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TECHNICAL ISSUES FOR BUILDING ENERGY RATINGS

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ABSTRACT

Current market practice in building energy efficiency lags far behind current cost-effective conservation practice, in part due to lack of credible information about how energy efficient homes are, compared to similar houses, and how much more energy and dollars could be saved for a specified additional investment. We show that, given the current spread in building efficiencies, the the differences in energy efficiency between houses on the market may typically be worth on the order of $2500, and in some cases more. We show that building energy efficiency ratings are an attractive tool for providing this information. We discuss the requirements for rating accuracy, some technical issues involved in designing a rating, and suggest a certification process for rating tools and users.

I. INTRODUCTION

A. The Lag in Market Response

The history of US residential building practice reveals a dismal track record in energy conservation. Fig. 1 shows that current cost-effective construction can reduce the space heating fuel intensity* of the average new U.S. gas heated single family home by 2/3 or more Clearly, price signals alone have not overcome a variety of existing market failures, including: lack of information about cost-effective conservation investments, lack of consideration of life-cycle costs by buyers, builders, and lenders, and lack of a basis for comparing energy performance among houses. A building energy efficiency rating provides a tool to overcome some of these problems, by indicating the amount of energy required to operate the house at a given level of comfort, and thus allowing comparisons among houses. In this paper, we show that the potential impact of building energy efficiency ratings on market value of homes is substantial, and address the technical issues associated with developing and certifying credible ratings.**

B. Standards, "Pass/Fail" Ratings, and "Absolute" Ratings

In the remainder of this introduction, we review briefly the advent of energy use standards and ratings for automobiles, appliances, and homes, and suggest that standards and ratings complement one another, although either one alone is useful.

For autos, of course, the U.S. has already adopted both mandatory CAFE standards (CAFE = Corporate Automobile Fuel Economy) and EPA stickers showing miles per gallon, that must be displayed on all new cars. The CAFE standards were beneficial, because they induced the manufacturers to start early to invest in new assembly lines, but the individual stickers have probably been instrumental in bestowing a high value on efficient cars, in both the new and used car markets.

For appliances, California has a successful program of both mandatory standards and labels; the Reagan Administration opposes both Federal and State standards but [accepts] the existing mandatory labels.

*Fuel intensity is defined here as the fuel requirement per unit floor area for a particular energy end use. It includes on-site efficiency of fuel conversion; unless specified as "resource energy" it does not include powerplant conversion or transmission/distribution efficiency.

**Historically, energy ratings for appliances and cars have taken the form of labels or stickers appearing on the equipment itself. We envision a similar format for display of a building energy rating (a simple 1 or 2 page graphic and/or written information sheet), but because the term "label" may connote mandatory compliance, we use the term "rating" to emphasize its voluntary nature.

For buildings, the U.S. (along with many other countries) has, for various reasons, followed a path leading to standards and pass/fail ratings only. In 1977, the Edison Electric Institute initiated the National Energy Watch (NEW) Program, a pioneering home energy rating program. Unfortunately, the program provided for a Pass/Fail criterion only, i.e., a new or existing home could qualify for certification as "energy efficient" by achieving a minimum point score, but there was little motivation for the builder to exceed the threshold, or for the buyer to pay for "extras." EEI guidelines for the program encouraged credit for use of renewable resources; while they did not require extra credit for gas heat or gas appliances, individual participating utilities could (and did) choose to include them (see Fig.2).[1] NEW has now been adopted by 170 utilities, but for most of them we believe it is still a Pass/Fail program. Wisconsin, Florida, and several other states, counties, cities, and trade organizations have also adopted building energy standards, guidelines, or Pass/Fail ratings. Pacific Northwest Laboratory has cataloged 47 rating systems of varying complexity now in use in the U.S.[2] Descriptions of additional, detailed energy analysis programs may be found in Feldman and Merriam,[3] or Merriam and Rancatore.[4]*

By specifying minimum energy efficiency, standards eliminate the most inefficient fraction of new building stock. They fail, however, to encourage efficiency beyond the minimum in new homes, and usually ignore existing buildings. Pass/fail ratings encourage a (fixed) improvement beyond a minimum efficiency and apply to both new and existing buildings. However, once the threshold score is achieved, no further improvements are encouraged, regardless of cost-effectiveness. Even systems that supply ratings on a continuous scale usually put the scale in terms of "stars", points, or adjectives rather than energy units or dollar cost. Yet, builders, owners, and lenders ultimately require information about dollar costs and savings in order to make economically optimal investments. In the absence of explicit energy or dollar ratings, the information will be inferred and incorporated into purchase decisions by indirect, unknown, and possibly incorrect processes, depending on the individuals and circumstances involved.

Historically, the variability of occupant and weather effects on energy consumption, and the error in predictions of actual (as opposed to design) energy use for a given set of conditions, have discouraged calculation of ratings explicitly in energy or dollar units. However, we offer evidence (below) that state-of-the-art energy analysis programs are now capable of supplying sufficiently accurate predictions of energy use under known (or standardized) conditions to supply useful ratings at reasonable cost. In short, while standards serve to set minimum energy performance, home energy ratings can encourage cost-effective investment in conservation beyond the minimum. In the following sections we explore some technical issues related to design and implementation of such rating systems.

II. THE CASE FOR COMPREHENSIVE RATINGS: PG&E'S ECH PROGRAM

Mandatory energy standards for new homes typically limit their coverage to items which would be expensive to add later and which will last for a large fraction of the 50-100 year life of a home; insulation, multi-glazed windows, thermal mass, etc. But the typical home-buyer is interested much less in utility bills 50 years hence, than in those next month. If gas is cheaper than electricity for heating space and water, cooking, and drying clothes, he wants to be told how much cheaper and to decide for himself whether the added cost for a home with gas service and gas appliances is worthwhile. And he wants to compare, in dollars, the costs and savings of a home with a more efficient furnace, water heater, or air conditioner, a low energy refrigerator, freezer, or heat exchanger, better lighting, low-flow shower heads, insulating shutters, and the like.

PG&E's highly successful ECH Program covered all of the above*. Figure 2 shows a sample ECH agreement filled out, based on some recommendations by PG&E's John Hailey, who was in charge of the program. Hailey has recommended a total of 125 points (saving 375 therms/year of resource energy, worth about $200/year). Only 50 of the 125 points were related to the shell of the house, whereas 75 represent savings from fuel choices and transient, flexible items:

*This discussion has focused on the U.S.; however, we note that that members of the Organisation for Economic Co-operation and Development (OECD) have, since the mid-1970's, been interested in appliance labels (Organisation for Economic Co-operation and Development, Committee on Consumer Policy The Energy Label: a Means of Energy Conservation, OECD, Paris, 1976) and that the new French Agency for Energy Management is seriously committed to ratings for both new and existing residences. (Giles Olive, French Agency for Energy Management, personal communication).

*Fig. 3 shows the growth of ECHome market penetration, which reached 66% of all new homes in PG&E's service territory by 1981.

lighting, thermostats, even low-flow shower heads and a clogged furnace filter indicator. Of the "hardware" items (i.e., excluding choice of orientation), the shell upgrade costs $200 and rated only 35 points ($6/point); the rest cost $155 and rated 70 points ($2/point), so in this case the "comprehensive" options save three times as much per dollar invested as the shell upgrade.

Instead of using an absolute rating scale, as we would recommend today, PG&E made comparisons with Title 24, awarding points only for beating it, and setting a threshold of 50 points for certification. But the virtue of basing the points on Title 24 was very transient, since Title 24 is updated every few years. To us it is now clear that the only reliable reference point is consumption (or efficiency) in absolute terms. That is, building ratings should look like auto fuel economy ratings (which list absolute mpg, not mpg compared with other models) or appliance ratings, which give the absolute energy use in dollars. Of course, as with the appliance labels, we advocate helping the purchaser by comparing each house with the best and worst on the market, within a "comparable" category.

III. LABELS FOR EXISTING HOMES — UPDATING LABELS

A. Relation to RCS Audits So far, we have discussed primarily ratings for new homes. Such systems are easier to implement than ratings for existing homes because it is easier to determine insulation levels, for example, by examining the plans and specifications for a new home than to estimate insulation R-values in the walls of an existing home. Ratings for existing homes require on-site audits, since plans and specifications, even if available, may not show renovations, repairs, and deterioration in the structure. Pacific Northwest Laboratory estimates that for many potential rating systems, the incremental cost of calculating a rating during an on-site audit will be small.[5] The recently created Residential Conservation Service (RCS) program provides an obvious delivery system for coupling ratings to on-site audits*, but most existing RCS programs have not yet taken advantage of the opportunity.

B. Ratings at Time of Sale In California, at least 11 counties/cities (comprising about 17% of the state's population) now require an inspection of existing houses, usually at time of sale, to certify presence of significant conservation measures, and/or installation of missing items.[6] This is also a logical point at which to rate the house, to provide buyer and seller with important, up-to-date information on its efficiency.

*Such audits can be valuable even for rating new homes, since actual construction may vary from plans.

This brings us to a final point that sums up the difference between a building and a rating, and why a rating is more effective. A new building standard is a one-shot affair and governs mainly the shell. A rating can more easily be comprehensive and can be updated every time that the building is sold, and, in fact, every time that the owner invests in a major improvement. As a result, it can provide far more complete and current information about the house and a better measure of the house's relative worth.

IV. THE MARKET VALUE OF A LABEL

A. New Homes Referring back to Fig. 1, and using an average floor area for single family gas heated homes of 1567 ft^2,[7] we see that selected new gas heated homes in 1979 consumed about 50 MBtu* less for heating than existing gas heated homes, equivalent to roughly a $250 annual savings**. Recalling from PG&E's checklist that further savings from efficient appliances and non-structural features were about 225 therm/y ($110/y), we add these to the shell savings for a total of about $360/y.

The market value of an investment (e.g. incremental price paid for an energy efficient house) which yields a stream of annual savings (e.g., dollar value of energy savings) will be affected by many factors which are difficult both to measure and to predict (e.g. interest and discount rates, amortization periods, inflation). However, we note

*One MBtu = 1.06 GJ, or 10 therms.

**The calculation from Fig. 1 proceeds as follows:
1979 stock use was 66 MBtu/1000 ft^2, at 4657 DD^oF NAHB '79 survey houses used 34 MBtu/1000 ft^2, at 4200 DD^oF
New houses in 1979 were built, on average in a climate 10% warmer than average 1979 stock, but they were also about 10% larger, and the two effects should approximately cancel; for purposes of this calculation we assume this is also true of gas heated single family houses. Therefore, using average floor area for 1979 gas heated stock single family houses (1567 ft^2), we calculate the difference in energy consumption as:
Energy savings = Gas use of 1979 stock − Gas use of NAHB '79 average house

$$= [(66\ \text{MBtu}/1000\ ft^2 - 34\ \text{MBtu}/1000\ ft^2)](1567\ ft^2)$$

$$= 50\ \text{MBtu}$$

that typical bank loans for autos and home improvements are made at a real rate of 10%, that is, an investment by the bank of $100 yields an annual return of $10. We further note that for the ECHomes, which yielded an average savings of $150 in annual energy costs, homeowners surveyed by PG&E estimated an increased value of their homes of about $1200 (1982$).[8] This is reasonably consistent with a 10% return, although homeowner estimates of fuel savings were unclear, and may have been higher than $150/year, thereby reducing the return. Finally, we note that in another PG&E survey,[9] the median additional amount that customers claimed they were willing to pay for a home with "the latest conservation features" was $5000. For this paper, we assume that homebuyers require about a 10% return on their energy conservation investments, which means that the new 1980 houses which saved $360/year were worth, on the average, $3600 more than average existing stock*.

B. Existing Homes. Wall et. al,[10] in a paper presented at this conference found from a survey of retrofits in existing buildings a median savings of 22%. If this is a representative figure for retrofit potential in average gas heated stock, this implies, under the assumptions of the previous section, and including appliance savings, typical savings over existing stock of $220/year, or an increased value of $2200 for a** retrofitted and rated existing house. We note that for the owner, the net value of the retrofitted house will be the increased value due to the energy savings ($2300) minus the retrofit capital costs.

*This increased value of $3600 is actually the present value of the energy savings resulting from the houses' greater efficiency, and represents the maximum incremental amount a buyer would be willing to pay for that efficiency, regardless of the actual cost of the extra features. In a "perfect" market, builders would add (and buyers would pay for) extra features until their capital cost equaled the present value of the resulting energy savings.

**The calculation proceeds as follows: Savings = .22x(Space heating for 1979 stock gas heated single family homes)

$$= .22 \times (66\ \text{MBtu}/1000\ \text{ft}^2) \times (1567\ \text{ft}^2) \times 5\ \$/\text{MBtu}$$

$$= 114\ \$$$

Total savings = Heat savings + appliance savings (using PG&E estimate- see earlier section)

$$= 114 + 110\ \$ = 224\ \$$$

C. All Homes The division above is a bit artificial, since new homes quickly turn into existing homes, but we have seen that the efficiency of some new U.S. houses is worth $3600 above that of existing gas heated stock. We further note that we have so far considered only typical new and existing homes; more efficient new homes that are still cost-effective would have heating costs reduced by another $90, which in turn increases their value by another $900. The total increase in value for energy efficient new houses is then $4500, compared to existing stock. Furthermore, existing stock includes some houses which are below average - further increasing the total spread in operating costs. In the rest of this paper we shall then frequently say that a rating should easily influence the value of a typical house by "plus or minus" $2500, recognizing that this is a conservative figure that may underestimate the range of building energy efficiency.

D. An Example We refer to our sample rating in Fig. 4, calculated on Lawrence Berkeley Laboratory's Computerized, Instrumented, Residential Audit (CIRA) for a real house in Walnut Creek, California. The rating is designed to identify for the homeowner a variety of "target" ratings and the energy savings resulting from improvements he might choose to make, compared to his current rating. In this case, the house costs $200/year more to operate than a new house built to California standards, or a difference in present value of $2000. We also see an estimated savings of about $500/year in utility bills, ($5000 present value) between the house in its present state and after a $2900 retrofit.

V. THE "STANDARD" OR "REFERENCE" HOUSE

An accurate rating requires a valid test procedure, e.g. the standard urban and highway driving cycles for autos. The same holds true of houses; in order to have a meaningful rating of the building energy efficiency which can be used for comparisons among houses, factors such as occupancy and weather must be normalized. We must not confuse the home-buyer by having New York City base its ratings on a thermostat setting of 72°F, and having New Jersey adopt 68°F. It seems easiest to have national or regional standard occupancy and weather chosen by DOE/HUD, with appropriate advice from industry and professional societies.

We note here several conventions and adjustments which should be considered in defining such standard.

There is a minor debate as to whether the standard house should be of a standard size, or whether a large house should indeed have a larger energy use rating, just as an eight-passenger wagon is rated at fewer miles per gallon (i.e., more gallons per mile) than a Honda Civic. We strongly prefer not correcting for size, and argue that we have taken care of this point on our suggested rating (Fig. 4), where we give for comparison the energy use of the same house as if were uninsulated and after retrofits.

Some further adjustments, not shown in Fig. 4, should be made for the number of occupants and the appliance use, on the grounds that larger houses (with more people) will use more lights and hot water and run the dryer more often. Since occupancy and appliance use will not necessarily scale linearly with floor area, standard curves for each should be developed from local census and survey data.

We conclude by noting that the "standard" conditions may result in poor predictions of actual energy use by elderly people, who spend most of their time at home and prefer warmer-than-average temperatures, or for families with many children and grandparents. We therefore suggest that a service, called "The Rating-Game", be offered by enthusiastic utilities, in which, for an annual fee, the owner of a rated house can inform the utility of a few personal points about his home--occupancy, thermostat schedules, and use of non-standard items like a pool or a spa. The utility could then easily calculate the family's probable use at the end of each month, taking into account last month's weather and these individual preferences. The home-owner could then compare these tailored predictions with his actual bills and decide whether he should check his furnace efficiency, boast at cocktail parties, and/or nag at the kids to keep the doors closed and take shorter showers.

VI. ACCURACY OF LABELS

A. Occupancy Effects

We showed above that a rating can be expected to modify the value of the house by ±$2500 or more, if the buyer believes that the rating is sufficiently accurate, that is, that the predicted energy is sufficiently close to the energy use that would be actually measured under standard operating conditions. A reasonable estimate of what constitutes "sufficient" accuracy can be based on two observations: 1) The rating has been calibrated to predict energy use for the house under standard reference conditions, which are typical of local occupancy and weather patterns, and which should yield predictions close to the actual local average use; 2) Variations from average energy consumption* due to differences in lifestyle among families living in identical houses have been shown to contribute to as much as a 2:1 variation in energy consumption,[11,12] with a standard deviation ranging from 15-25% (see Fig. 5). To a first approximation, therefore, a reasonable requirement for the accuracy of a rating (predicting energy consumption under standard, i.e. average, operating conditions) is in the latter (±15%) range, since greater accuracy will tend to be swamped by variations in owners' lifestyles. For instance, for a lender considering whether to extend a borrower's debt/income ratio from 28% to 29%, and without knowing how the family will actually operate the house, uncertainty in the standard predicted consumption will tend to be confused with spread in occupancy effects. Furthermore, to a given purchaser this spread is irrelevant. Family A is interested in the energy features of a house as a commodity, like a car or a refrigerator, and doesn't care how carefully or carelessly the previous owner (Family B) managed the house. For Family A, the standardized operating assumptions used in calculating the rating for each of the houses they are considering for purchase provide a consistent, useful basis for comparison.

B. Market-Price Effects

In some situations, however, even a 15% error may significantly affect the value of the house, or the lender's willingness to provide financing. In the previous section, we suggested that credible ratings could influence the market price of a house by an amount equal to the present value of energy savings. Using reasonable assumptions for discount rates and lifetimes, this present value corresponds to annual energy savings (or payments) times a multiplier of 10. Figure 1 shows that for existing U.S. gas heated houses (averaging 1567 $ft.^2$), the total energy bill will be about $1250/year. If the rating is wrong by 15%, the energy component of the house price can then be skewed by: ($1250)(10)(.15) = $1875

In climates with higher space conditioning costs, the error will cost more. Obviously, then, there is a significant monetary value to investing in increasing rating accuracy, both by using the best possible rating tool and by paying an auditor for sufficient time to do an accurate job.

As we have noted elsewhere,[13] in calculating building energy consumption, the accuracy of the output of course depends on the accuracy of the following inputs and algorithms:

1. Weather
2. Occupancy: i.e. schedules for thermostats, appliances, window management, venting, and water use
3. Input data that describe a house: U-values, dimensions, infiltration, etc.,
4. Algorithms used in energy analysis, and microclimatic corrections to weather data.

Since, for a rating, Weather and Occupancy are specified, the remaining sources of error are Input and Algorithms. This suggests three basic steps in developing a rating system to meet required accuracy, outlined in the next section.

Certification of Rating Tools and Users

We propose a certification system which will accomodate a variety of tools and raters.* The general approach is similar to that used to certify operation of airlines. First, the aircraft itself must pass tests of safety and performance, and then the pilot must demonstrate competency. Finally, after initial certification, the aircraft and the pilot undergo continuing monitoring, servicing of the aircraft and further training of the pilot as appropriate, and, if necessary, license revocation. The same process, applied to certification of ratings, allows a great deal of flexibility in the design and use of rating tools, as long as desired accuracy is maintained. We suggest the following certification process:

1. Validation of the rating tool. In this step the accuracy of the algorithms are tested by experts comparing predicted to measured energy use in well-monitored houses. Through intensive monitoring or control of weather and occupancy and by expert preparation of input, errors from sources 1,2, and 4 above are minimized. Remaining error is a measure of the accuracy of the algorithms alone. For such validation, accurate data from a few well monitored houses, representing the range of housing types and climate to be rated, are far more valuable than sketchy data, of unknown or poor accuracy, from thousands of houses. Some data are now available on algorithm validation. Figure 6, from BECA-Val[14] summarizes some preliminary results of a compilation of documented comparisons between actual energy use and that predicted by energy analysis programs. For commercial buildings, detailed computer programs were accurate to within about 10% when correct input data were available. For residential buildings, accuracy of building energy analysis programs was generally better than 10% when the buildings analyzed were intensively instrumented and monitored to eliminate errors in input. Two simplified programs suitable as building energy efficiency rating tools were, on average, accurate to within 15% for submetered and for less intensively monitored occupied houses. We note that these studies present an optimistic picture of program accuracy, since many of the comparisons were not "blind", i.e., the analysts had access to metered data during the simulations. Those that were blind (e.g., CIRA in Fig. 6d, DOE-2 in Fig. 6d, REAP in Fig. 6c), with some exceptions, still did acceptably well. Although much work remains to determine under what circumstances these and other programs have acceptable accuracy, these preliminary results suggest that some programs will be adequate for calculation of ratings.

1a. User-friendliness. In order for the users other than the program developers to successfully predict energy use, the tool must be not only accurate, but comprehensible with a reasonable amount of training.

2. Certification of Auditors or Appraisers. Once the tool is validated and made user-friendly, the auditor should be professionally and legally responsible for entering reasonably accurate input data onto a rating form or computer terminal, and this input must be carefully preserved to resolve future disputes. The first step in certification is testing the user's ability to audit the house, e.g. to make measurements and to distinguish correctly between R-7 and R-11 insulation or between light-reflecting and heat-absorbing window films. Some measurements are difficult to make in all cases, e.g. wall insulation levels, or infiltration rate. The auditor should be able to recognize these cases, and obtain assistance/permission to make more costly measurements, or to write a warning, i.e., "I suspect there is no wall insulation. If the insulation level is R-11, the rating will indicate a yearly energy bill of $1250; if it is R-0, add 20% ($200). To resolve this uncertainty, I'll need an extra half-hour,

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*Sonderegger and Wilson, in independent studies, have compared energy use in structurally identical buildings and have each found a 2:1 variation in energy use between the 10% of households with the lowest and the 10% with the highest consumptions. In Wilson's work, some variation might have been attributable to presence or absence of basement insulation (building characteristic); however, since presence correlated with the practice of basement heating (occupancy), this is arguably occupant-linked (see references, above).

*We use "certification" to mean validation and certification of the computer programs or other tools used to calculate ratings, as well as the testing, licensing (and license revocation) of "raters" - who of course will include auditors, appraisers, and consulting engineers.

and permission to drill some small holes in the wall."

Some rating tools allow discretion or ingenuity in inputs, e.g. simulation of party walls in apartments by an input of "infinite" insulation. This sort of "trick" will vary between rating tools. Therefore, the second step in user certification should test the user's ability to obtain correct predictions using a specific rating tool (much as pilots are certified to operate a specific aircraft).

3. Monitoring of rated houses. As a rating system is implemented on a large scale, the actual energy use of rated houses should be continuously monitored to detect:

   o large overall deviations (e.g. > 15%) from predicted energy use;

   o changes or trends away from the average operation used for the rating reference;

   o major inaccuracies for particular housing types or regions;

   o inaccuracies due to implementation of new construction technologies not previously modelled by the rating tool.

Program validation and auditor licensing establish the overall accuracy of the rating system; to assure the buyer that the accuracy is within 15%, this certification should be performed by a responsible entity such as a state government or industry trade group. By establishing a "performance" criterion (accuracy) rather than a "prescriptive" criterion (accepted methodology), certification is available to a large number and variety of potential rating tools and auditors (e.g. private entrepreneurs, utilities, non-profit organizations).

The credibility of the certification process is supported by the ongoing monitoring process of Step 3 above. Monitoring fulfills several important functions: 1) detection of problems, as outlined above; 2) early resolution of problems, before complaints become widespread and the credibility of the rating is damaged; 3) provision of a mechanism for resolving complaints, when they are received; 4) providing a basis for de-certification of rating tools or auditors, where necessary.

4. Handling Liability Issues

Suppose that a customer does indeed call his rater to complain that his energy use last month exceeded his rating. The rater will first ask if the family has operated the home according to standard conditions, or may offer to recalculate the bill taking into account their higher thermostat setting, etc. (see comments about the "Rating Game", above). If the customer is still unsatisfied, the rater should send out his "House Doctor", who, along with the customer, can review the rating form. In case of an input error, the rating will be corrected; if the dispute has advanced to the point of calling in an outside reviewer (e.g. state or local inspector), the rater may be required to make restitution to the homeowner. If the rating form is correct, and the family energy bill really is surprisingly high, then something is probably wrong and should be fixed. The House Doctor can then perform a valuable service by finding an unexpected air bypass, hot water leak, or refrigerator that has lost most of its freon, etc. All this may indeed take some time and cost money, but it will not be wasted in litigation -- it will be spent efficiently finding and fixing energy leaks, which is just what ratings were invented to do.

In this discussion we have assumed that most of the time the basic computer programs are adequate. Of course, experience, as well as complaints, over the years will turn up areas where the programs need improvements; as suggested above, these improvements should be required by the certifying agencies.

This sequence of procedures and responsibilities is summed up in Fig. 7 as a warranty for a rating, which would appear, e.g. on page two of the rating in Fig. 4. The warranty is intended not only to tell homeowners about the information provided by the label, and their rights and responsibilities in using it, but also to motivate them to pay attention to their energy use habits and to the maintenance and improvement of their property.

CONCLUSIONS

We have outlined the need for building energy efficiency ratings, offered evidence that their chances for success are good, suggested a criterion for the accuracy of rating tools and auditors, and sketched a process for certification and ongoing monitoring. We have found elsewhere that the requirements for rating tool accuracy can be met (though are not necessarily met by all tools).[15] We are aware of extensive, but undocumented, utility experience with training and testing of auditors. We believe that the next step should be a pilot project to further test tool and auditor abilities, and further, to design and test a full scale certification and monitoring process.

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14) Wagner and Rosenfeld, op. cit.

15) Wagner and Rosenfeld, op. cit.

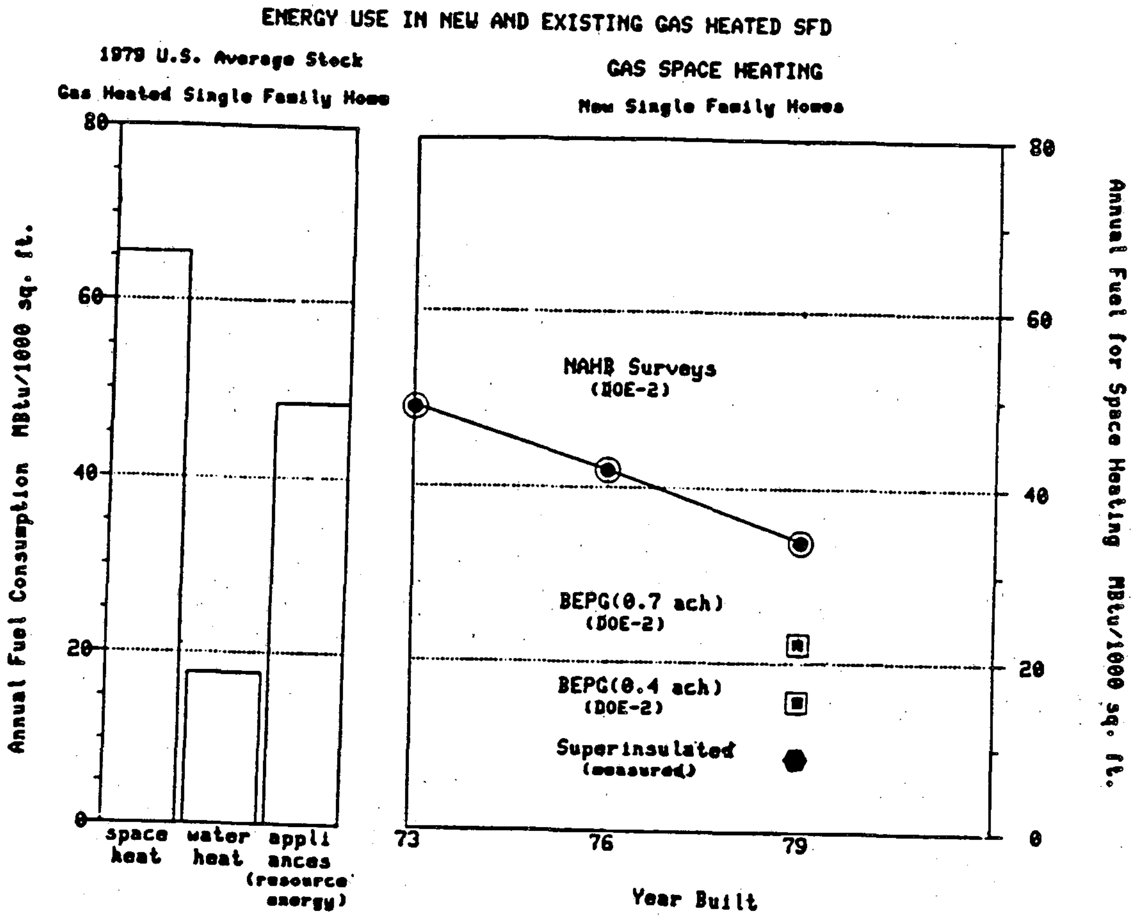


Fig. 1. Energy Use in New and Existing Gas Heated Single Family Houses

The bar graph shows average space heat and appliance energy use for the 1979 stock of gas heated single family homes. Space heat and hot water use were calculated from NIECS utility billing data (Meyers, 1982). Appliance use is based on unit consumption and appliance saturations used in the ORNL model and includes electric appliances, such as refrigerators and lighting (air-conditioners are excluded), with electricity counted in resource energy units, using 1 kWh = 11,500 Btu. The points labelled "NAHB" are DOE-2 computer simulations of space heating in homes built by builders surveyed by the National Association of Home Builders in 1973, 1976, and 1979. The simulations were normalized to the Washington D.C. climate, which has approximately the same number of degree-days as average new building stock. Because of the non-random nature of the NAHB survey, results cannot be extrapolated to all new homes. Furthermore, the assumptions used in the simulation may not acurately represent actual occupant lifestyle or building characteristics, however, they serve here as an example of energy use in new homes now on the market. "BEPG" represents proposed federal energy guidelines for practice that more closely approaches minimum life-cycle costs, using the same assumptions about thermostat settings, furnace efficiency, and free heat as the NAHB points. "Superinsulated" is the average of the 15 best-performing superinsulated houses of 30 for which detailed data were available in Ribot et. al., 1982. It represents measured energy use, normalized to average degree-days for new buildings, using assumptions comparable to the NAHB and BEPG point.

	Points Allowed	Score	Incremental cost ($)
(1) Major Appliances:			
Gas Range	13	13 e	-
Oven with light and window	1		
Microwave oven	10		
Dishwasher with switch controllable drying cycle	5		
Gas dryer outlet	10	10 e	25
(2) Space Heating/Cooling			
Set-back or programmable thermostat (not for use with heat pump)	16	16	60
Clogged filter indicator	8	8 e	20
Used with air conditioning	10		
Air conditioning - 1 point per 0.1 increment in EER exceeding state requirements. Points will only be awarded in areas where air conditioning is required as defined in PGandE Schedule D-1.			
Solar Assisted Space Heating System: One point will be awarded for each 2 square feet of properly located (orientation and tilt) collector			
(3) Water Heating:			
Insulation blanket	5	5	25
Solar Assisted Water Heating System: One point will be awarded for each square foot of properly located (orientation and tilt) collector			
Insulated hot water piping first four feet from water heating unit	2	2	15
Insulated hot water piping throughout	5		
Showerheads with flow-control devices rated at 2½ GPM or less	4	4	10
(4) Weatherization:			
Caulking (per 1,000 sq. ft. of floor area) **(Assume a 1,500 sq ft house)**			
– Exterior sole plate only	7		
– Seal all plug outlets only	4		
– Total exterior (doors, windows, electrical/plumbing penetrations, sole plate, top plate, plug outlets)	23	35	200
Ceiling R-30 (per 1,000 sq. ft. of floor area)			
Heating benefit	5		
*Cooling benefit	2		
Walls R-19 (per 1,000 sq. ft. of wall area)			
Heating benefit	7		
*Cooling benefit	4		
Perimeter insulation for slab on-grade floors with moisture barrier (per inch of insulation thickness exceeding state standards)	12		
Conventional floors (per 1,000 square feet)			
– R-19 instead of R-11	2		
– R-11	10		
Double glazing (per 25 sq. ft. window area)			
Heating benefit	3		
*Cooling benefit	1		
Thermal drapes, moveable insulating shutters, blinds, roller shades, integral louvered screens or other glazing insulation features (per 25 sq. ft. window area)			
Heating benefit	2		
*Cooling benefit	1		
Reflective glass or film on east or west facing glazing (per 25 sq. ft.)			
*Cooling benefit	4		
Subtotal		93	$355

*Points awarded only in areas where A/C required – see (2).

	Points Allowed	Score	Incremental cost ($)
Insulated exterior doors (per door)			
– 2" wood, solid core	1		
– 1¾" with solid polystyrene core and thermal break	1		
– 1¾" with solid urethane foam core and thermal break	3		
Attic ventilation (* cooling benefit only)			
– Eave vents with continuous ridge vent	4		
– Eave vents with gable vents	2		
(5) Chimney (fireplace):			
Positive damper, without gas outlet	3	3	-
Fireplace – Glass doors	5		
– With heat exchanger	6		
– Connected to central space heating ducts	5		
– With outside combustion air supply (dampered or used w/glass doors)			
Free-standing model	2		
Air tight wood burning stove	10		
	20		
(6) Lighting:			
All incandescent and fluorescent fixtures surface mounted	2	2 e	-
Fluorescent Application:			
– Exterior - Porch/Patio	3		
– Kitchen area	5	5 e	-
– Laundry area	1		
– Bathrooms (all)	7	7 e	20
– Bathrooms (full only)	5		
– Recreation or family room	3		
– Shop or garage	1		
(7) Passive Solar Design Features:			
Heating Benefit:			
House to lot orientation (minor axis within 25° of true south)	15	15	- *
South facing glass in excess of 25% of total glazing area (per 3 sq. ft.) (Where glazing exceeds 22% of floor area of room being passively heated, room must be protected from excessive heat gain)	2		
Evergreen trees providing protection from prevailing winter winds on north, northeast or northwest exposure (per tree, 15 gal. minimum if newly planted)	1		
Cooling Benefit:			
Deciduous trees providing summer shade on west, east, or south facades (per tree, 15 gal. minimum if newly planted)	2		
Roof overhang or operable exterior awnings on south exposure for each 2 inches exceeding 12 inch horizontal overhang (maximum 32" overhang)	1		
(8) Active Solar Design Features (for future adaptation):			
Increased slope on south-facing roof (minimum unobstructed roof surface 8 ft. x 8 ft. with required structure to support future solar panels) (per each 5° over 25° slope, 40° maximum)	2		
Rough plumbing for future solar hot water retrofit (must include 2' x 2' minimum space and stubbed control valves for future hot water storage tank)	5		
(9) Other			
TOTAL POINTS		125	$375

* **Can account for extra costs due to site constraints or poor planning**

Figure 2. ECHome Rating Sheet Filled out with 125 Points.

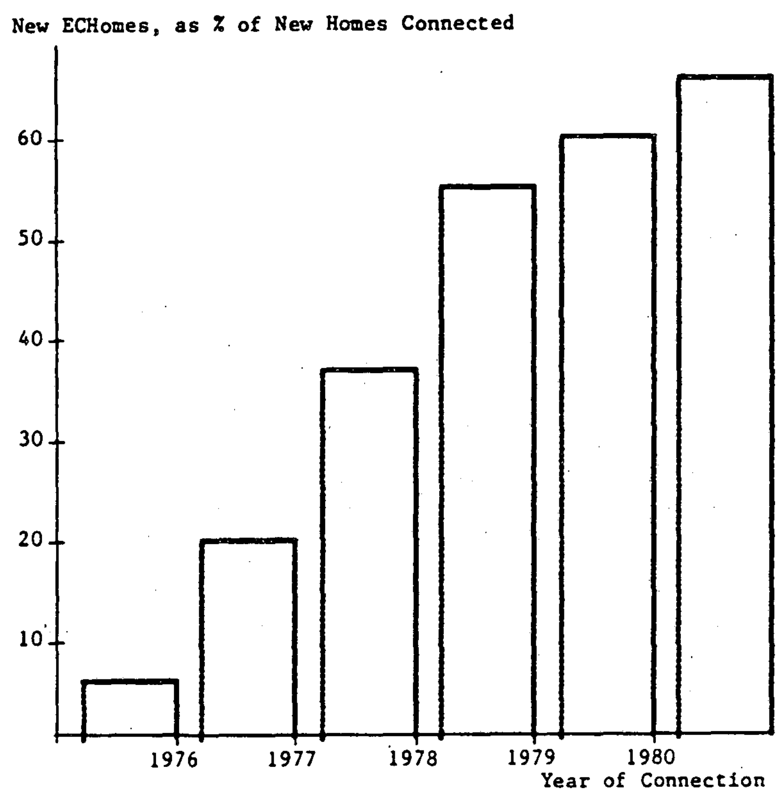


Fig.The bargraph shows the number of new Energy Conservation Homes (ECHomes) certified each year, from 1976 to 1981, as a percentage of all new homes connected by Pacific Gas and Electric Co. Data are from B.C. Richardson and G.W. Haddow, The Development, Implementation and Evaluation of the Energy Conservation Home Program, presented at the 1982 Summer Study on Energy Efficient Buildings, Santa Cruz, CA, 1982.

HOME ENERGY RATING

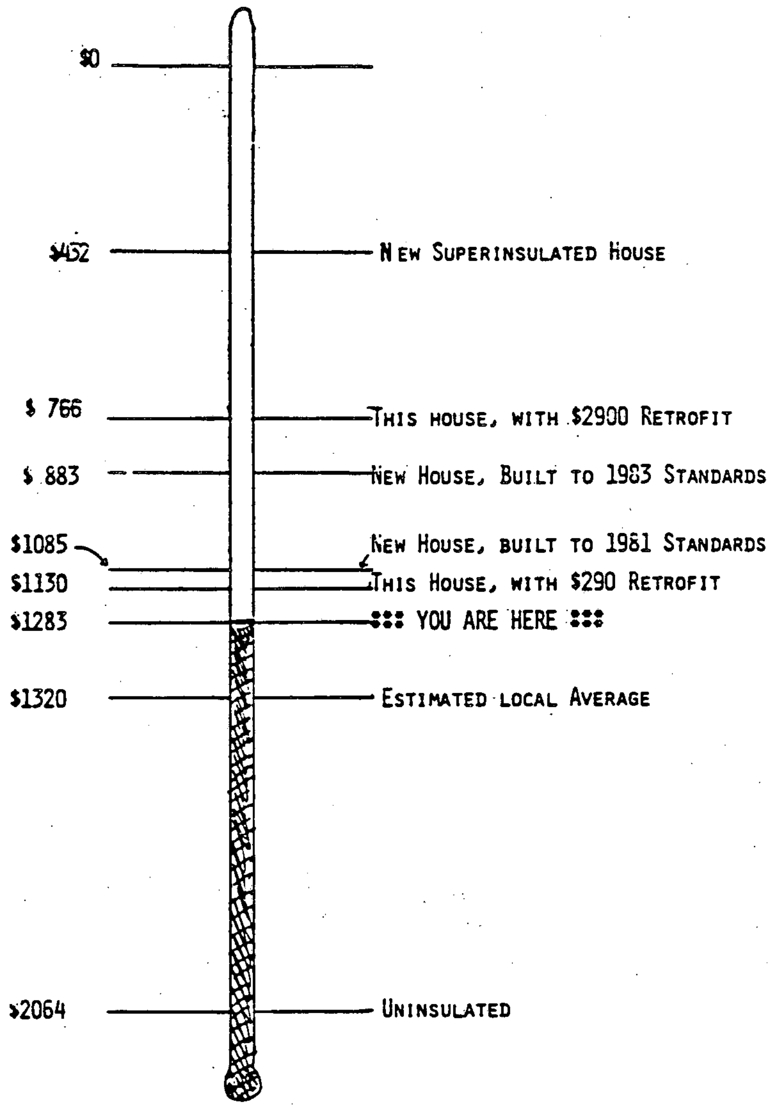


Fig. 4. Annual total energy bill (gas plus electricity) for 1939 Cherry-hill Drive Walnut Creek, CA, in 1983 $. The floor area of the house is 1500 ft². The dollar predictions assume that the house is operated under Standard Residential Operating Conditions, either "as is" (marked "You Are Here") or at various degrees of improvement over the uninsulated, single-glazed version at the bottom. For comparison, the energy bill of new homes of the same area 1500 ft² built to various standards, are indicated. Note that even a super-insulated house with efficient appliances costs $432 /year, mainly for water heat and the appliances.

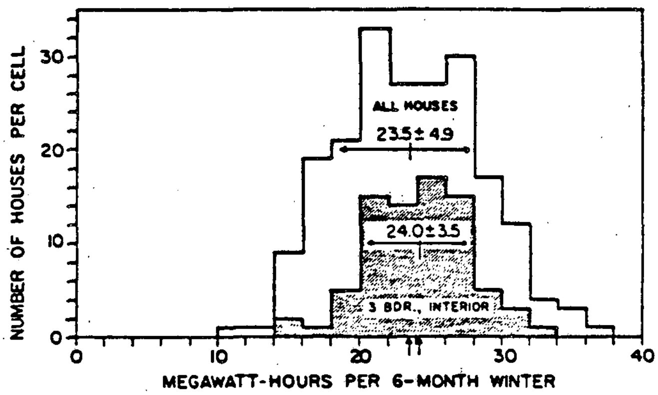


Figure 5a. Occupancy Effects at Twin Rivers. (Source: Sonderegger, Movers and Stayers.)

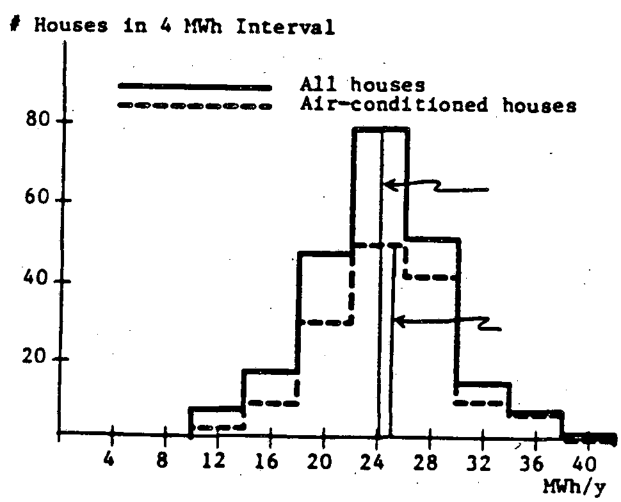


Figure 5b. Occupancy Effects in Houses in Windsor, Canada. (Source: N.W. Wilson, Energex '82.)

NOTE: For complete references for figures 5a and 5b, see Reference section.

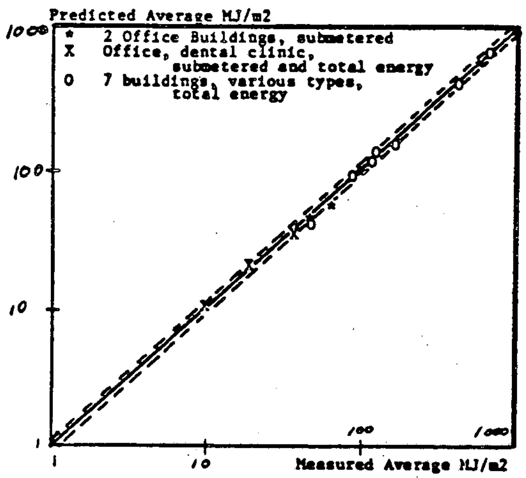


Figure 6.a

Predicted vs. Metered Site Energy Use in Commercial Buildings. For degree to which analysts had billing information during simulation of buildings, see Ref. 13.

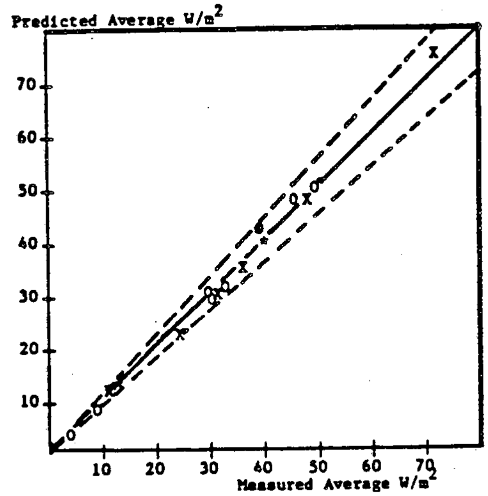
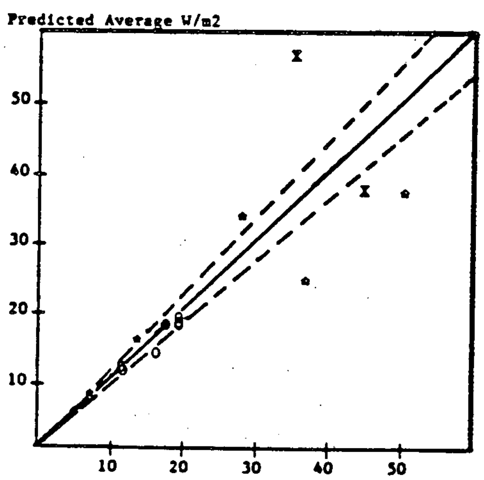


Figure 6.b

* NBSLD, high-mass house in test chamber, heating only
X NBSLD, townhouse in test chamber, heating and cooling
O REAP, detached houses outdoors, heating and cooling

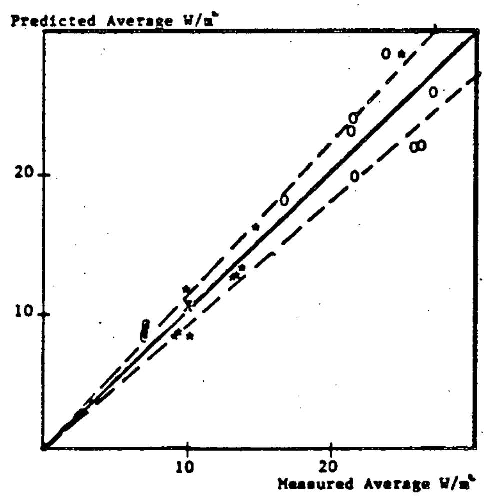
Predicted vs. Metered Site Energy Use in Intensively Monitored Buildings. For degree to which analysts had access to metered data during simulation, see Reference 13.



* REAP, remote sites, heating and cooling
X Same, scaled by one half to fit plot
O CIRA, Midway, 4-5 house averages, heating

Figure 6.c

Predicted vs. Metered Site Energy Use in Submetered Buildings. For degree to which analysts had access to metered data during simulation, see Reference 13.



* HOTCAN, detached houses, heating
@ DOE-2, 22 and 74 house averages, cooling
X DOE-2, 75 house average, heating
O CIRA, detached houses, total gas

Figure 6.d

Predicted vs. Metered Site Energy Use in Non-submetered Buildings. For degree to which analysts had access to metered data during simulation, see Reference 13.

HOME ENERGY RATING DESCRIPTION AND WARRANTY

The energy rating of this house has been calculated by Energysense, Inc., using the computer program RATE-IT. The State of California maintains test houses operated under U.S. Standard Residential conditions. The California Energy Rating Office (CERO) has compared predictions by RATE-IT 2.3B with metered energy use of the test houses and found agreement to within a standard deviation of 11%, which satisfies the State requirement of 15%. Accordingly, the CERO has certified RATE-IT 2.3B as a rating tool.

The input to rating calculation for this house was made by Energysense Auditor

Jane Doe on 12-2-82 (date)
The auditor's input data are reproduced on page 4.

Your actual energy use could easily differ by 50% from the prediction of the rating, depending on the individual habits and size of your family. If you are concerned that your use is higher than predicted, compare your thermostat setting (day and night), outside air and hot water temperatures, lighting, and appliance use with the Standard Residential Occupancy Conditions on Page 3. Then, if you are still concerned, contact your auditor to verify the auditor input data and to check your house and appliances for unexpected flaws. Then, if you are still dissatisfied, inform CERO.

Energy prices may have increased substantially since this house was audited. For an update of the energy bills predicted by this rating, contact your utility.

Figure 7. Example of possible warranty, which could appear on page 2 of a home energy rating. All agency and personal names are fictitious.