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Technology for Energy-Efficient Buildings

Progress and Potentials: Many Suggestions and Some Opportunities for Collaboration

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A French translation of this talk is available from Agence Francaise Pour la Maitrise de L'Energie, 27 rue Louis-Vicat, 75015 Paris, France.

ABSTRACT: Data and the results of experiments are presented in the form of figures. Suggestions for French policy and French/American collaboration are given in each of the areas listed in the Table of Contents.

Table of Contents

I. Introduction

It's a great pleasure to be here. When I did experimental particle physics, until 1974, we always worked with international teams, and my group at Berkeley always had several European visitors--usually at least one Frenchman or Frenchwoman.

When I switched from experiments with particles to experiments with buildings, I thought that my international collaborations might decrease--but luckily my family and I both love Europe and European building scientists seem to like what we're doing, so by 1979 we had established an Orsay/Berkeley collaboration to transplant our computer program, DOE-2, to Paris. Dr. Louis-Marie Chounet and his group RAMSES have metrified and Europeanized the program and are currently using it to design multifamily retrofits and to validate its accuracy on HLM apartments at Dreux. The metric version of DOE-2 now runs on computers all over the world. In addition, a microcomputer program (CIRA--metrified by Jean Yves Garnier in Paris), also developed at Berkeley, is spreading quickly.

We currently have visitors from many countries and formally exchange personnel with France, Belgium, Sweden, and China. These exchanges have been productive for both sides because investment in efficiency is generally more attractive than investment in new energy supply. So, you'll see from the rest of this talk that I've lost all shyness about giving unrequested advice to non-Americans (and Americans!), and I'm eager to launch more collaborative developments and experiments.

II. International Comparisons

The format of this talk is a commentary on 19 figures.

Figure 1 is a scatter plot of energy use in 1970 and in 1978 by industrialized countries. Each country is an arrow, with its tail representing 1970 and its head at 1978. The arrows seem to fall on two different tracks:

- The main sequence (to steal a concept from astronomy) covers all of Europe except the U.K. and Switzerland (which has almost no heavy industry). At today's prices, these countries are spending 10% of their GNP for energy and, like you at this conference, are planning to reduce that fraction.

- The big energy spenders are a band of three countries where energy has been almost as cheap as water and was spent accordingly. At today's energy prices, we three English-speaking countries would be spending (wasting) on energy 20% of our GNP if we were still following our pattern indicated by the 1970 tail of our arrows. Instead, we are trying to catch up with you. I've updated the U.S. arrows to display that between 1973 and 1982 we've reduced our Energy/GNP by 20%.

I seriously believe that the U.S. can start exporting oil by 1990 and also achieve your main sequence slope of 10% of GNP spent for energy. But, of course, by then you hope to have dropped much lower.

I wanted to show Fig. 1 first so that when I show great U.S. improvements in Figs. 2, I will already have admitted that much of our remarkable gains are the result of having started from a very energy-inefficient baseline.

III. Autos and Commercial Buildings

Figure 2a shows progress in auto fuel economy. The U.S. seems to be lagging behind Europe and Japan by about 10 years. The American rush towards increased efficiency is driven not only by gasoline prices but by mandatory standards and mandatory labels. Of these, I particularly recommend a fuel economy label on every new and used car; the U.S. currently labels new cars only.

Figure 2b shows progress in office building energy efficiency. Figure 2b shows that during the period 1950–1973, new commercial buildings indulged in an energy orgy, markedly more indulgent than that of autos. This amounts to a lot of energy use because in America commercial buildings consume about the same amount of resource energy as do automobiles. The explanation for the dramatic rise was a vogue for hectares of glass facade, bright lights everywhere, and oversized HVAC (Heating, Ventilating, Air Conditioning) systems which were thermodynamic nonsense. As you can see, current progress is rapid and again the U.S. trails Europe (in this case, Sweden) by only about 10 years. I'll talk about the Swedish Folksam "Thermodeck" building at Farsta along with Figs. 10 and 11. It's enough for now just to say it stores enough heat from lights and people to get through a Stockholm winter with almost no conventional heating.

In Jeff Harris' version of Fig. 2b, he has added X's representing successful new U.S. buildings. We'd like to add some French X's. Who has measured data?

I have a recommendation for advancing the acceptance of efficient commercial buildings. For a year or so, let's give a large cash incentive for demonstrated savings of peak power and fuel. By "large," I mean at least equal to the avoided capital investment in power plants ($500 to $1000/kW) or the avoided societal cost of burning oil at roughly $10–$20/barrel ($500 to $1000/kW[thermal]). This incentive will cause architects to learn some new and important tricks and also to start working more closely with engineers.

IV. Residences: Envelopes, Water, Appliances

Figure 3 gives data and time trends on American single-family houses. There is no room to fit any French data, but they are similar.

We measure electricity in resource or primary energy (so that it costs about the same as fuel). The left-hand block is energy use in existing buildings. We see that space heating and appliances use comparable amounts of energy and dollars.

On the right, we plot new homes. Their use of space heating is unfortunately not falling as fast as fuel for autos or energy for commercial buildings, presumably because homebuilding is a much more fragmented industry, and frankly I don't understand how the market can work <u>at all</u> when we have no energy use labels on residences.

At the year 1979, we see four points:

a) The NAHB survey of current practice.

b) U.S. Government Building Energy Performance Guidelines (BEPG) for a cost-effective home, if one leaves fresh air at the current average of 0.7 air changes per hour (ach), which is quite unnecessary.

c) BEPG for a "cost-effective" home at 0.4 ach. This 0.4 ach can be thought of as either reduced ventilation with no heat recuperation or as approximately 0.2 ach of uncontrolled infiltration with about another half an air change per hour with heat recuperation. But, despite the official BEPG title, I feel that "cost-effective" is computed incorrectly--without allowance for the savings for downsizing the furnace and air-distribution system.

d) Truly cost-effective superinsulated homes. This corresponds to the better one-third of the superinsulated homes in our BECA-A compilation.

The NAHB survey points present an overly optimistic view of progress in new building construction*, but if one draws a straight line through the slowly improving NAHB annual survey points, it reaches the superinsulated levels by 1994. I don't believe we'll get there so soon, but I do believe that our grandchildren will think of superinsulated U.S. homes as "turn-of-the-century" homes--even if the French should make them standard practice by 1985!

We are making slow but steady progress in reducing the need for space heat, but we must note that in a superinsulated home, space heat is only 10-20 units, whereas typical water heat is still 20 and appliances are 50. We're not doing much R&D on limiting hot water use or recuperating its heat, and in Europe you don't yet even have labels on all appliances. To me, the data in Fig. 3 call for two recommendations:

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*The NAHB survey is a voluntary, entirely non-random survey in which the best builders have the most incentive to respond. By way of comparison to the optimistic extrapolation from these points, we note that in 1983, superinsulated houses represented only a tiny fraction of U.S. new building construction, and builders in California and the U.S. are resisting standards far less stringent.

1. Any home energy rating system (such as I discuss in Section VI) must cover hot water and appliances.

2. The next R&D target must be integrated HVAC and appliances; I'll discuss this along with Fig. 18.

V. Superinsulated Homes and Passive Solar Homes-- Active Solar Space Heat Doesn't Pay

In Fig. 3, we saw that superinsulated homes can reduce the annual bill for space heat to $50 in the average U.S. climate (2600°C HDD) or $100 in Canada. With insulation, the heating season is reduced to a few winter months when daylight hours are short. This small heat bill, concentrated in a few winter months, kills active space heating and even competes severely with extravagant passive solar use of glass in very northern latitudes. Of course, it is still an excellent idea to concentrate some windows to the south and build greenhouses for the amenity they provide in the spring and fall.

Figure 4 shows the cost-effectiveness of various experiments with low-energy houses. The sloping lines represent the limit of cost-effectiveness for natural gas and electric resistance heat (at two different real discount rates). Now that the two biggest U.S. mortgage/lending agencies are giving bigger and better loans for energy-efficient homes, optimistic Americans should consider the 3% real interest rate lines. We see that the Saskatoon, Canada, homes are a great success (and have taken half the Saskatoon new-home market). MHFA (Minnesota Home Finance Agency) and SERI (Solar Energy Research Institute) homes are "getting there" (and will "arrive" as gas is deregulated), but on the other extreme our three active-solar dots are too expensive.

Like the proverbial pilgrim looking for an honest man, we have followed hundreds of leads for five years looking for data on cost-effective active solar homes. Many of the solar homes have energy data but no good cost data; others have heating fuel data but include an unmonitored wood stove. Can anybody help us? Figure 4 came from BECA-A and is discussed more by Jeff Harris in his talk here.

VI. Home Energy Rating Systems--"HERS" or "LABELS"

In 1977, the Edison Electric Institute initiated the National Energy Watch (NEW) program, a pioneering home energy rating system. Unfortunately (probably because of lack of confidence in their computer programs and their auditors), the program provided only "Pass/Fail" criteria, thus failing to motivate the builder to exceed the threshold. And the program was limited mainly to new homes and usually to space heating and cooling.

o PG&E's ECH (Energy Conservation Homes) Program

In 1979, the Pacific Gas and Electric Company (PG&E) decided to greatly strengthen their Energy Conservation Homes Program to go much further than the NEW programs. California had just passed "Title 24," Energy Performance Standards for new homes, and PG&E decided to offer its "ECH" label to any homes which beat Title 24 by 10%, with EXTRA CREDIT for additional measures. Northern California home builders discovered that this voluntary rating was so popular with home buyers that 2/3 of the homes built in PG&E territory soon qualified. And, although only 50 "points" were necessary to beat T-24 by the 10% threshold, by 1980 the average builder was marketing 75 points (see Fig. 5). In 1980-81, John Hailey of PG&E was recommending 125 points (25% beyond T-24--see Fig. 6), and many builders were going that far. So, the ECH Program really influenced the quality of new homes. In 1982, California was scheduled to update Title 24 all the way to the economic optimum, so PG&E decided to drop ECH as unnecessary. It's a pity that they did not instead switch it to existing homes!

At the beginning of the program, PG&E lacked confidence about its ability to predict accurate savings labeled in kWh and "therms" of gas, so they hedged by defining "points," each point representing (of all things) 300 MJ of resource energy (3 "therms" or 30 kWh), each worth at the time about $1.50/year. The heating and cooling points were calculated at LBL using DOE-2, and I'm pleased to say that later monitoring pretty well confirmed the calculations.

We return to discuss Fig. 6. We included it because we wanted to show that the majority of the PG&E measures do not affect the envelope of the house. Of Hailey's recommended 125 points, only 50 are envelope-related, whereas 75 represent savings from fuel choice and transient, flexible items: fluorescent lighting, set-back thermostats, even low-flow shower heads and indicators for clogged furnace filters. 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.

Next, I point out that we are finally beginning to collect very reassuring data on the accuracy of computer programs for residential energy rating. Figure 7 is taken from our Validation Compilation [BECA-Val '82]. It shows that several programs are now reliable to ±10%. it even includes one French point using DOE-2 at Dreux. In his talk here, Jeff Harris presents more such data in his Fig. 12, including several points from our own microcomputer program CIRA, which is also running in France. Figure 8 shows a label which can be printed out by CIRA at the end of one of its runs.

At this time--1983 (probably in part because of increasing confidence in computer programs)--there is greatly increased interest in graduated (quantitative) and comprehensive ratings for both new and existing homes, all stimulated by the availability of bigger and better loans for energy-efficient homes.

In her talk here, Maxine Savitz discusses HERS (Home Energy Rating Systems) and in particular the Mass-Save Experiment. I also have written on HERS [Rosenfeld and Wagner '82; Rosenfeld and Schuck '82] and will be happy to overwhelm you with reprints and data. But in this brief talk, I conclude my discussion of ratings with some technical recommendations for government or state officials.

Role of Government in Ratings

Ratings, and rating demonstrations, need the following government support:

1. Definition of Standard Home Occupancy Conditions--e.g., thermostat schedules, number of occupants, hot water and appliance use.

2. Certification of Computer Programs or Rating Forms. Each computer program should be tested against real homes and against a standard reference program, which has been calibrated to agree with a real home. It should "predict" the measured energy use to within about ±10% and get extra credit if it does better. We at LBL have written and are validating the two programs on which quantitative ratings have been based (DOE-2 for the PG&E ECH Program, and CIRA for the Mass-Save HERS). We'd like to collaborate with any other agency interested in labeling homes.

3. Unlike computer programs, of which probably only 20 or 30 will be popular at any given time in the U.S., there will be thousands of auditors. So, while computer programs should be centrally certified, auditors should be licensed by local licensing boards.

4. There must be provisions for quality control, procedures for complaints, and penalties for incompetent or dishonest auditors. The audit data forms must be registered and retained so that they can be checked if the auditor's predictions turn out to be inaccurate, and the sponsoring agency must update the ratings as participating homes are retrofit.

Final Recommendation: Ratings are more effective than are standards. Both France and the U.S. should sponsor many demonstration programs for both new and existing homes.

VII. Commercial Buildings: Daylighting and Thermal Storage

Daylighting isn't very important in residences (they are already daylit), and thermal storage isn't very important because internal gains (except for solar) are small. But in offices during working hours much free heat is generated. With proper thermal storage the office can then coast overnight and over the weekend.

o Daylighting

Let me make a suggestion for cheap daylighting that will save power in the winter, and power and undesirable heat in the summer. The reason you save heat in the summer is that daylight is cooler than artificial light: daylight provides 100-120 lumens/watt, fluorescent lamps provide about 70, and a 50-W incandescent lamp provides only 15.

My suggestion is to separate the daylighting part of the window (top 60 cm, extending up the the ceiling) from the view part, as shown in Fig. 9. The top part should be clear glass and provided with a white or silvered venetian blind to bounce light off the white ceiling. The top of the overhang should be painted white. All this permits optimum daylighting under all weather conditions.

The view part of the window should be treated separately, and in warm climates should use solar-control (reflective) glass. Its venetian blind should be separately operated, so that it can shade desks on hot sunny days, without interfering with the daylight coming in above. And, of course, we are working on new technologies to replace the low-tech shades.

My advice is, "Try it on a few buildings--and see if you like it."

- Thermal Storage--The Swedish Thermodeck System

By now, it is generally recognized that thermal storage is cost-effective in commercial buildings. The question is whether to use the concrete structure itself, or to use water to store heat in the winter and coolth in the summer. So, let me tell you about a Swedish system that is proving so cheap and effective that half the new buildings in Stockholm are using it.

A concrete floor-ceiling slab represents a convenient and large amount of thermal mass (about 100 watt-hours/m^2K). The trouble is that if it is isolated from the room or office space by acoustical tile on the ceiling and rugs on the floor, then it is not in good thermal contact with the occupied space.

Fortunately, manufacturers want to make prestressed, reinforced concrete floor-ceiling slabs that are thick (20-30 cm) for the sake of rigidity, but light for the sake of economy--so the slabs are usually extruded with long hollow cores. (Even if the slabs are poured in place, the same considerations apply, and it is easy to pour the concrete around a serpentine duct.) In Sweden, Andersson and Isfält (1979) have shown that by blowing room air through these ducts, using only tiny amounts of fan power (0.3 W/m^2 as compared to 15 W/m^2 for lighting), they can control the flow of heat to and from the slab.

A computer simulation of four typical designs is shown in Fig. 10. Curve (a) represents a rug and acoustical tile in a well-insulated room, or any room on a mild day. Lights and people heat up the air rapidly, and after an hour occupants will open the windows or turn on air conditioning. Thus, they store no heat for the next chilly morning. Curve (b) shows the ceiling tile and rugs still in place, but air circulated through the hollow cores, as in the Thermodeck system. Curve (c), which is indistinguishable from (b), shows the ceiling tile and rug removed, but no Thermodeck. Curve (d), which may be "overkill," shows no ceiling tile and rugs, plus Thermodeck.

The Swedes have very well-insulated buildings, so they use this technique routinely to store heat (in the winter) over nights and weekends, and to store summer nighttime "coolth" to keep the building comfortable the following afternoon. The first of these buildings, the Folksam building in Farsta, was represented by the lowest Swedish point in Fig. 2b.

Figure 11 shows the measured temperatures in the Farsta Folksam building during a winter week and two weekends--one cloudy, one sunny. Note that without conventional heat, the building pumps its temperature up during the week and coasts over the weekend.

In France, or in America where it is warmer, the technique is also attractive for storing outside night coolth during the summer. In Berkeley we have added approximate Thermodeck algorithms to several programs and used them in the computer design of such a building in Sacramento. We find that it saves 10% in peak power and permits a Sacramento building to get through the summer without a conventional chiller, using only a two-stage evaporative cooler.

I urge all participants in this colloquium to experiment with the successful Swedish technique.

VIII. Multifamily Retrofit--Microcomputer Control of Hot Water "Reset" Temperature

Figure 12 shows our compilation of residential retrofits. Please find and look at only one point: Page Apartments (OA2.1), which saved in each apartment 50 MBtu/year (worth $400/year of oil) for a one-time-only installed cost of $200. The figure is taken from BECA-B, and Page Apartments are described therein.

The basic idea is simple and can be generalized to most multifamily retrofits and all new apartments. The Page Apartments are part of Trenton, New Jersey, public housing. Page has a hot water (radiator) heating system, with the water controlled ("reset") by an external hydraulic thermostatic controller--which, as usual in older public housing, worked poorly or not at all.

The retrofit contractor, Bumblebee EMS, decided that it was silly to fix the outdoor temperature sensor/controller. Its job, after all, was only to control the indoor temperatures, and to do this without knowledge of the effects of sun and wind. In these days of cheap microcomputers, why not just sense the temperature of all the apartments and use bell-wire (in fact, existing bell-wire) to convey this information to a microcomputer. The first thing this experiment showed, of course, was that the apartments were very hot (typically 28^{o}C) and needed balancing. During a few months of careful balancing, the apartments were slowly brought down to a daytime temperature of 24^{o}C, which was comfortable for the many elderly residents, and down to 22^{o}C at night. And fuel use came down from 900 gallons/apartment to 460, with a few other improvements in energy management, all of which were made easier by the Apple computer. The payback for the retrofit was half a year.

If the job of a data center is to advertise the best successes and warn about the failures (and we have already warned about active solar heat), then surely this success deserves advertisement and further implementation. A further thought is that if microcomputer control makes sense for retrofit, it makes even better sense in new construction.

Every new apartment automatically has one or two phone lines installed. We say, during construction, add another one for computer control. (Soon progress in telephone technology will allow computer control over the same line that handles the regular phone service--but the spare line costs next to nothing, and it will turn out to be useful for something). Even if the individual apartments have the latest in controls and meters--thermostatic radiator valves and calorie-meters--the microcomputer can scan for very cold apartments (open or broken windows?) and very hot ones (poor balancing?). If the apartments do not have the latest technology, the microcomputer is, of course, even more effective.

If there are no calorie-meters and the occupants are on the honor system to save heat bills, then the computer could still help by mailing to the tenants a monthly distribution of apartment temperatures, with each tenant able to know only the temperature of his own apartment but able to see where he sits in the community.

Portable Thermostats

We've been talking about better temperature control for apartments. We conclude this section with a suggestion for better control of single-family homes, which usually rely on a fixed thermostat.

These days, as energy prices rise and family sizes shrink, more people (particularly the poor and the elderly) are heating only part of their homes, and the warm rooms may not be well coupled to the thermostat.

In Philadelphia, the Reverend Frank Kinsell, whose Institute for Human Development is helping poor or elderly homeowners to develop warm rooms, has himself developed a $50 portable electronic thermostat, which turns the furnace off and on by a ripple voltage over the house electric distribution lines. Just turn down the main thermostat and plug the portable unit into the wall plug in the room you want to control. It will communicate with a control unit mounted near the furnace.

I personally believe that all new homes should be designed to permit warm-area zoning at times during the life of the home. In addition to portable thermostats, this suggests insulation in the floors and perhaps in the walls, and the possibility of closing doors at the top or bottom of stairs.

IX. High-Technology Research

So far, I have discussed entire buildings. Next I should address the issue of applied research on such questions as plasmas for electric lights, new materials and films for windows, diffusive combustion for less polluting kerosene heaters, etc.

We at LBL spend most of our effort on high-technology research and claim that it has paid off magnificently by advancing by several years the arrival on the market of energy-efficient products.

Figure 13 shows how our work on high-frequency power supply for electric lamps has accelerated (by about 5 years) annual savings of $15B, which corresponds to 200TWh/year. This is equivalent to the total electric sales of all U.S. civilian nuclear plants and to 80% of all French electricity. It was accomplished by an investment of a few million dollars! I frankly doubt if there are any more $15B dragons left out in the forest to slay, but I can suggest lots of lesser dragons worth $1-5B per year. We should discuss whether any of these targets deserve cooperative research.

X. Ventilation and Indoor Air Quality

In France last year, you lowered your residential outside air requirements from 0.7 ach (air changes per hour) to 0.5. This decrease of 0.2 ach, extrapolated to all houses in France, corresponds to an annual savings of about $1B for space heating. This is indeed a commendable savings, but I have no idea whether it is too little, too much, or just right, and I am not aware of any surveys of indoor air quality that support it.

In the U.S., we are concerned with radon and combustion products in residences and with formaldehyde and other organics in all buildings. Figure 14 shows the concentration of radon gas (which can cause lung cancer) based on a survey of 98 U.S. homes. We see that the average concentration is about one unit (called a pCi/liter), which corresponds in risk of lung cancer to each occupant smoking about one cigarette each winter day when the windows are closed. That doesn't particularly worry me, but we also see three houses that correspond to a pack of cigarettes each day for each occupant or several person-packs per day. That does bother me, and in the U.S. we are trying to initiate a national survey to find all the pockets of radon.

Figure 15 gives the results of Fig. 14 converted to a rough estimate of lung cancers/year--2,700 in the worst few percent of our homes. How much comparable data do you have or plan to get for France?

Figure 16 shows another problem--emissions from a kerosene heater. At 1.9 ach in our small experimental chamber, the NO_2 concentration rises to 20 times the EPA guidelines for outside air and to 5 times the California 1-hour guideline of 0.25 ppm. If I planned to spend many intimate evenings with such a heater, I would want at least three air changes per hour.

How can we get this information across to consumers? First, we note that there are two sorts of kerosene heaters: convective, which usually burn with a white flame, and radiative, usually with a cooler blue flame which generates about four times less NO_2. The concentrations in Fig. 16 are for a white-flame heater.

My recommendation is to require an efficiency label on kerosene heaters. Of course, if you don't ventilate the room, the efficiency is 100%, but if you introduce enough outside air to dilute the NO_2 to 0.25 ppm, then on a cold Paris night the efficiency falls by about 30%. It seems only fair to make that information available to all purchasers.

To hark back to Section VIII, where I discussed warm rooms and portable thermostats, I should point out that the kerosene is simply a makeshift, somewhat unsatisfactory way to achieve a warm room. The U.S. Department of Energy, and probably the AFME, has the responsibility to show people how to achieve zone heating more efficiently and satisfactorily by turning off radiators in unused rooms (or in America, by closing warm air registers) and, of course, by fixing the furnace so that it will perform efficiently at reduced loads.

XI. Two Proposals for International Collaboration: The Next Generation of DOE-2/Cal-Eco/CIRA; Simulation of Integrated HVAC/Water/Appliances

Two areas where international program collaborations have worked out particularly well for me are data bases and computer programs. In particular, I want to mention two computer programs whose time has come but which would be less of a drain on both of our research programs if we collaborated and perhaps brought in a third country.

o Building Energy Analysis

It is surely time to start the next generation of building energy analysis programs, such as DOE-2, Cal-Eco, and CIRA. DOE-2 was designed in 1975, and its successor could not be in use before 1986. Meanwhile, computer hardware and software have changed unrecognizably, building shells and HVAC systems have changed, and algorithms have been improved.

The success of programs like CIRA shows that it is time to write a new international standard Building Description Language that can be run on a microprocessor to input any program, either simple programs to run in the same micro or the ultimate standard reference program to run remotely. By 1985 we should be able to standardize Building Description, just as FORTRAN standardized Formula Translation 25 years ago.

o Integrated HVAC/Appliances/Water (HVACAW)

In Section IV and Fig. 3, I pointed out that we now know how to build superinsulated homes which use less energy for space heat than for hot water and appliances--specifically in the ratios of 10:20:50. I concluded that the next R&D target should be combined as "HVACAW."

At Berkeley, Professor Brent Stearns and I have been toying with HVACAW for about a year and find it very frustrating to work without a decent computer program. It's a bit like turning children loose in a toy store and telling them they can have only one present for Christmas. Almost everything looks attractive, but what is best? And, like toys, some configurations of appliances are best in summer, some in winter, and some in between.

What we need is a general network program that can easily simulate many different hookups of devices. The program must be driven by different typical weather-days: from hot to cold, from humid to dry, and by different appliance-use schedules.

It must be able to call on modules that simulate everything from a heat pump to hourly flow of grey water, to the clothes dryer that might occasionally be the load for the heat pump. Each of these modules must have data on first cost and lifetime. Finally, the control language should be compatible for the research simulation phase and for the real controllers that will run real hardware--this greatly simplifies design and validation of later experiments and commercial devices.

I think it would be stimulating and productive to put together an international collaboration to write such a program, and I believe we could cost-share with the appliance and building industry.

* * * * *

In Fig. 19, I summarize my many suggestions. Thank you for your attention.

Acknowledgements

I have borrowed figures and ideas from colleagues throughout the Energy Efficient Buildings Program, in particular from the Buildings Energy Data Group. I especially thank Barbara Shohl Wagner.

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References

o Andersson, L. O., K. G. Bernander, E. Isfält, and A. H. Rosenfeld (1979). Storage of Heat and Coolth in Hollow-Core Concrete Slabs. Swedish Experience and Application to Large, American-Style Buildings. LBL 8913, EEB 79-1.

o Rosenfeld, A. H. and L. Schuck (1982). Building Energy Rating Systems: Panel Summary. Reproduced from Proceedings of the 1982 ACEEE Conference on Energy-Efficient Buildings, Santa Cruz, CA. LBL 16074, EEB 83-2.

o Rosenfeld, A. H. and B. S. Wagner (1982). Technical Issues for Building Energy Use Labels. Presented at 1982 ACEEE Conference on Energy-Efficient Buildings, Santa Cruz, CA. LBL 14914, EEB-BED 82-13.

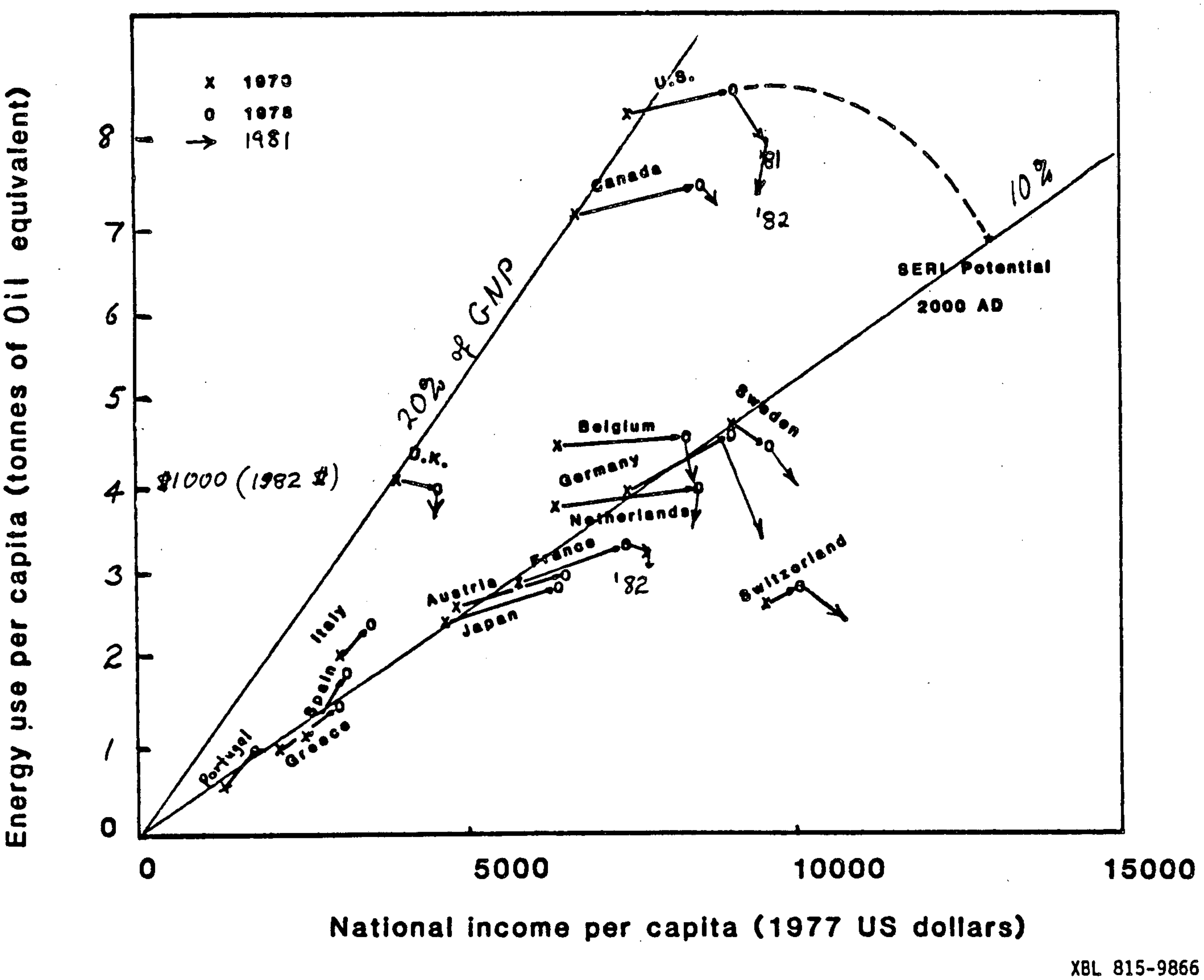

Fig. 1. 1970 and 1978 resource energy use by some industrialized nations. The conversion from national currency to dollars was done only once (for 1978). Along each national arrow, we used national deflators; this avoids jitter from fluctuations in exchange rates. Source: UN Statistical Handbooks.

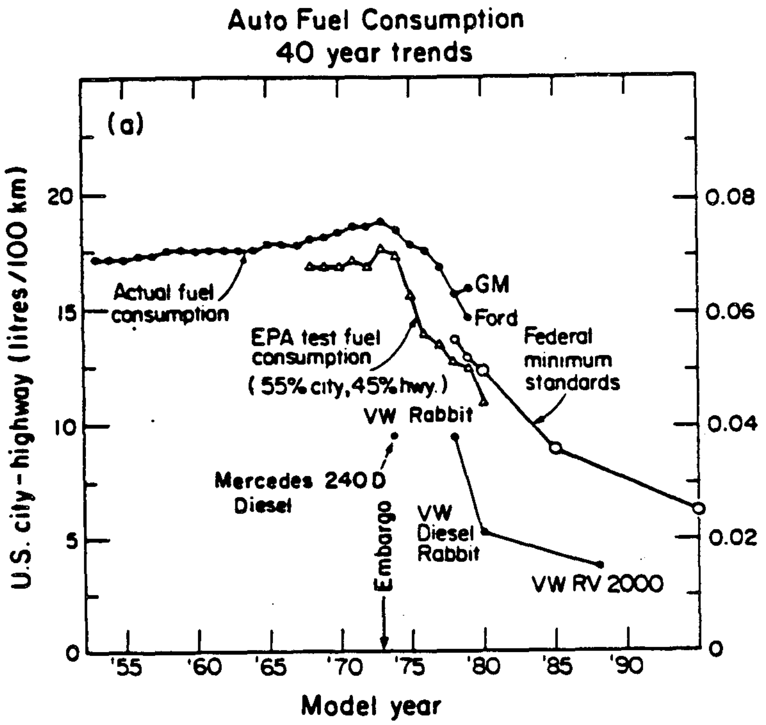

Fig. 2a. Forty-year trend in fuel consumption of new U.S. auto fleet and some foreign competition. Source: Cray and Von Hippel, Scientific American, 244, 36 (May, 1981).

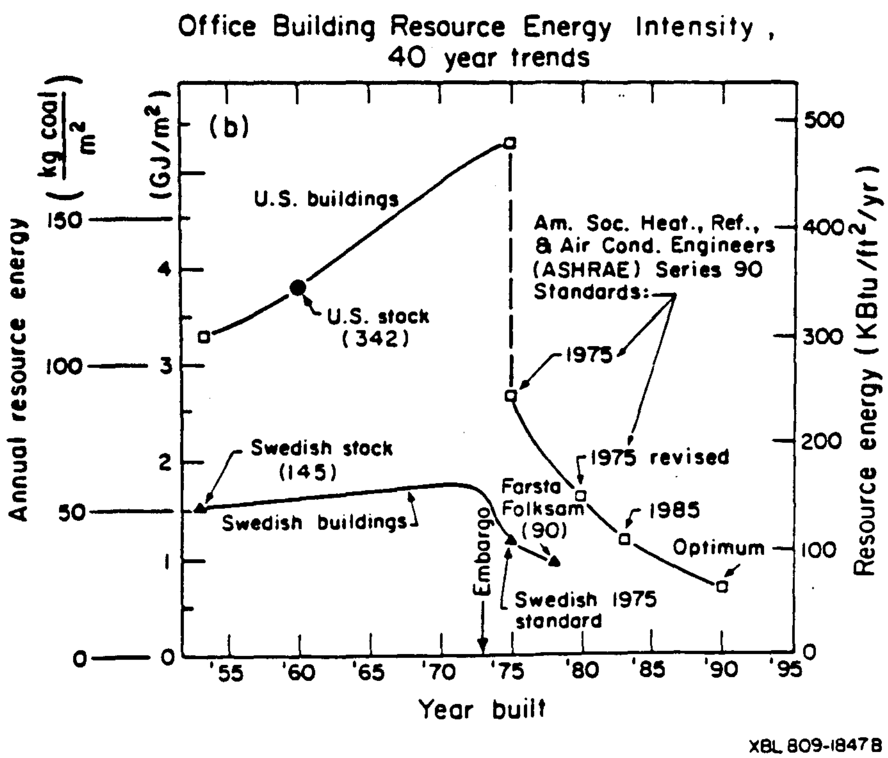

Fig. 2b. Forty-year trend in annual energy use per unit floor area of new U.S. and Swedish fuel-heated office buildings. Electricity for lighting, cooling, etc., is counted in resource energy units of 11,500 Btu (12 MJ) burned at the power plant per kWh sold. Source: A New Prosperity--SERI Solar/Conservation Study, Brick House Publishing Co. (1981).

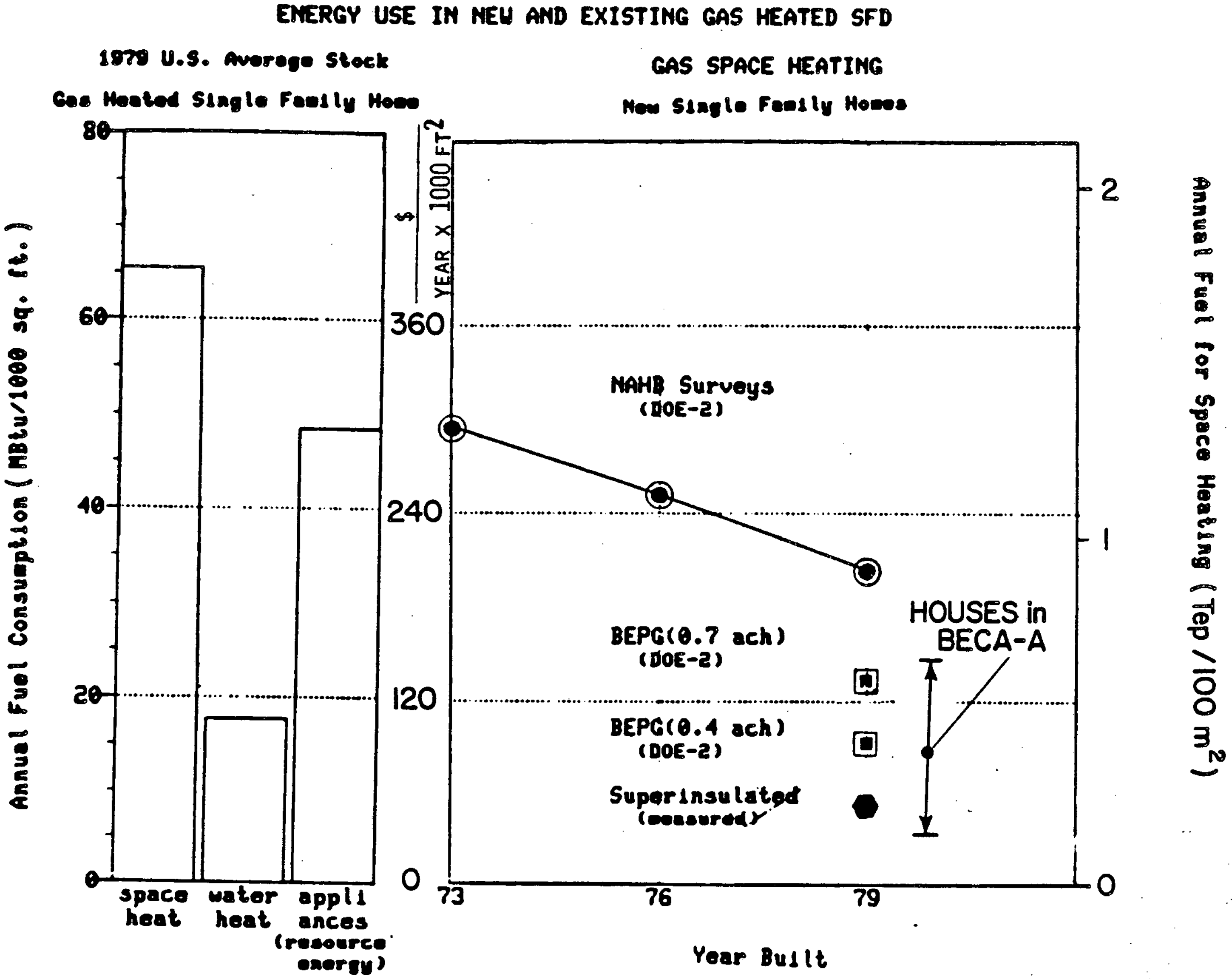

Fig. 3. Energy Use in New and Existing Gas Heated Single Family Houses

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.

Source: Rosenfeld/Wagner (1983)--Labels.

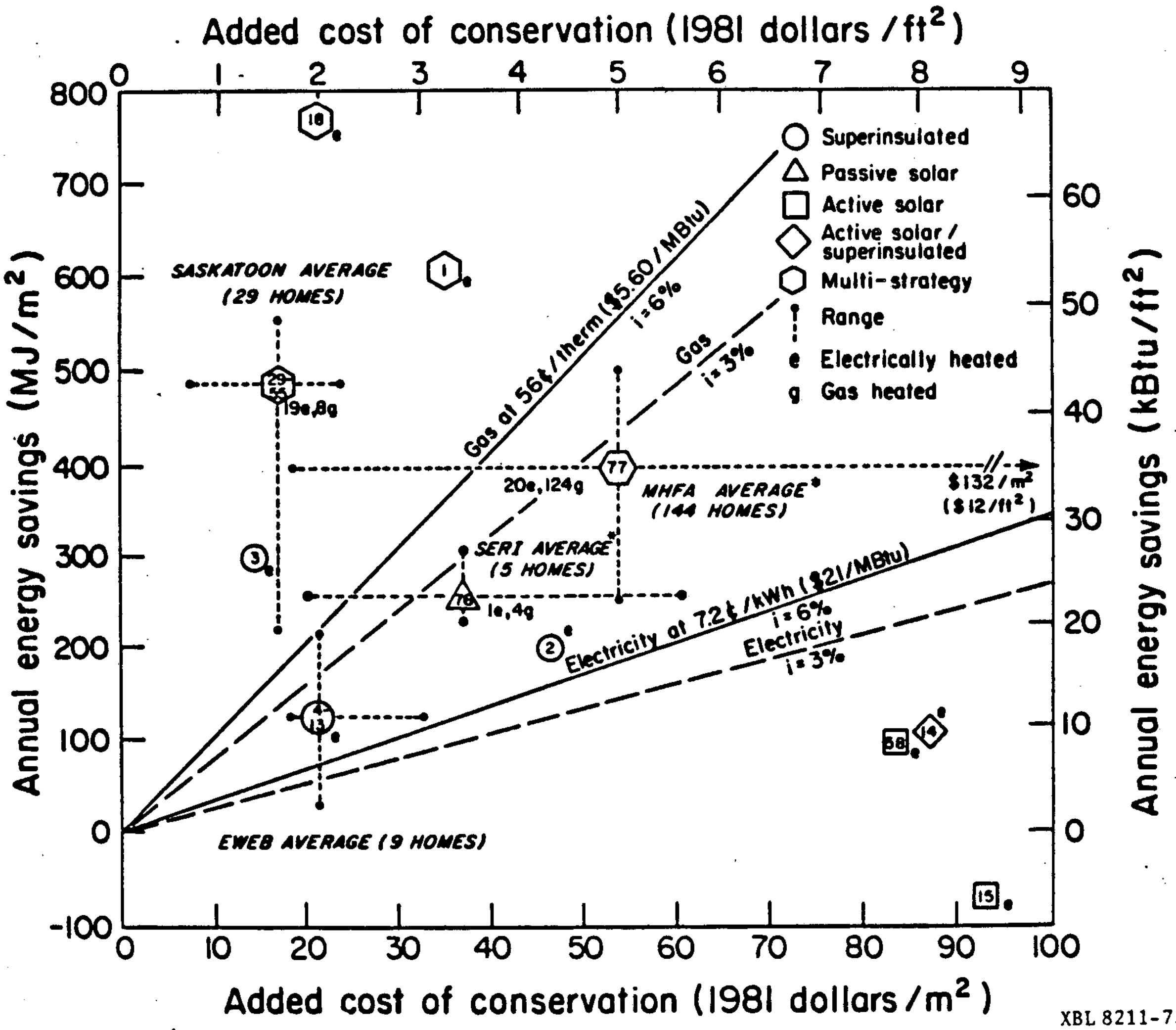

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Figure 4. Two-hundred-one-seven-house scatter plot of annual energy savings vs. added first cost of conservation and solar features. The energy savings represent the difference between the home's annual thermal intensity and the current U.S. building practice line of Figs. 1 and 2. The reference lines drawn from the origin represent the boundary of conservation cost-effectiveness against recent U.S. average residential energy prices for electricity (7.2¢/kWh) and gas (56¢/therm). Since conservation is typically a "one time" investment, the future stream of energy savings for 30 years are converted to a single present value, assuming 6% or 3% real interest rate. The home is cost effective if its point lies above the reference line in question. Source: BECA-A (1983).

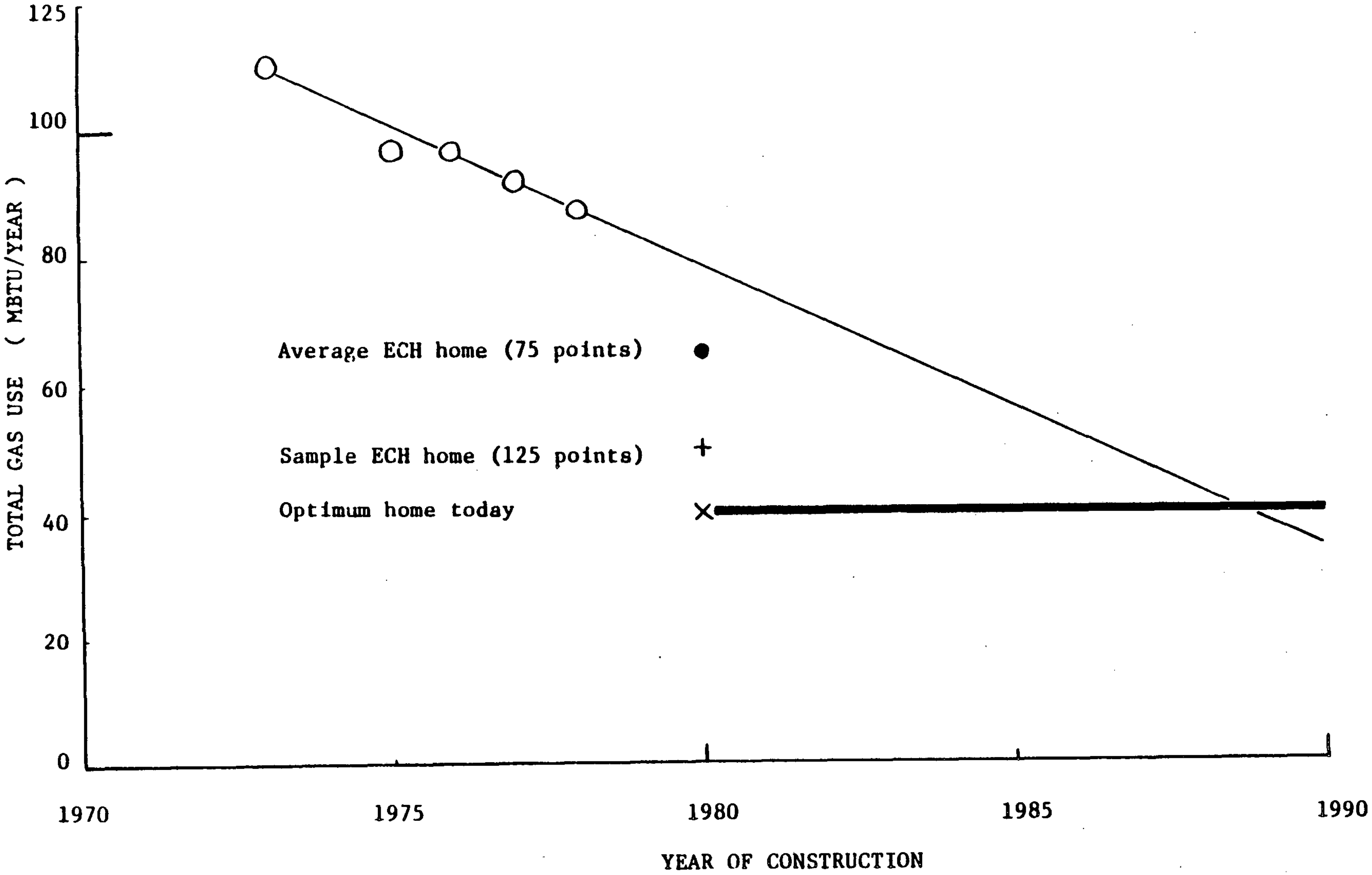

Figure 5. Total use of gas in new gas-heated homes supplied by Pacific Gas and Electric Company in Northern California. Open circles are average billed use of gas for homes built in the year indicated. The solid dot is the calculated gas use of the average home qualifying in 1980 as an Energy Conservation Home; 60% of all new homes qualified. The " + " is the sample Energy Conservation Home marked up on the score sheet at the end of this report (125 points, i.e. 375 therms, for $175). The " x " is the estimated use for a home built today in Fresno's climate that minimizes its lifetime costs. Presley Homes currently advertises that its homes are as good as least cost. The thick horizontal line is the economic optimum energy use, on the assumption that gas and gas conservation costs remain constant in real dollars. This figure is in the same format as Figures 3 and 4, except that the points are actual metered gas use, instead of being estimates based on building plans.

	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)	2		
Free-standing model	10		
Air tight wood burning stove	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

Fig. 6. Rating Sheet for PG&E's ECH New Home Rating, filled out for 125 points for an incremental cost of $375. The 125 points correspond to 37.5 MBtu/year of resource energy, worth about $225/year. Electricity savings are indicated by e.

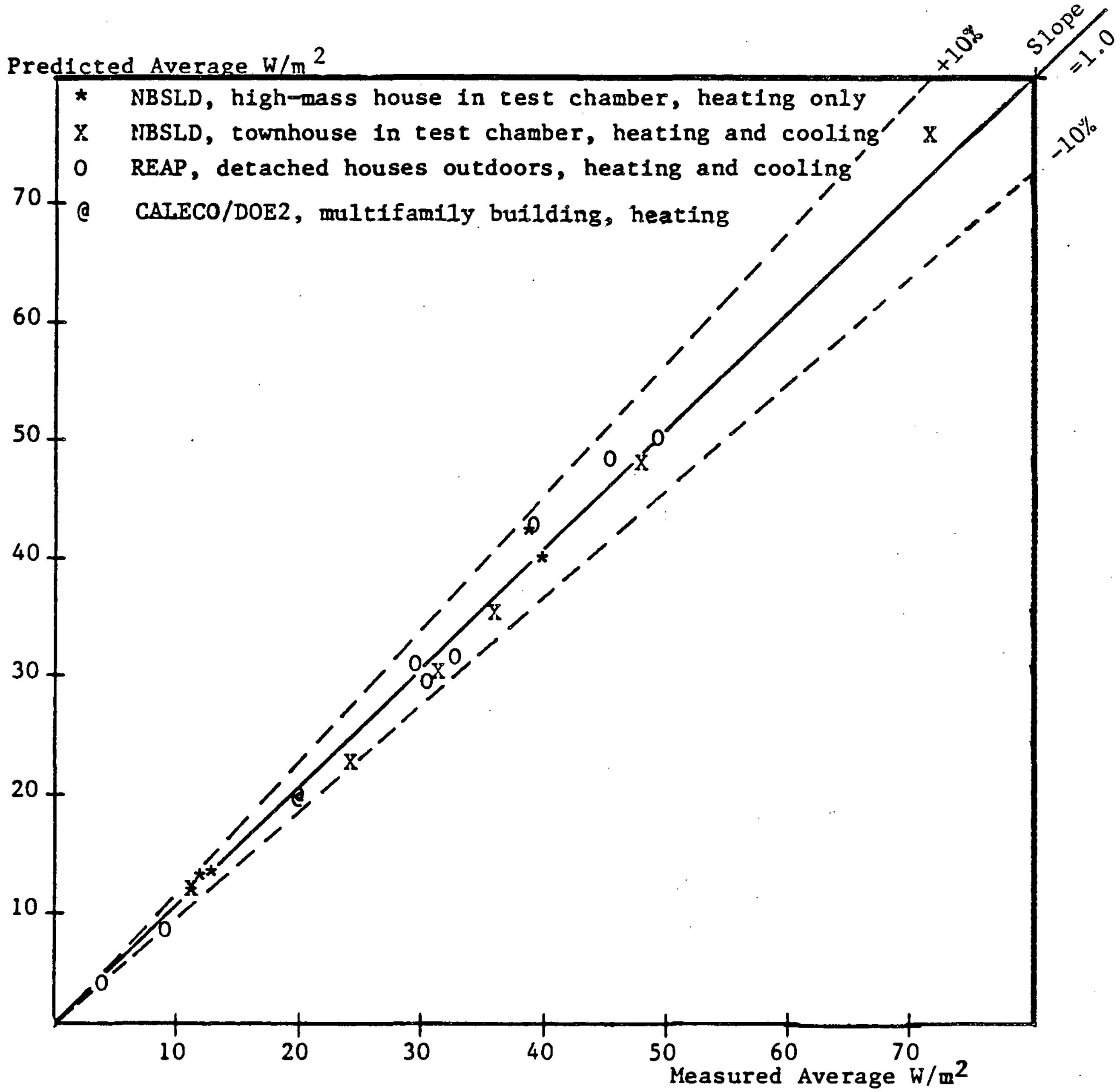

Fig. 7. Residential Buildings; Intensively Instrumented and Monitored. Predicted vs. Metered Site Energy Use, Averaged over Monitoring Period (1 day to 1 year). Source: BECA-Val (1983).

HOME ENERGY RATING

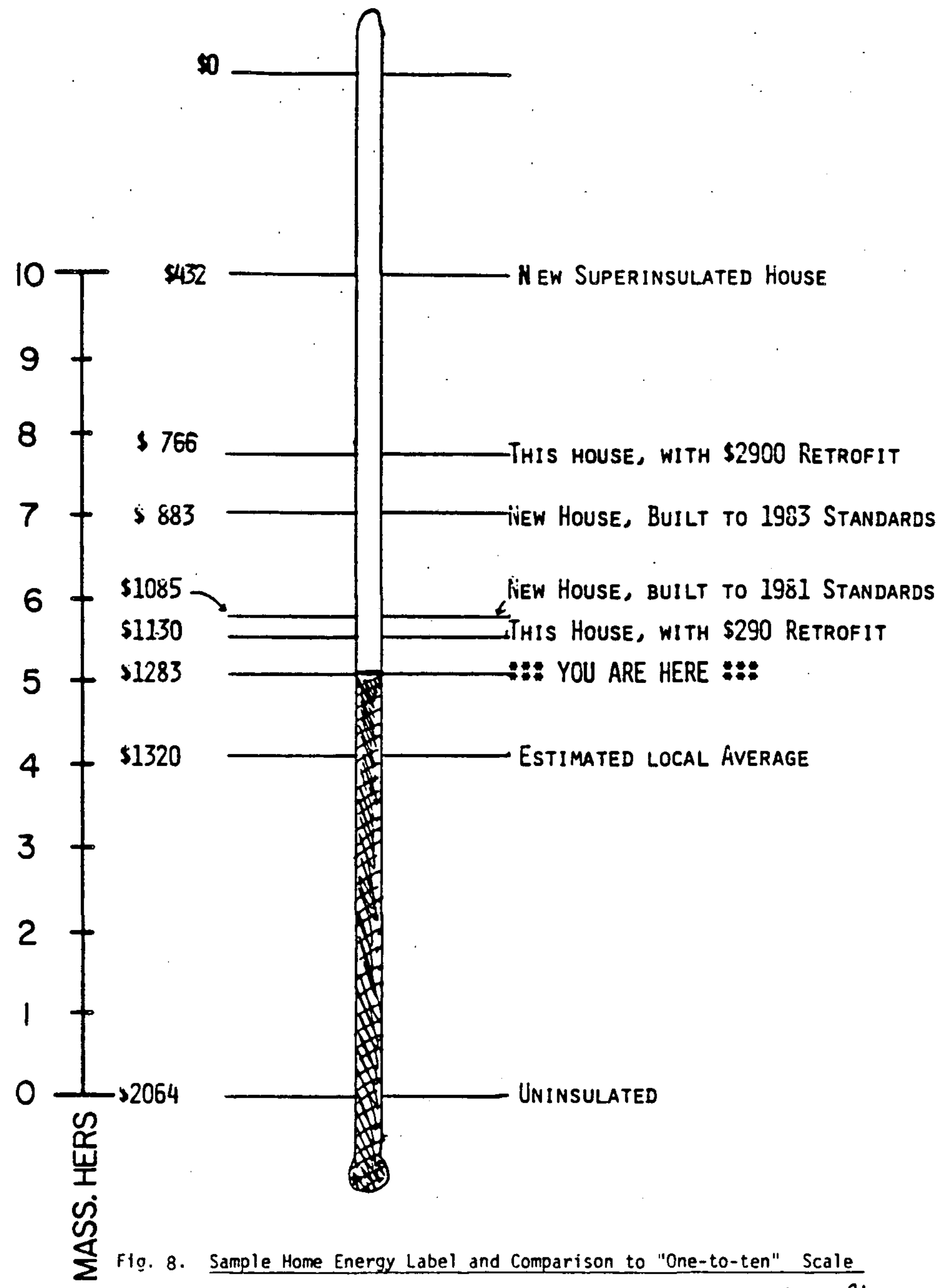

Fig. 8. Sample Home Energy Label and Comparison to "One-to-ten" Scale

Annual total energy bill (gas plus electricity) for 1939 Cha[illegible] Drive, Walnut Creek, CA, in 1983 $. The floor area of the house is 1500ft². 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 1500ft² 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. The Massuchetts rating scale, shown for comparison, is based on similar calculations, but includes space heating only.

Sources: Rosenfeld and Wagner, "Technical Issues for Building Energy Ratings" LBL-14914, and Energyworks/Alliance to Save Energy Massachusetts Home Energy Rating Brochure.

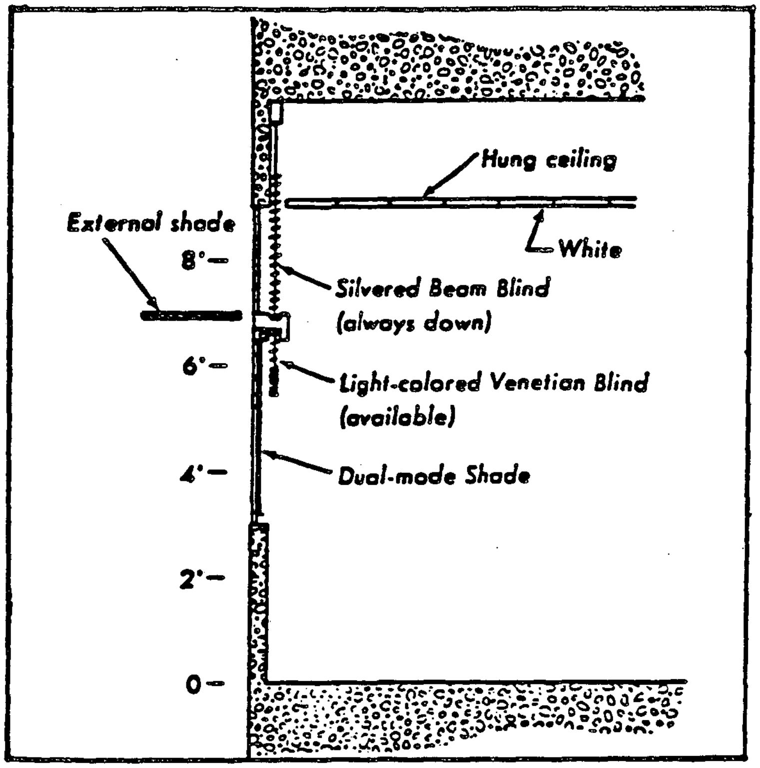

Fig. 9. Separation of daylighting window above an overhang from view window below. On South windows there should be an overhang painted white on top to act as a light shelf. Source: Rosenfeld and Selkowitz (1977).

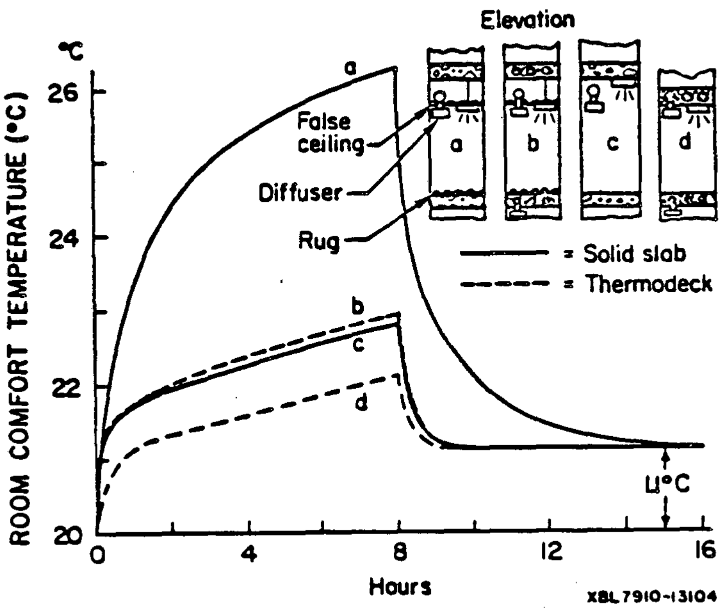

Fig. 10. Response/relaxation curves calculated by the BRIS-program for equal rooms with two different slabs, each with a heat capacity of 100 Wh/m^2K. The surroundings are assumed symmetric on all sides (as in an office in the core of a building). 15 W/m^2 of lighting (50% radiation) is turned on for the first 8 hours of each run. The cases are as follows:

a. 20-cm thick solid concrete slab, with rug, insulated, suspended ceiling, and plenum. Resistances assumed were: rug -- 0.1 $(W/m^2K)^{-1}$; insulated false ceiling -- 0.5; plenum -- 0.17.

b. Same as a., but slab is 30 cm. thick Thermodeck.

c. 20 cm. thick concrete slab, but bare -- no rugs, suspended ceilings, plenum.

d. Same as c., but slab is 30 cm. thick Thermodeck

Source: Andersson et al. (1979).

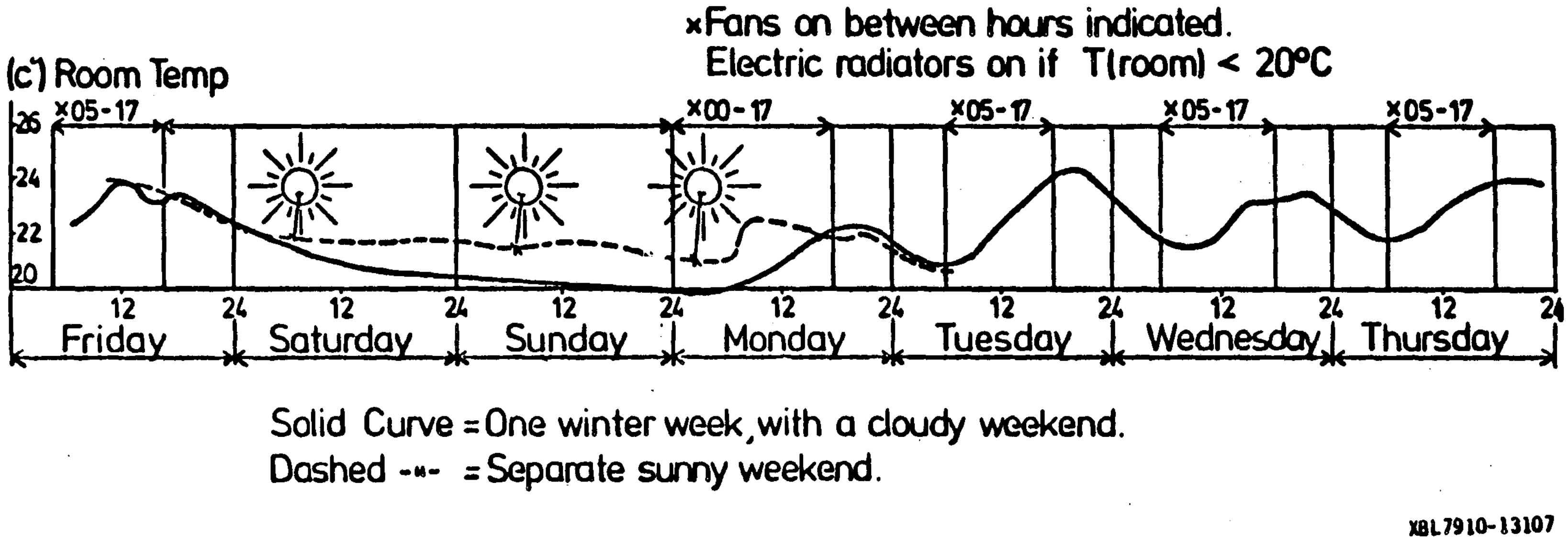

Fig. 11. Measured temperatures in a NE-facing office of the Farsta Folksam building during a winter week. T(out) varied between -2 and -10°C. Source: Andersson et al., 1979.

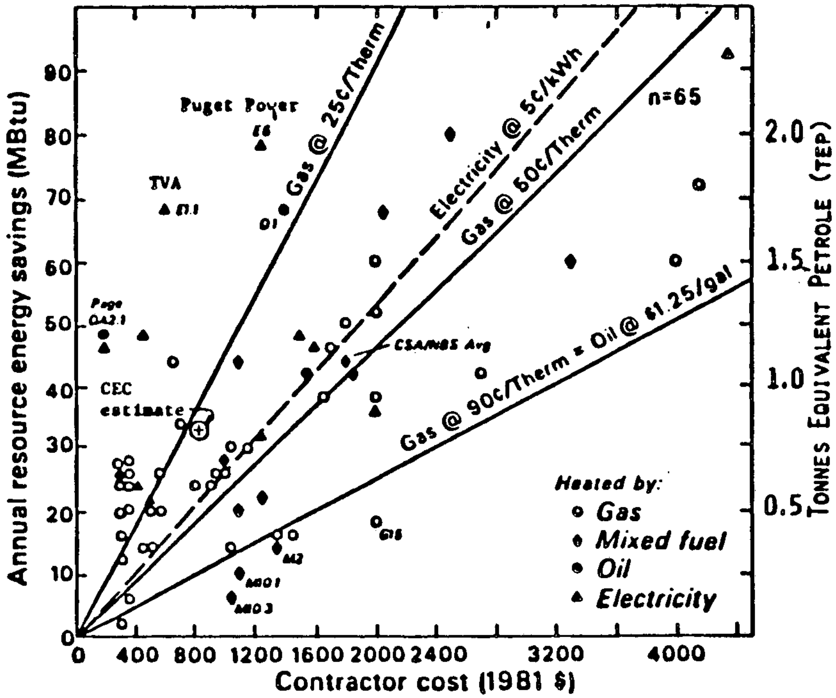

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Fig. 12. Annual resource energy saving vs. contractor cost for 65 residential retrofit projects. Annual savings, in resource energy, after retrofit are plotted against the contractor cost of retrofits. The sloping reference lines represent the boundary of cost-effectiveness for typical residential energy prices. Since conservation investments are typically "one-time," the future stream of energy purchases for 15 years is converted to a single present value, assuming a 7% real discount rate. The conservation retrofit is cost-effective if the data point lies above the purchased energy line for that fuel. Electricity is measured in resource units of 11,500 Btu per kWh sold.

Source: Wall, et al. (1982)

EEB Research is remarkably cost-effective. Societal pay-back times of days or weeks, yet the market is advanced by years.

- PART 1: Successes from past work, 1975 - 1982.

1. High-frequency ballasts for fluorescent lamps.
2. Energy-efficient screw-in bulbs to replace incandescents.

Base Case	Fluorescent	Incandescent
'82 Use (BkWh)	220	180
'82 Value at 7¢/kWh	$15 B	$12 B
Option	H-F ballast	Compact fluorescent
Savings at 100% Penetration	40%	75%
Value	$6 B	$9 B
Market Advancement (years)	5 Y	5 Y
Cost of Conserved kWh	2¢	2¢ (a)

(a) CCE for Norelco assumes target price of $15 (to match Westinghouse compact fluorescent), not initial $25.

Fig. 13. Savings in electricity for lighting.

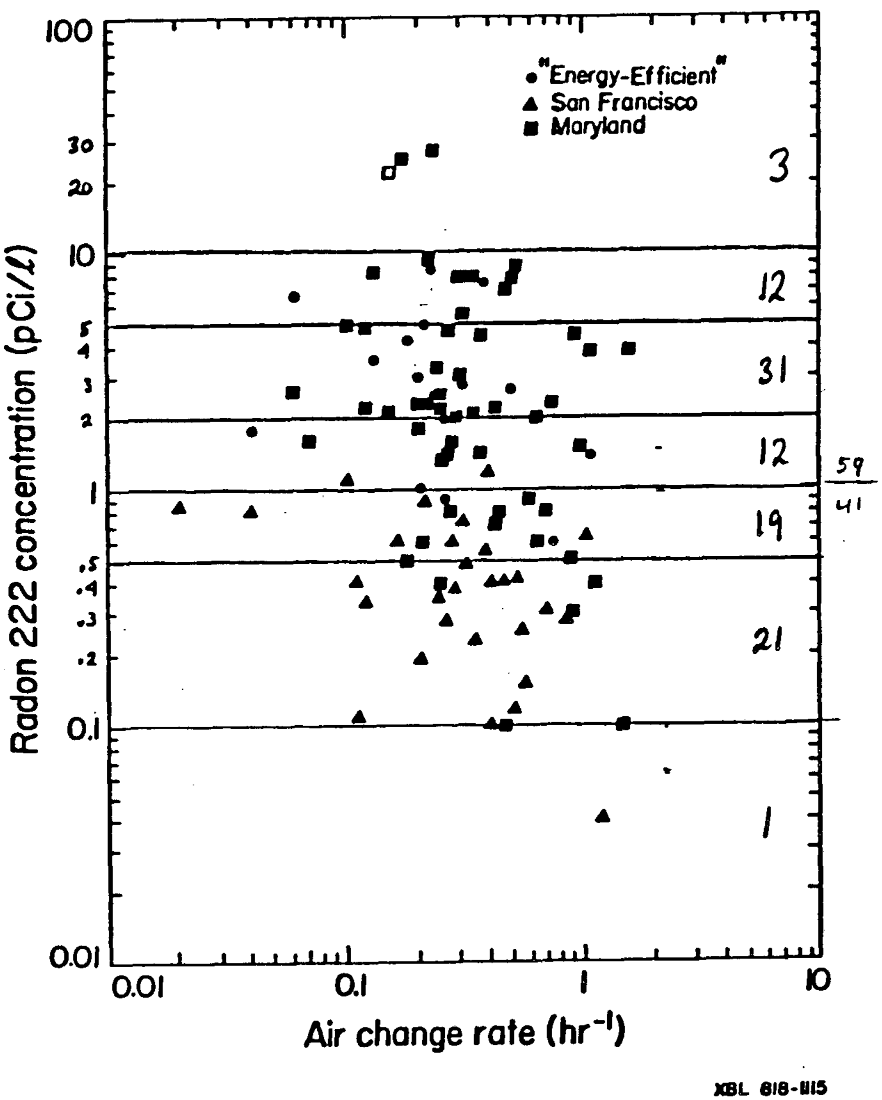


Figure 14. Radon 222 concentrations versus air infiltration rates in 98 homes. Source: Nero et al., LBL 13415, EEB-Vent 81-38, submitted to Health Physics September 1981.
Note: One pCi/liter is equivalent, in risk of developing lung cancer, to smoking about one cigarette daily, on those days when the windows are closed.

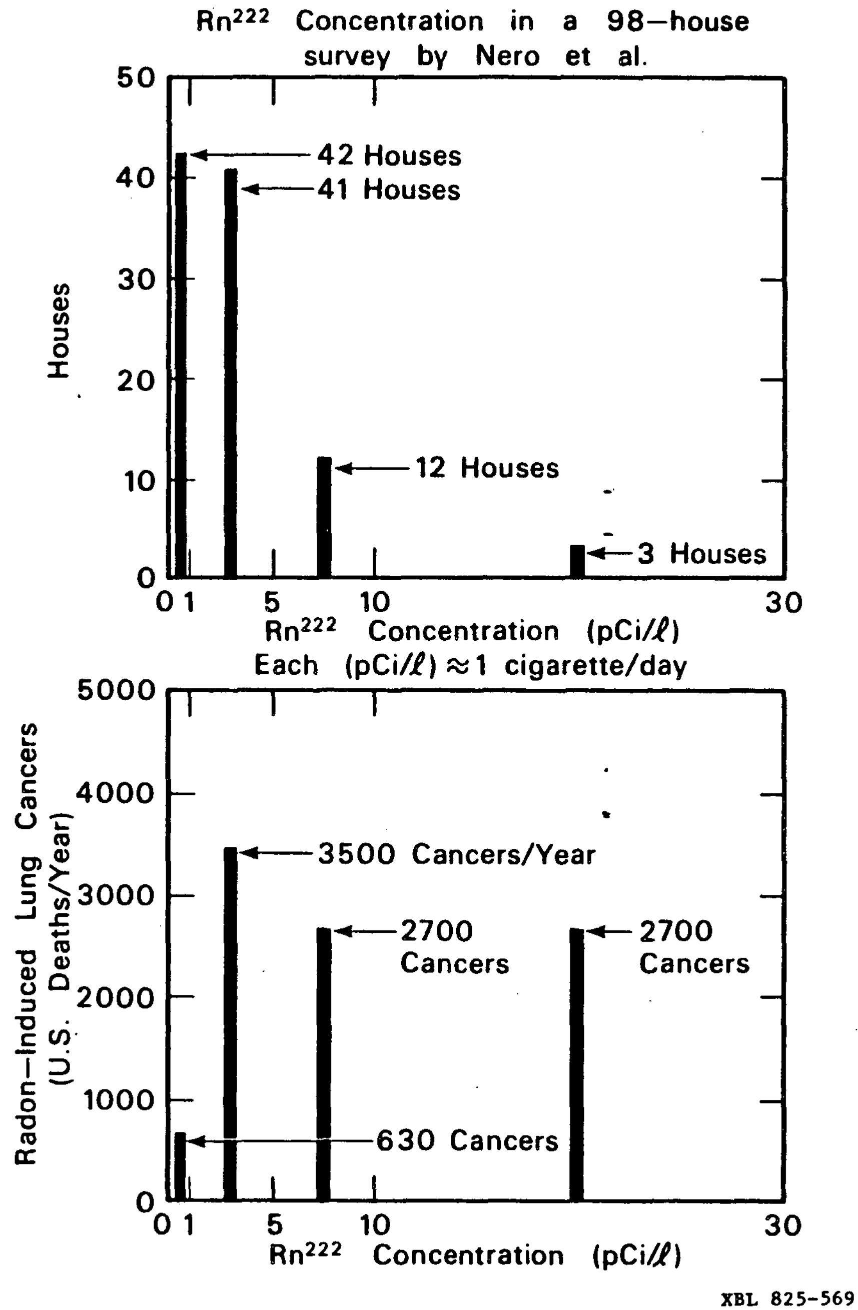


Fig. 15. Radon 222 data from Figure 1--"binned" by concentration (top) and converted to annual lung cancers (bottom).

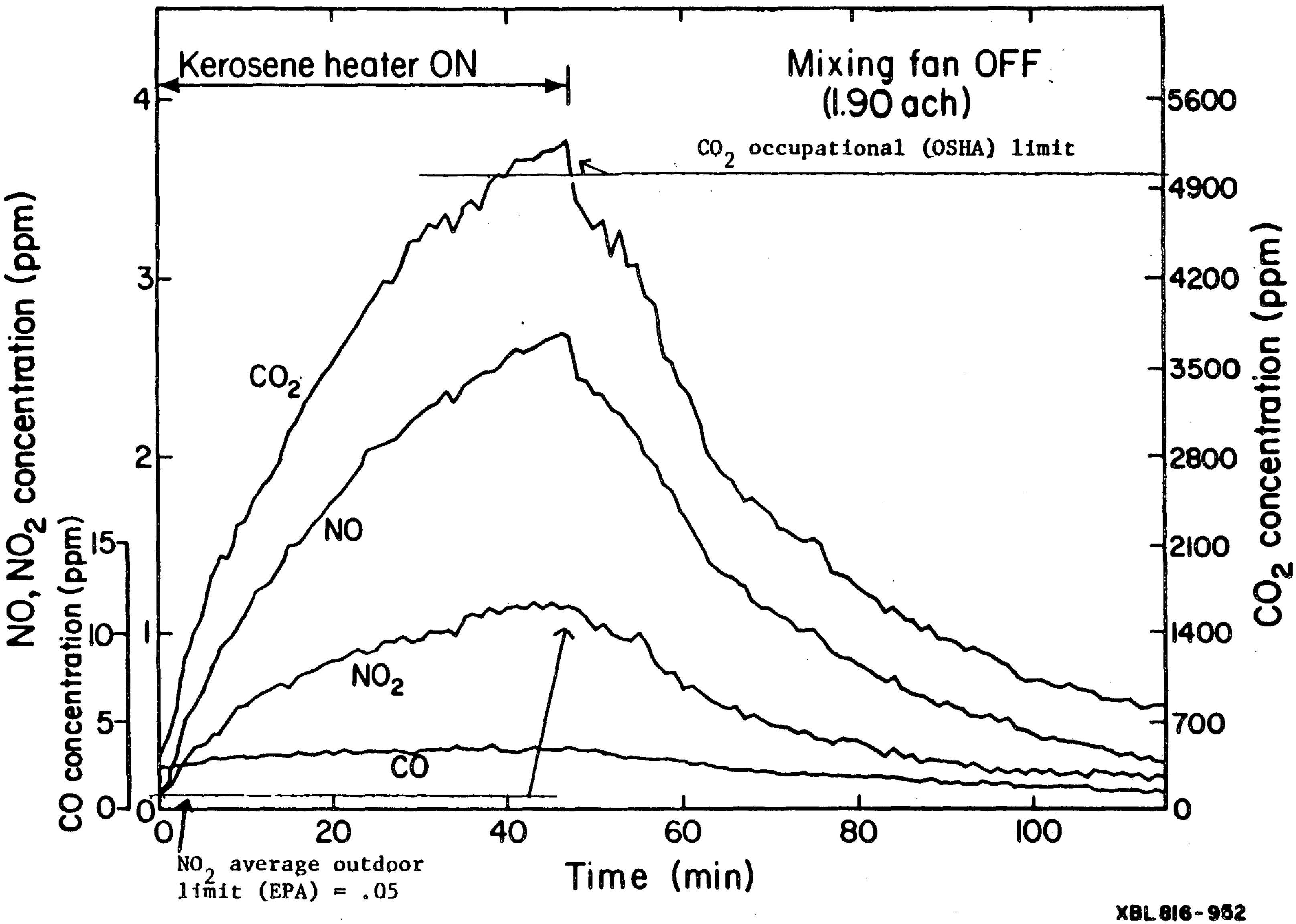


Fig. 16. CO, CO_2, NO, NO_2 emissions from a portable kerosene-fired space heater (convective type) in a]7 m^3 enviromental chamber. (Particulate concentrations, not shown, were negligible.

Fig. 17.

AREAS FOR INTERNATIONAL COLLABORATION

WE ALREADY HAVE AN LBL/ORSAY COLLABORATION TO METRIFY, ADAPT, AND VALIDATE DOE.2 = CAL-ECO.

LBL ALREADY EXCHANGES PERSONNEL WITH FRANCE, SWEDEN, BELGIUM, AND THE PEOPLES' REPUBLIC OF CHINA.

I. EASIER AND MORE ACCURATE BUILDING ENERGY SIMULATION (DOE.N)

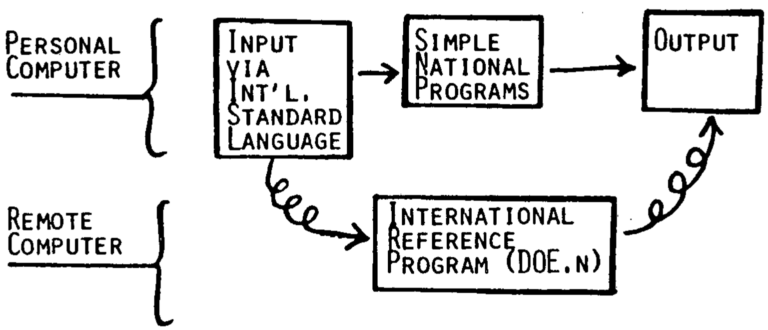


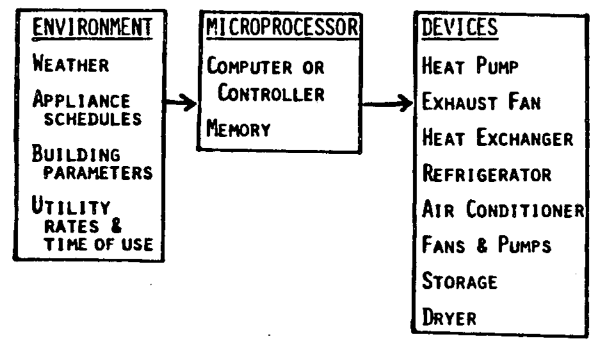
Fig. 18.

INTEGRATED HVAC/APPLIANCES/WATER (HVACAW)

<u>EXAMPLE</u>: WATER FOR SPACE HEAT AND DOMESTIC USE SHOULD BE HEATED BY WASTE HEAT FROM THE EXHAUST AIR OR AIR CONDITIONER, REFRIGERATOR, GREY WATER, AND POSSIBLY SOLAR COLLECTORS.

WE SHOULD DEFINE A SINGLE INTERNATIONAL LANGUAGE AND COMPUTER PROGRAM WHICH CAN:

- FIRST SIMULATE CONFIGURATIONS OF DEVICES AND STORAGE
- LATER CONTROL THE REAL HARDWARE



PHASE I: DESIGN	SIMULATED	COMPUTER	SIMULATED
PHASE II: LAB TESTING	SIMULATED	MICROPROCESSOR	REAL
PHASE III: REAL WORLD	REAL	MICROPROCESSOR	REAL

FIG. 19. SUMMARY OF SUGGESTIONS

LABELS: NEW AND EXISTING HOMES, COMPREHENSIVE, CALIBRATED.

COMMERCIAL BUILDINGS: TRY SWEDISH "THERMODECK" STORAGE.
SEPARATE WINDOWS FOR DAYLIGHTING AND FOR VIEW.

MULTIFAMILY RETROFIT: MICROCOMPUTER CONTROL.

NEW RESIDENCES: INTERNAL ZONING--INTERNAL INSULATION AND PORTABLE THERMOSTATS.

HIGH-TECH RESEARCH AND DEMONSTRATION:
MATERIALS FOR WINDOWS, LAMPS, REFRIGERANTS,...
WINDOWS, LAMPS, HEAT RECUPERATORS,...

VENTILATION AND INDOOR AIR QUALITY:
SURVEYS AND DATA. EXHAUST AIR HEAT PUMPS VS. S-E-X.
KEROSENE HEATERS.

PROGRAMMING COLLABORATION:
NEXT GENERATION OF DOE-2 OR CAL/ECO.
NETWORK PROGRAM TO SIMULATE INTEGRATED APPLIANCES.

BUILDINGS ENERGY DATA CENTERS:
MONITORING, CRITICAL REVIEW, DATA BASES.

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