $21 (out of $60). Discrepancies between CIRA and DOE.2 were of similar magnitudes in both heating and cooling, but never more than $20. This seems to us to be acceptable agreement for both tools.

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

VII. WHAT'S LEFT TO BE DONE?

Our experiment suggests that for a group familiar with building energy analysis, the certification process for HERS tools is tractable. However, some national decisions are still needed.

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. 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. This will obviate one of the annoyances for this experiment--the setback duration of the DOE.2 data base did not agree with that programmed in CIRA.

And, of course, the local sponsor must still make many decisions, such as to select and calibrate a secondary standard (particularly for cooling) and specify how accurately a rating tool must agree with that standard. We suggest, in addition to merely accepting a tool as "satisfactory" (e.g., good to ± $100) over a certain domain, that the validating sponsor give extra credit to the more accurate tools by stating that they were good to ± $xx for typical local homes.

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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. Figures 1,2 and 3 from this report suggest that there are now available many adequate computer programs. The text, however, warns that most "validation" studies have been inconclusive because incomplete or missing data have allowed many authors to "tune" input parameters until they get agreement with measurements.