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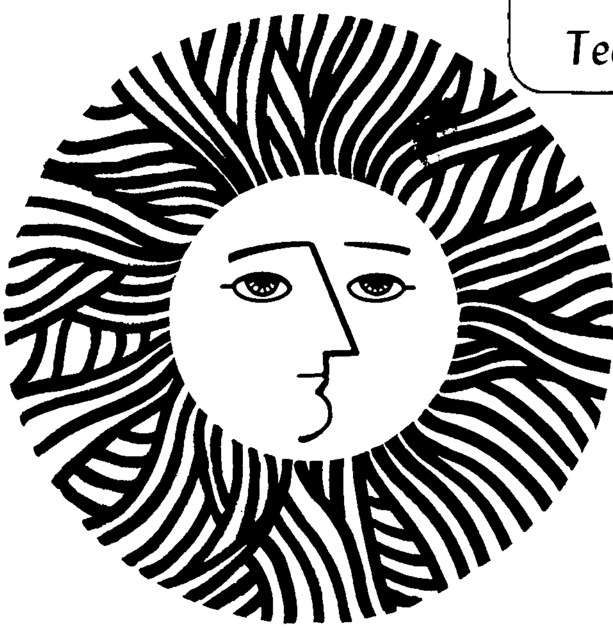
ACCELERATING THE BUILDINGS SECTOR'S SLUGGISH RESPONSE TO RISING ENERGY PRICES BY FEDERAL R&D, INFORMATION, AND ANALYSIS PROGRAMS

Arthur H. Rosenfeld and Mark D. Levine

April 1981



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ACCELERATING THE BUILDINGS SECTOR'S SLUGGISH RESPONSE TO RISING ENERGY PRICES

by Federal R&D, Information, and Analysis Programs.

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Testimony
before the
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Abstract

The response of the buildings sector to the recent rapid rise in the price of energy has been perceptible but very slow. A history of low energy prices has left the US with a stock of buildings which use far more energy than a least-cost building stock would. With energy costs continuing to rise much faster than general inflation, this delay in market response costs households and consumers billions of dollars each year. The difference between actual and optimal strategies may be measured either by an implicit consumer discount rate, or by the number of years it might take for the market to reach today's cost-minimizing level of energy efficiency. Currently, the consumer discount rate is between 15% and 40% in real dollars instead of the 2.7% which mortgage rates averaged between 1963 and 1981. We take this 2.7% to be the value of the consumer discount rate for home improvements when adequate trustworthy information is available. The market lag is between 15 and 30 years. We discuss ways of speeding the market's response to higher energy costs for the buildings sector with special reference to the role of the federal government.

Federal support is indicated in two main areas: (1) programs to alleviate possible public health and welfare effects, (2) programs to speed the day when the market's performance is closer to optimal. The first area includes research programs such as indoor air quality. Reducing the leakage of heated or cooled air from buildings can save half a million barrels a day of oil equivalent (approximately one quad per year), but may have undesired health effects. Indeed, research has shown that for certain indoor air pollutants, health effects may already be occurring in today's poorly sealed buildings. Research on this topic can help ensure that "leak plugging" in homes and commercial buildings will not affect public health, but it is precisely this type of R&D that is least likely to be supported by private industry.

The second area calling for government involvement to reduce market lag industry includes testing and labelling homes for their energy consumption; development of essential diagnostic equipment that would be difficult to patent (such as the Princeton/LBL blower door); and short-term technology development in areas where there is currently no US manufacturer (such as the air-to-air heat exchanger) or where inertia needs a small push to get it moving (such as electronic fluorescent ballasts). Details of all these examples are given, with costs and expected savings.

We conclude that there is a potential to save $50 billion annually by improved energy efficiency in buildings, and that federal programs costing a few million dollars each year could advance the date of there saving by several years.

I. INTRODUCTION

This paper is written in response to the Reagan Administration's FY 82 budget cuts, in which the Department of Energy's Office of Buildings and Community Systems program is reduced to less than one-third of Carter's FY 81 budgets In our judgment, these cuts will drastically reduce the research activities on energy efficiency in buildings. The immediate effects of the cuts will be to halt a multitude of valuable and important research activities. However, it will not be long before the effects will extend well beyond the research community. In the absence of essential research, information, and analysis programs on energy efficiency in buildings, much of the progress that the market has made in improving the efficiency of energy use in buildings will be slowed, to the detriment of all.

It is our thesis that there are several areas of research, and related activities, on building energy efficiency in which the federal government has a critical role. These areas include:

- Research in building science to advance the state of knowledge and to solve social problems (eg., indoor health effects).
- Programs to accelerate market acceptance of cost effective investment in energy efficiency, including:
  - energy efficiency labeling programs;
  - research and development that is unlikely to be undertaken by the private sector because it cannot be patented;
  - near-term technology development that the private sector is not organized to undertake, in spite of potentially large payoff.
- Government information programs for forecasting, planning, and analysis, so that the government has sufficient information to make informed decisions.

II. OVERVIEW

We agree with an important element of the Reagan Administration -- deregulation of oil as gas as soon as possible, and letting the market respond as fast as it can.

But we argue that market response in the buildings sector will take about 20 years unless the Federal Government takes some limited but critically important leadership role to accelerate market response.

Our annual energy bill is now over $1 billion/day ($400 billion per year), and one third of it goes to the buildings sector. Market response will eventually save about 1/3 of that, or nearly $50 billion/year in buildings. So every year that we can advance that response, we save tens of billions of dollars.

Moreover, the eventual resource energy savings in the buildings sector alone are comparable with our oil imports for all sectors. Can we then afford to hold our energy economy and our foreign policy hostage to its own built-in inefficiencies any longer than necessary?

In cars and appliances, as we shall see below, there is a lag of about ten years between energy price increases and the market's response of maximum efficiency. In buildings, this lag is much longer, 10 to 20 or more years. In the time scale of oil supply -- where there are wars, revolution, and instabilities every few years -- a potential maximum efficiency advance of ten years is indeed a significant help towards reaching energy stability.

If there is a case to be made anywhere in the U.S. economy for government actions to accelerate market response to rapidly changing prices, surely that case can be made most validly for building energy use.

III. CATEGORIES OF PROGRAMS THAT MERIT SUPPORT

In this main section of our paper we present 5 categories of Federal programs which reduce the life-cycle cost of buildings (without compromising their amenities) and improve indoor air quality, thus decreasing the present death rate from breathing radon daughters and other indoor pollutants (see the Box on Indoor Air Quality). Yet Federal programs in all five of these areas are being drastically cut. We shall show that this is unwise.

Before proceeding through our categories and examples, we should mention a current report by Hirst *et. al.*,[1] of Oak Ridge National Laboratory. They address these issues for all end-use sectors, while we confine our remarks to buildings. Hirst et. al. give 15 examples of cost-effective programs, in the form of 1-page exhibits. We reproduce at the back of this report a table of contents of Oak Ridge paper, to encourage the interested reader to obtain this paper.

CATEGORY A. RESEARCH ON BUILDING SCIENCE, INDOOR ENVIRONMENT AND HEALTH EFFECTS.

This is an area which is clearly the responsibility of the public rather than the private sector. Exhibit 1 describes the Ventilation and Indoor Air Quality program at Lawrence Berkeley Laboratory.

We also introduce Figure 1 to show that we have developed and tested hardware both to detect radon gas and control it effectively. Figure 1 shows the concentration of radon in a home in Mt. Airy, Maryland. The measurements cover two weeks. The non-scientific reader can best interpret the vertical scale by using the coarse rule of thumb that one unit corresponds in lung-cancer risk roughly to smoking one cigarette a day (which doesn't bother most of us), so that the maximum of 30 units corresponds to every man, woman and child in the home smoking 30 cigarettes a day (which is, a much more serious matter).

Example 1

INDOOR AIR QUALITY

In the United States, the natural infiltration of outdoor air causes, on the average, a complete exchange about every 1.5 hours of the 1,000 lbs. of air in the typical house. This is called 2/3 "ach" (air changes/hour). This natural exchange dilutes the indoor pollutants: combustion products, organics outgassing from particle board and furnishings, radon outgassing from soil and building materials, odors, water vapors, etc.

In 1975, in Sweden, a new building code, SBN 75, was passed with the intention of limiting natural infiltration in Swedish homes to 0.2 ach. Additional ventilation, to supply a total of 1/2 ach, was provided by mechanical means. This program was delayed because of problems with indoor air quality. Measurements (some of which could have been made before the code was written) showed that even the accepted 0.5 ach was inadequate for some homes. By inadequate we mean that at 0.5 ach (in Swedish homes) pollutants might build up to undesirable levels. Two pollutants of concern in Sweden and in the U.S. are radon and formaldehyde. Radon is a radioactive gas which breaks down into substances which increase the risk of suffering lung cancer. Formaldehyde is an irritant organic chemical.

LBL has also measured the radon gas in many homes. Exposures of the entire population, even to typically measured indoor concentrations, may cause 2000-20,000 lung cancers in the United States per year. Even more serious is the risk experienced by the several percent of the homes that have much higher concentrations. These would require special control measures.

One possible control measure is the supply of additional ventilation air using an air-to-air heat exchanger. In Europe and Japan there is a well established residential heat-exchanger industry. In California, LBL has set up a heat exchanger testing facility and has tested many foreign units. Only in 1980 did the first U.S. potential manufacturer present a prototype for testing.

In the United States in 1979, LBL made measurements of organic pollutants in one new home, equipped with new furniture, and found formaldehyde at levels which could cause discomfort to occupants. We do not yet know how long it takes for this formaldehyde level to subside, nor have we yet received funds to set up a laboratory to follow outgassing.

Because of the ignorance about indoor air quality and its cures, home-owners are understandably worried about tightening their homes, and builders are concerned about building tight new homes.

Even if we callously ignore the health effects of indoor pollution, we can consider its economic impact. Not until we understand the problem, can we confidently reduce infiltration. Reducing infiltration by 1/4 ach would mean an annual fuel saving of 100 therms of gas or 75 gallons of oil. Nationwide (including electrically-heated homes and air conditioning), this translates into 0.8 quads of resource energy, costing $5 billion/year. Yet DOE spends only $2 <u>million</u>/year on general indoor air quality research. EPA spends more, but only on special problems like the Love Canal.

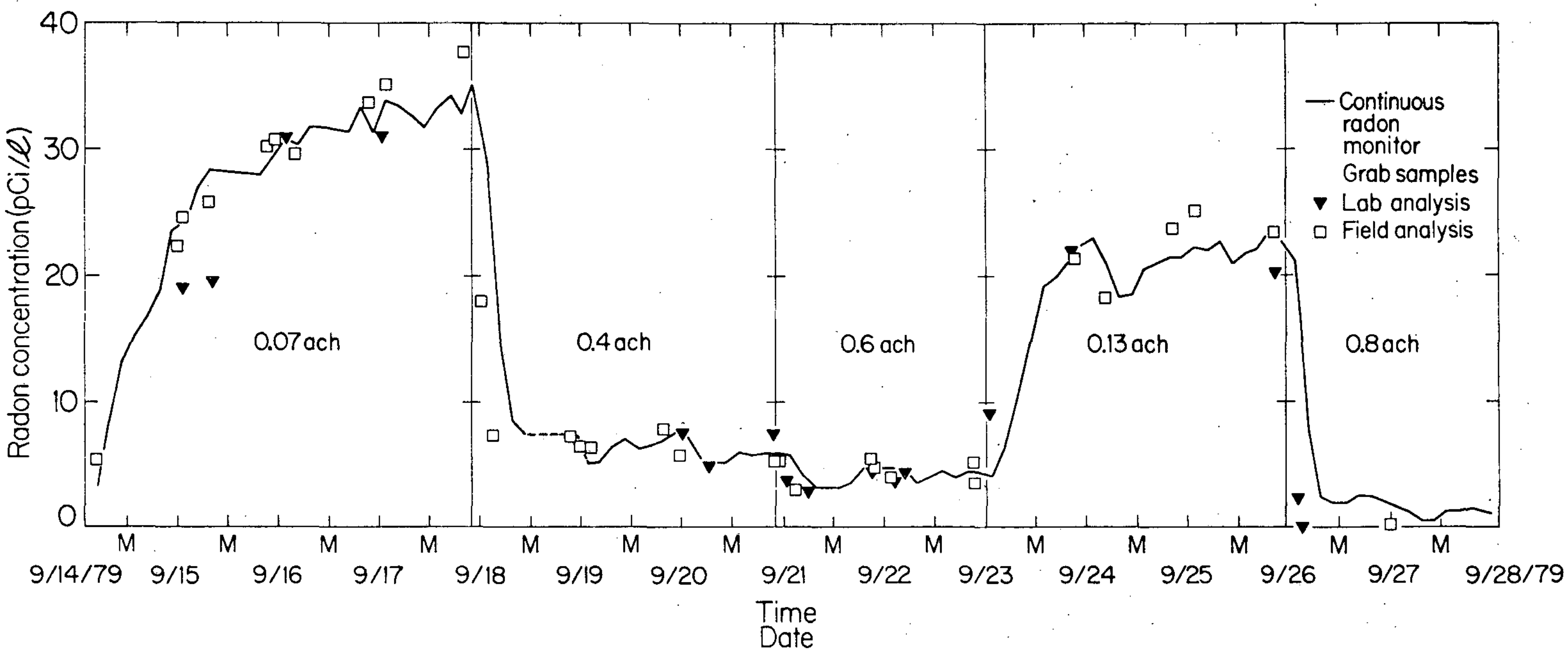
To pay for itself, then, the present tiny indoor air quality program only has to advance by <u>4 hours</u> the happy day when we can confidently tighten our homes.

The home was aired out, and then the windows were closed as the experiment began. We see the radon build up over about one day, and level off at about 30 (cigarettes/day) until an air-to-air heat exchanger was turned on. The level promptly dropped to 5 (cigarettes/day) for a few days. Then the mechanical-ventilation / heat-exchanger was turned off and the radon rose again. This time the natural infiltration rate was higher (it was windier or colder) and the radon level rose only to 20 (a pack a day). Finally heat exchanger was turned to a higher setting and reduced the radon to safe levels. These heat exchangers retail for $250 for window unit to $500 for a central unit, and demand only 50-150 watts of electric power.

If the radon level in this energy-efficient home dropped only to 5 at 0.5 ach, it seemed likely that there was a high concentration of radon in the soil gas in the neighborhood, and that conventional, leaky, homes should be measured also. LBL wrote a contract with Geomet to survey 59 homes, and their report[2] confirms our suspicions. Four of the homes have radon levels of over 10 on the main floor (two are 25); one basement of a conventional home measured 67. On the basis of this spotty evidence, and similar results in Pennsylvania, we worry that perhaps one percent of the homes (with over 2 million occupants) in the US may have radon levels above ten, where remedial action would be indicated.

Finally, to convey the importance of this new field of indoor air quality, opened up by DOE-sponsored research, we show a gas chromatographic spectrum of indoor pollutants sampled in new office space at LBL, compared with the air outdoors. Each of the indoor peaks represents a separate organic compound which needs investigation, and perhaps control measures.

Fig. 1 INDOOR RADON CONCENTRATION
Energy Research House
With Mechanical Ventilation
Carroll County, Maryland



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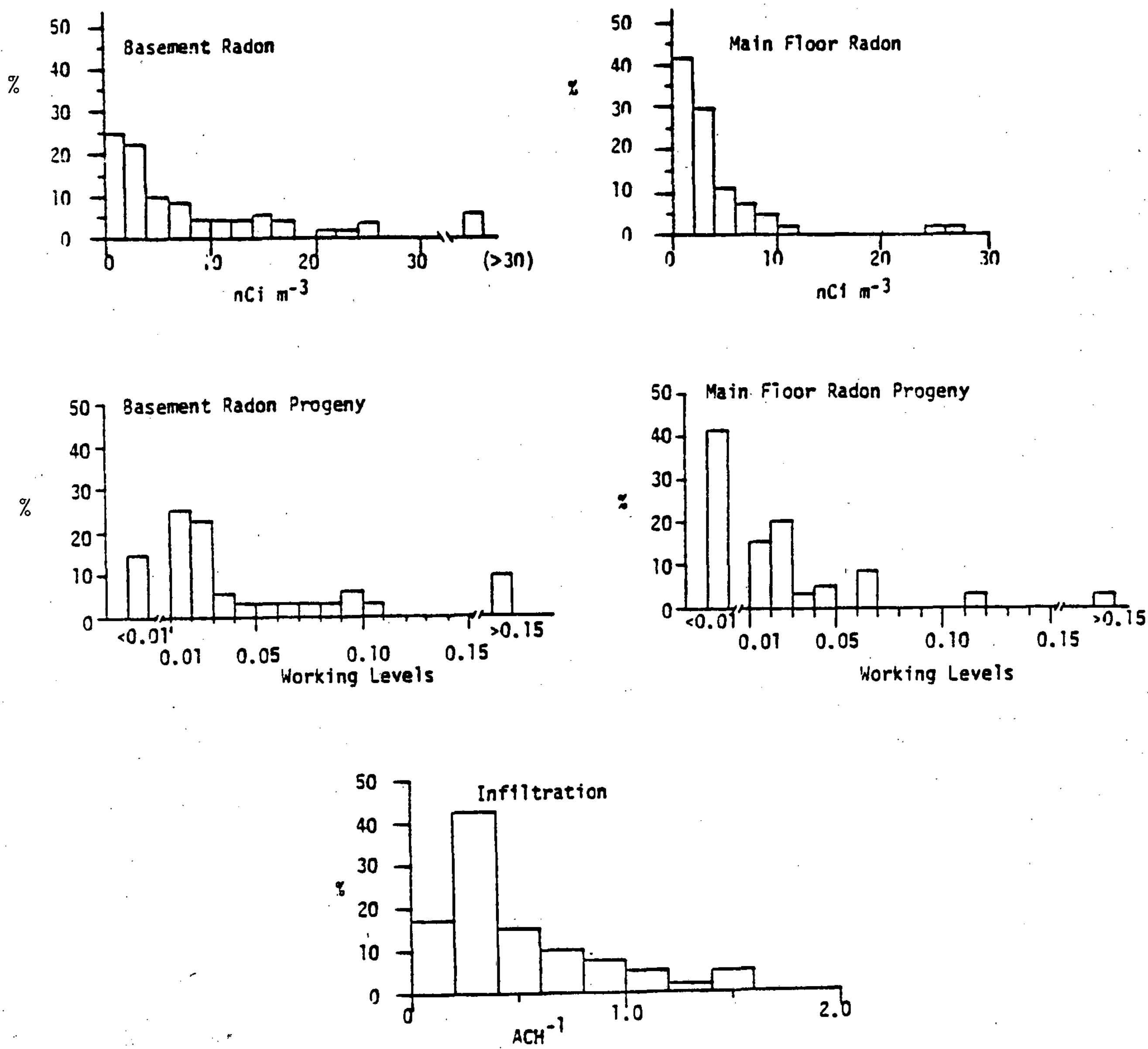
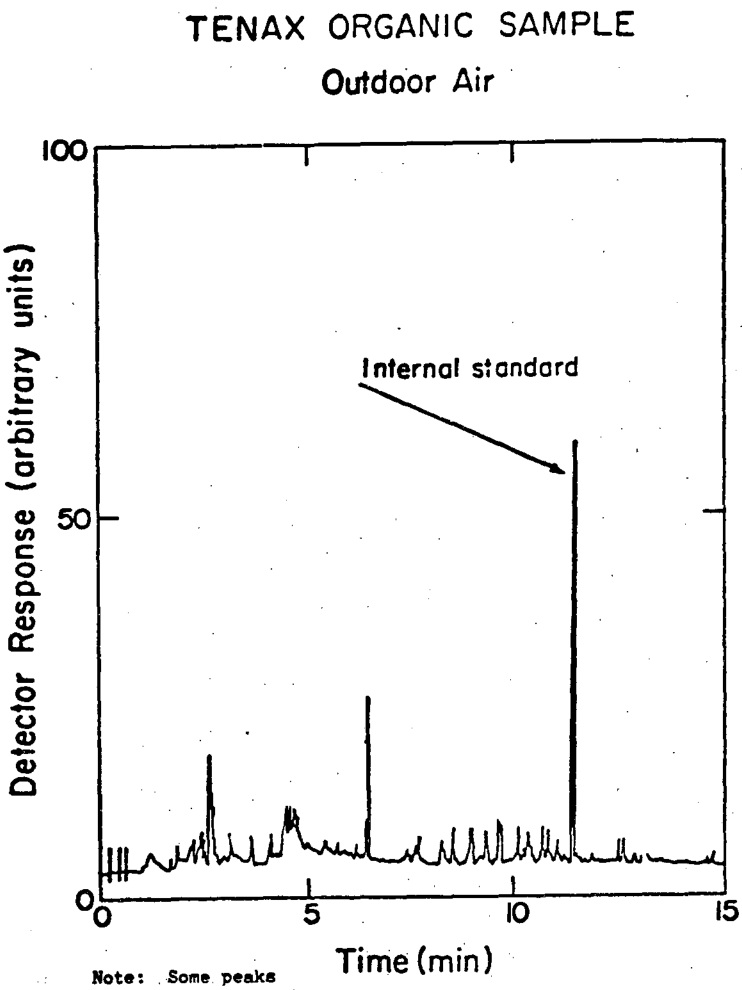
59 Homes in Mt. Airy, Md., surveyed by GEOMET for LBL.
GEOMET Report ES-877, Jan. 14, 1981



Note by A. H. Rosenfeld: on the top two histograms, the unit of 1 nCi/m^3 is the same as the 1 pCi/l in Figure 1, and is roughly equivalent in lung cancer risk to one cigarette per day; 20 is about a pack a day

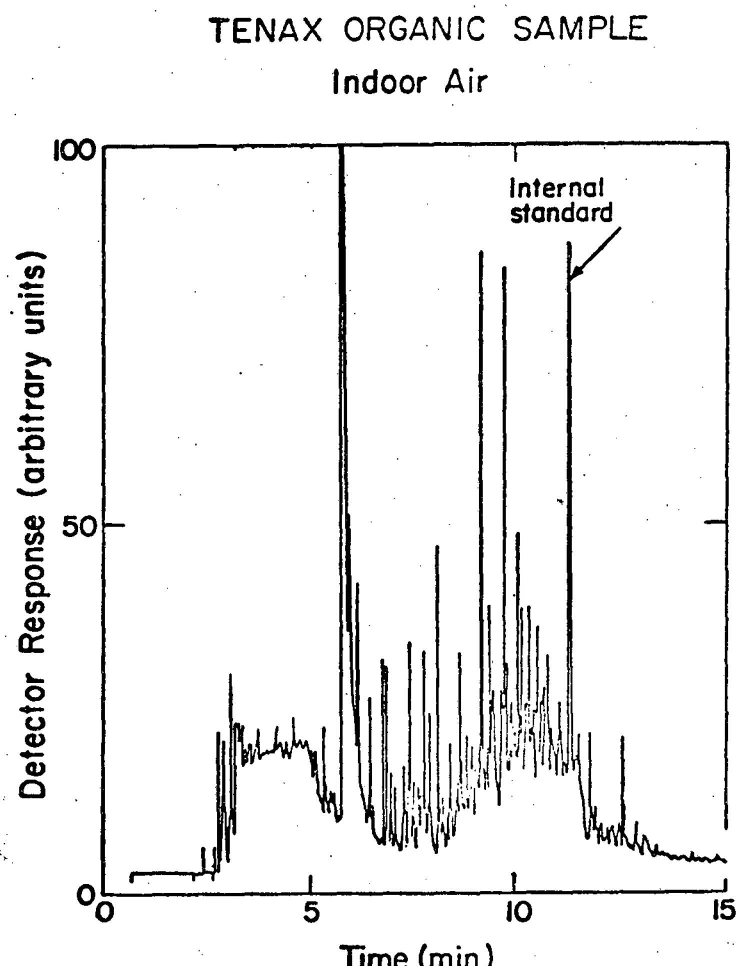
Figure 1a. Frequency distributions of radon concentrations and working levels of Rn progeny (basement, main floor) and infiltration for all homes in survey.



Note: Some peaks have been deleted to improve clarity.

Figure 2:

A COMPARISON OF THE ORGANIC CHEMICALS FOUND IN INDOOR AND OUTDOOR AIR, AS DETECTED BY THE GAS CHROMATOGRAPH.



Note: Some peaks have been deleted to improve clarity.

CATEGORY B. PROGRAMS THAT ACCELERATE MARKET RESPONSE

Market Lag in Energy Efficiency Investments

One of the most critical issues to the assessment of the federal role in energy conservation is the evaluation of what the market is likely to do without government involvement. We have sought answers to the following questions:

- What has been the historical response of the market to rising energy prices and to an increasing awareness of potential U.S. energy problems?
- What is an economically sound and socially desirable market response in the building sector to current and projected energy prices?
- How can one quantitatively evaluate the degree to which the market lags behind the desirable market response?
- If the market is lagging or unresponsive, what are the key factors that cause this phenomenon?
- What are the impacts of a market lag?
- What can be done to overcome market lags in investment in energy efficiency in buildings to avoid the worst impacts?

These are very difficult questions and we can only summarize the results of our investigation here. (Additional information is available in a forthcoming report by M.D. Levine.)[3]

In this section we shall discuss new homes in Figures 3, 4, and 7, and auto and commercial buildings in Figure 5.

New Homes

The first three questions are addressed for new residential buildings by the information presented in Figures 3 to 4, which apply to homes heated by gas and electric-resistance respectively. The top curve in Figure 3, with circles at 1972, 1975, and 1979 are average U.S. building practice on those dates, as surveyed by NAHB and translated into energy by computer analysis, using Lawrence Berkeley Laboratory's DOE-2 Computer program. Clearly, new homes are slowly getting thermally tighter.

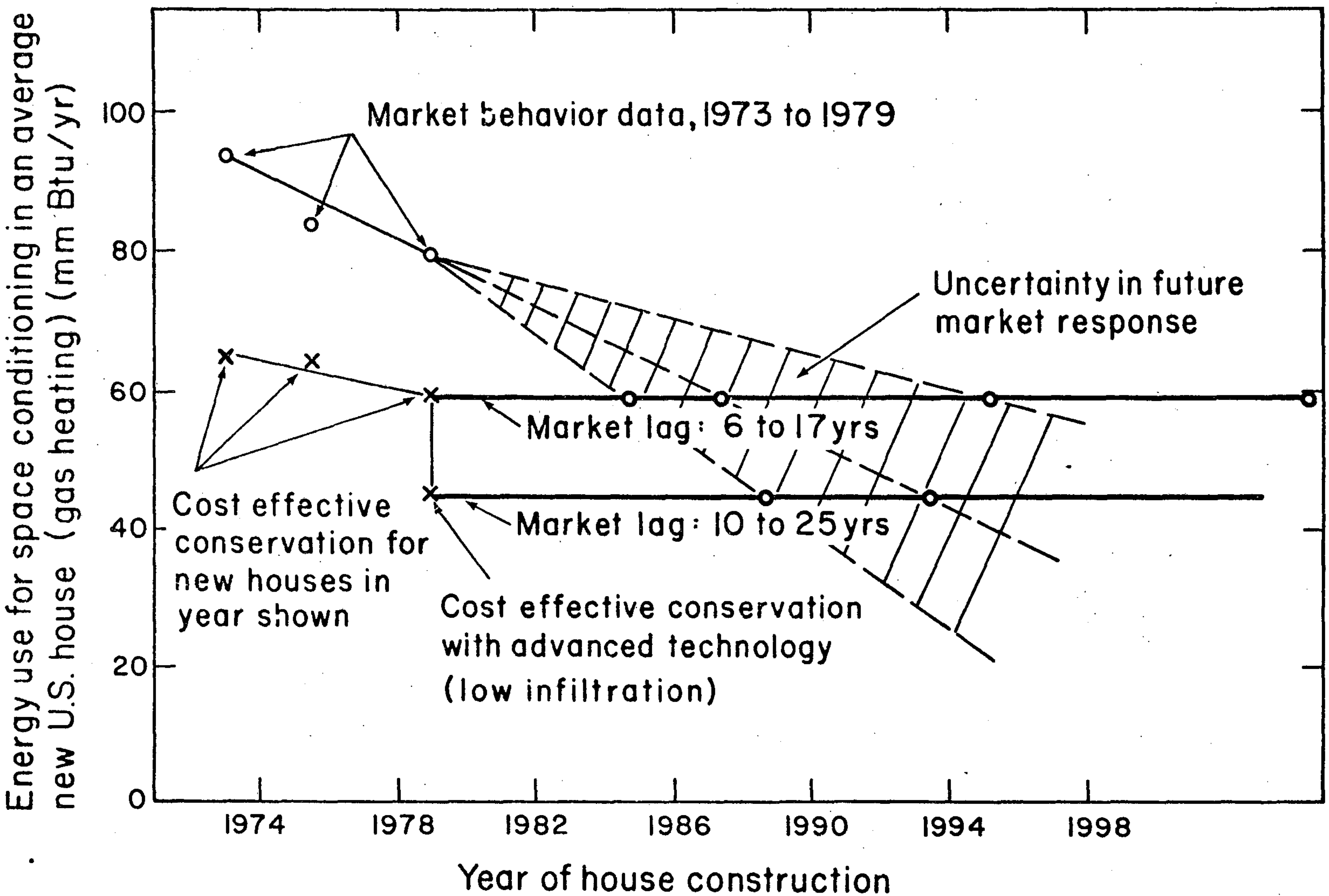


Figure 3. Market behavior and energy conservation in gas heated new houses in the U.S.*

* Based on LBL analysis of NAHB survey data on 300,000 houses constructed 1976-1979

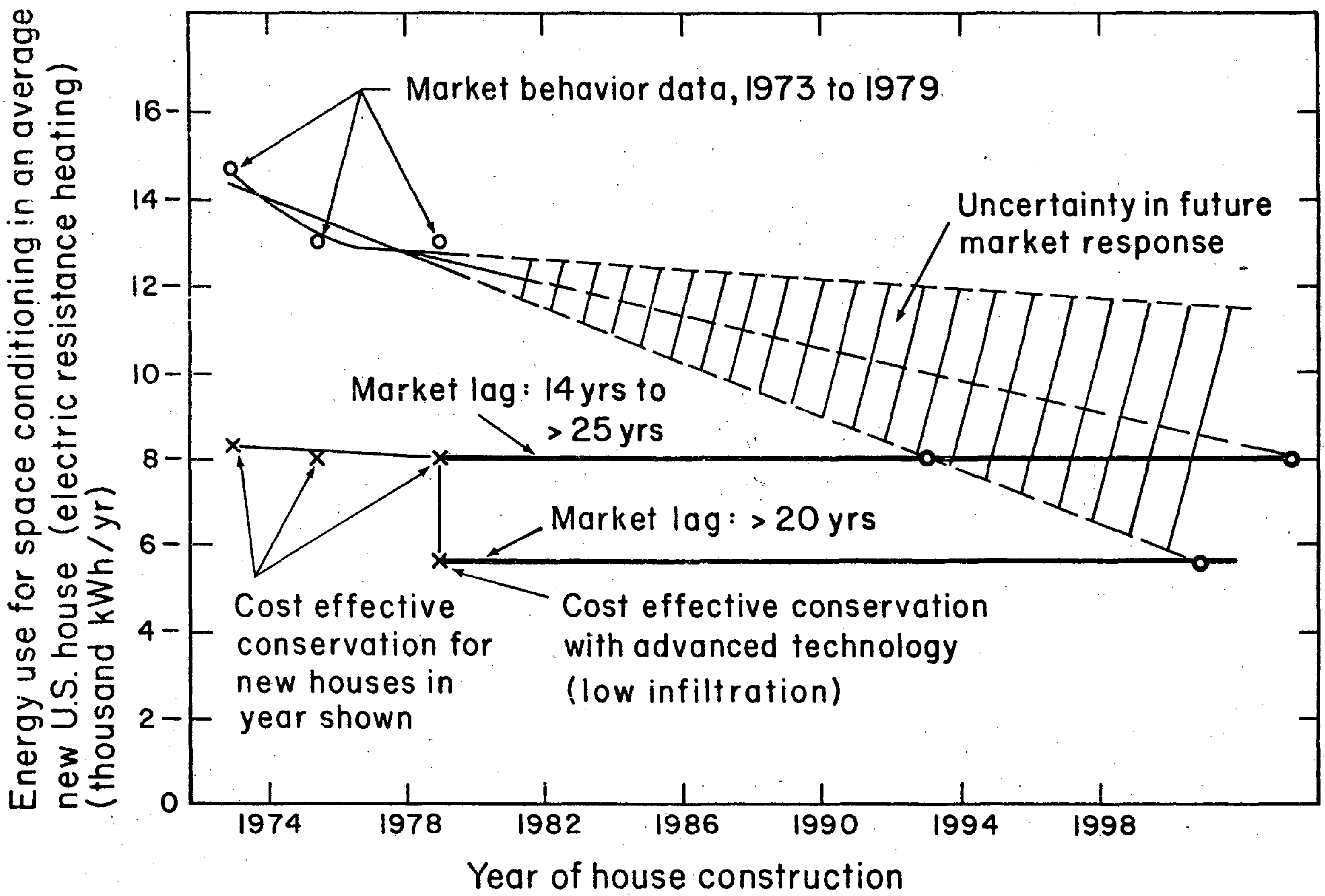


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Figure 4. Market behavior and energy conservation in electric resistance heated new houses in the U.S.*

* Based on LBL analysis of NAHB data on 300,000 houses constructed 1976-1979

The wedge starting at 1980 is our estimate of the uncertainty in projecting this trend. Additional research underway at LBL is attempting to narrow the range in this uncertainty. The lower curve, connecting the X's, represents the energy use by a simulated home built in the same years with all conventional cost effective conservation measures, using gas and electric prices for those years. We note that the homes with cost effective conservation measures use only about 2/3 as much energy as the real ones, and also improve with time.

Economists use a consumer discount rate to describe the shift between the perfect least-cost strategy -- the crosses in the diagram -- and the actual market decisions, the dots. The crosses assume the home-owner invests at a discount rate of 3% real, that is about 13% when present inflation is included. The "actual" dots correspond to a discount rate of 15% real.

Suppose we were to assume that fuel prices miraculously stopped rising after 1978-79, so the home with cost effective conservation in that year would also be the cost effective solution for the next decade or two. We then ask how long it takes the wedge to get down to this 1979 least-cost level. The answer is 6 to 14 years -- in other words, the length of time until our "projected market trends" (a very wide band) intersect the upper of the two horizontal lines.

The actual lag is, of course, longer than that, because new technologies will come in and pull down the least-cost line, and because energy prices will in fact continue to rise.

To illustrate the first point, we have introduced the concept discovered during the early 1970's of cutting the rate of natural infiltration of outside air with the use of a plastic vapor barrier with careful sealing of all seams -- and then restoring fresh air with mechanical ventilation through a heat exchanger. This technique adds about $400-700 to the cost of a new house, but saves at least 75 gallons of heating oil, or 100 therms of gas, each year. The lower X for 1979 shows this new cost effective technology with mechanical ventilation, and the horizontal lines labelled "low infiltration" projects that case into the future, again with no increase in fuel prices. In that case, the market wedge crosses the "low infiltration" line after 14 to 30 years.

Figure 4 illustrates the market response in houses with electric resistance heating. In this case, the lag is far greater than for gas heating, primarily because the higher price of electricity justifies much greater investment in energy efficiency improvements. The data show that the investment in energy conservation in houses with electric resistance is in fact no greater than in houses with gas heating, in spite of the greater payoff from such investment. Thus, the market lag in this case is at least 14 years (for the implementation of traditional conservation measures) and greater than 25 years (for low infiltration measures). To make matters worse, these lags are based on an optimistic assessment of market response (judging from past experience), and the lags could be very much longer unless there is a rather radical departure from past behavior of the market. The consumer discount rate corresponds to a surprising 40% real, equivalent to a 2-year pay-back on the initial investment.

The reasons for the sluggishness of the market in investing in higher energy efficiency in buildings are not fully known. In our judgment, the most important reasons are the lack of highly reliable information on the costs and benefits of efficiency improvements easily available to the home buyer and home builder. The difficulty and high cost of obtaining reliable information means that decisions are often made with inadequate information. This appears consistently to lead to an underinvestment in energy efficiency; the difficulty in raising capital for houses tends to make the problem even worse, in spite of the fact that a cost effective investment in energy efficiency will lead to lower monthly fuel bill plus mortgage payments.

The economic impact of this underinvestment in energy efficiency is significant and adverse. If approximately 1.5 million new homes per year consume 30 million Btu each more than is economically desirable, this is an annual increase in the U.S. energy bill of $315 million, for residential space conditioning alone. These houses last many years, and the extra fuel costs accumulate year after year (unless the houses are later retrofitted, at costs often much higher than efficiency improvements in new houses). In fifteen years, the <u>annual</u> needless extra expenditure on energy for space conditioning just the new houses built in this time period is $4.7 billion, if the market fails to catch up with the optimum investment in energy efficiency.[1] In the more likely case (in Figures 3 and 4) that the market does continue slowly to close the gap between actual and economically desirable investment in energy efficiency in residential buildings, the <u>annual extra</u> fuel bills for space conditioning just for new houses built over the next fifteen years is in excess of $2 billion.

The foregoing discussion provides a rough but quantitative assessment of the problems of the market unresponsiveness and lags in residential efficiency investments.

Autos and Commercial Buildings

Having shown a lag of about 20 years for new residences, we turn our attention to autos and commercial buildings. We shall show that autos, under the pressure of mandates and foreign competition, seem to be responding in about 10 years. Commercial buildings also seem to be responding rapidly.

For cars and office buildings we have not done any simulation of optimum efficiency. Rather, we have simply plotted in Figure 5 the European competition, which is probably not optimized for least-energy-cost, but at least is closer than U.S. Products, as seen (for cars at least) by the success of foreign imports.

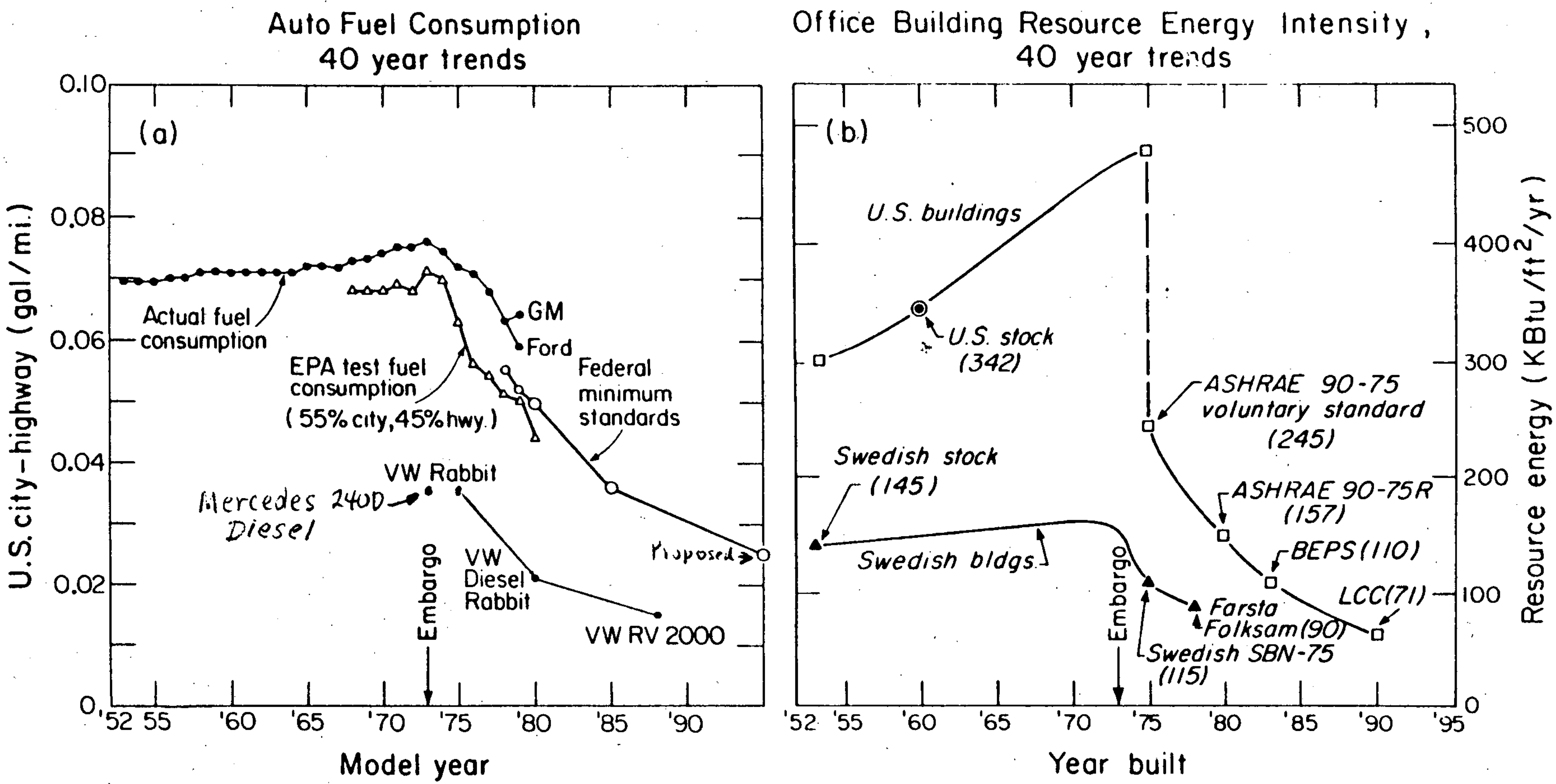

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Fig. 5 Horsepower Race, Autos vs. Office Buildings. A 40-year perspective, measurements vs. calculations Sources: Society of Automotive Engineering Transactions, 750957; J. Pierce, 1975, Scientific American 232.1 (Jan 1975); F. von Hippel, 1980, "U.S. Transportation Energy Demand - Draft Report," (July 1980). Office Buildings: Energy Efficient Buildings - Draft Report, LBL 11300, EEB 80-6.

Note the similarity in shape of the two curves for cars; the top one labelled "Federal Minimum Standards" shows the target US new car fleet average; the bottom one shows some efficient European cars which are closer to the U.S. economic optimum. The US fleet average trails the optimum by at least 10 years, would trail more were it not for EPA miles/gal labels, and might have trailed even more were it not for the mandatory standards. It is interesting to note that the 1985 standard of 27.5 miles per gal. when proposed in 1975, was greatly influenced by the availability then of the Mercedes 240 D, which already achieved 28 mpg, and was judged to be acceptable to Americans and near the economic optimum.

Swedish buildings are heated with hot water from district heating systems at prices comparable with US fuel, or with electricity at prices comparable with U.S. electricity. The buildings would use the same amount of energy if they were at the economic optimum, but even the Swedish buildings are probably not yet at economic optimum. Even so they are about 10 years ahead of the U.S., under the optimistic assumption that U.S. buildings will economize as fast as would have been required by BEPS in 1985 and will reach by 1990 the life-cycle optimum design for 1978.

The remainder of this paper discusses the appropriate role of the Federal Government.

CATEGORY B1. INFORMATION PROGRAMS AND LABELS FOR CARS, APPLIANCES, HOMES, AND BUILDINGS.

After the 1973 oil embargo, the Congress imposed first a voluntary <u>appliance labelling program</u>, and then when that failed to produce very many labels, a mandatory labelling program, to be followed in 1981 by mandatory standards.

For <u>buildings</u>, labels were never considered, but mandatory standards were to take effect in 1981. Many utilities sponsor voluntary labelling, and Florida has a mandatory program.

Mandatory <u>auto</u> fuel economy labels took effect in 1975, and have been at least partly responsible for raising fleet miles/gallon from 14 in 1975 to 27.5 in 1985. The gasoline conserved by this doubled efficiency costs the consumer about 40¢ per gallon saved -- generally considered an excellent investment compared to the alternative of paying $1.40 per gallon purchased.

1. The case for labels.

Labels induce consumer confidence to invest in superior appliances, homes, and buildings, both for their energy savings during his ownership, and because the labels establish a resale value for the investment.

Example 2

PG&E's Energy Labels for New Houses

Edison Electric Institute's National Energy Watch covers many labelling programs. We describe here one with which we are familiar. It is inducing builders to invest about $375 for improvements which save 375 therms/year of resource[4] energy. This corresponds to a cost of conserved energy of 7¢ per therm saved,[5] i.e. about ten times cheaper than the "third tier" California price of gas and electricity. In 1977, California adopted a mandatory building energy code (Title 24) which is periodically updated, but is still far from a least-cost design. So Pacific Gas and Electric Co. awards "points" to builders for features beyond those mandated.

Under Title 24, a Northern California home uses about 400 therms annually for space heating, plus 300 for water heating, plus 8500 kWh of electricity (equivalent to 1000 therms of resource energy): total 1700 therms.

Each PG&E point corresponds to an annual saving of 3 therms (or 30 kWh). To qualify, a builder must reach a threshold of 50 points. If he chooses to go beyond this threshold, PG&E will so certify and pay him $2 per additional point. PG&E's experience is plotted in Figure 7.

Builders have discovered that Energy Conservation Homes are popular and sell fast, so 60% of all new "connects" now qualify, and the average number of points is 75, i.e. 25 beyond threshold. This is a potential savings of 225 therms (13%). One large builder, Presley Homes, advertises 150 points (450 therms, i.e. 26% better than Title 24). For comparison, PG&E estimates that even the average non-qualifying home is now 25 points (4%) better than Title 24. A sample score-sheet is attached, filled out to show how a builder can reach 125 points (one therm/day) for $375.

Inspection. Before awarding the certificate and $2/point incentive, PG&E representatives inspect between 10% and 100% of the new homes. This service is popular with builders because the inspection often uncovers poor work by subcontractors.

PG&E has surveyed owners of Energy Conservation Homes. They respond that the homes are comfortable, and feel, on average, that the features they purchased are worth $800, to them as owners, and at the time of resale. This is an interesting clue that the market can recognize energy efficiency in labelled homes, just as it now places a high value on energy-efficient cars.

The PG&E program has been judged so successful that a form of it will be taken over statewide by the Calif. Public Utilities Commission in July 1981, and tied to the California "line-extension credit plan."

Conclusion.

The present authors agree with President Reagan that decontrolled energy prices will lead naturally but slowly to more efficient buildings. But credible labels are a dramatic aid to market forces, and will advance the market response by many years. In its haste to abolish mandatory standards for appliances and buildings, the administration should not overlook labelling, and should provide the appropriate tools and infrastructure.

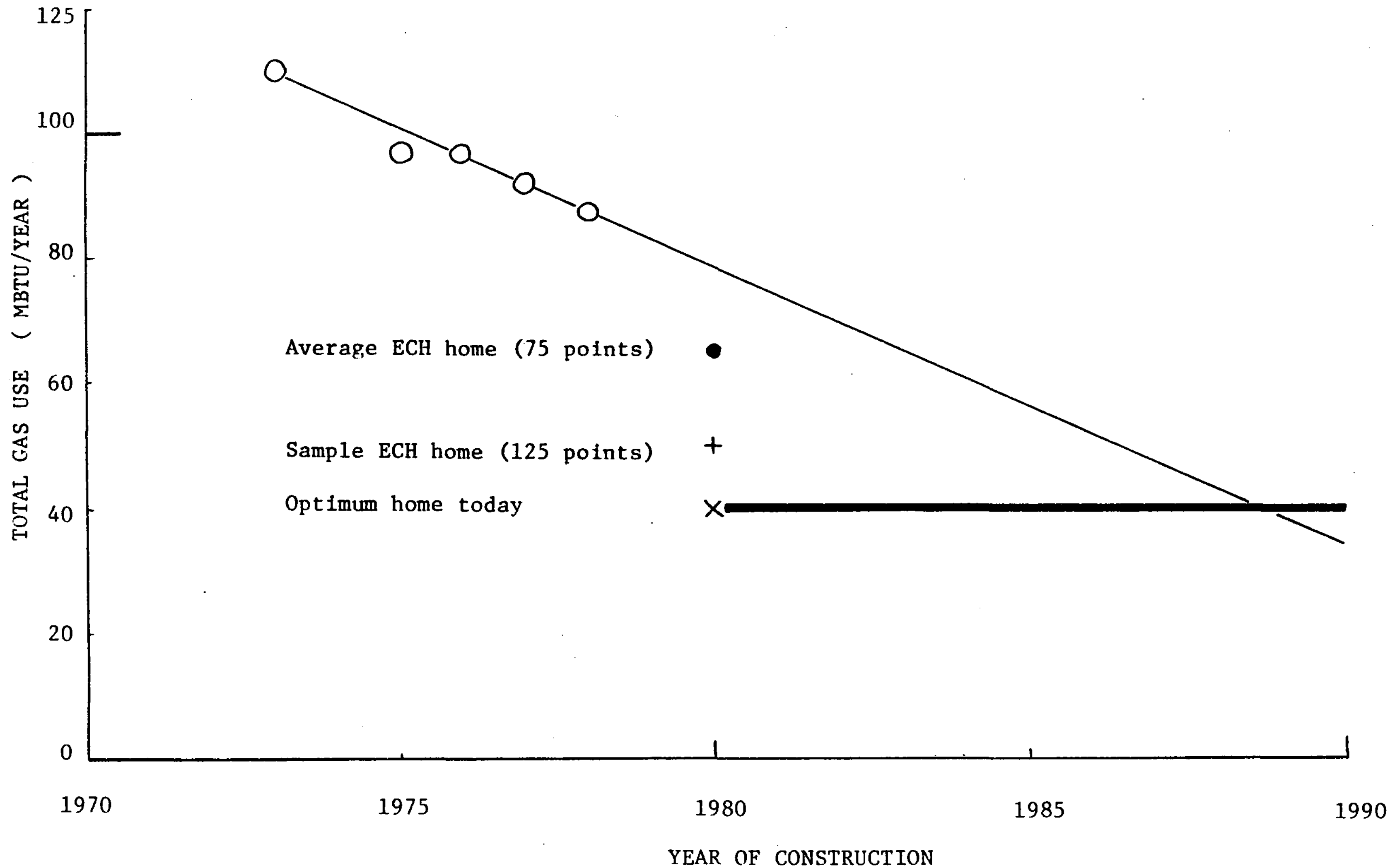

Figure 7. Total use of gas in new gas-heated homes supplied by Pacific Gas and Electric Company in Northern California. Open circles are average billed use of gas for homes built in the year indicated. The solid dot is the calculated gas use of the average home qualifying in 1980 as an Energy Conservation 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.

Thus labels strengthen the market for efficient products, and help the conscientious manufacturer and builder.

To be effective, the labels need not be mandatory, but they must be widespread, so that comparison shoppers can find them, and avoid unlabelled appliances and buildings.

And to be effective, they must be credible, accurate, and verified, at least by spot checking. Roughly one third of auto workers are assigned to quality control; it is clear that some small fraction of new buildings should likewise be tested for thermal efficiency and indoor air quality.

2. Proper role for the Federal Government.

For cars and appliances, there is general agreement that labelling is best handled at the national level. But homes and buildings are tailored to local climate and energy supplies and prices, so labelling programs can best be handled by states or utilities.

But a labelling program requires the following tools, which, because of economy of scale, are most efficiently provided by the Federal Government. These standard tools include:

a. Research programs to calculate the optimum sequence of options to get from current building practise to least cost, based on lifecycle economics.

b. Calculation of "Conservation Score Cards" and Manuals of Recommended Practise.

c. Development of equipment and procedures for testing thermal integrity, air and duct leakage, HVAC (heating, ventilating and air conditioning) systems, and indoor air quality.

To show that states and utilities need some federal help in formulating residential energy labels, we cite the fact that both Florida and California have labelling programs, yet neither state had enough information to include credit for low infiltration, <u>even though</u> this is the single most cost effective measure, and neither state has the resources to organize a field monitoring program to validate the labels.

3. Savings by Reducing the Consumer's Discount Rate

The discount rate implicitly used by the homeowner to decide whether or not to conserve may be very high; the earlier analysis showed that for new California homes it may be 40% above inflation for electrically heated homes, 15% above inflation for gas heated homes. The impact of these high rates may be estimated as follows:

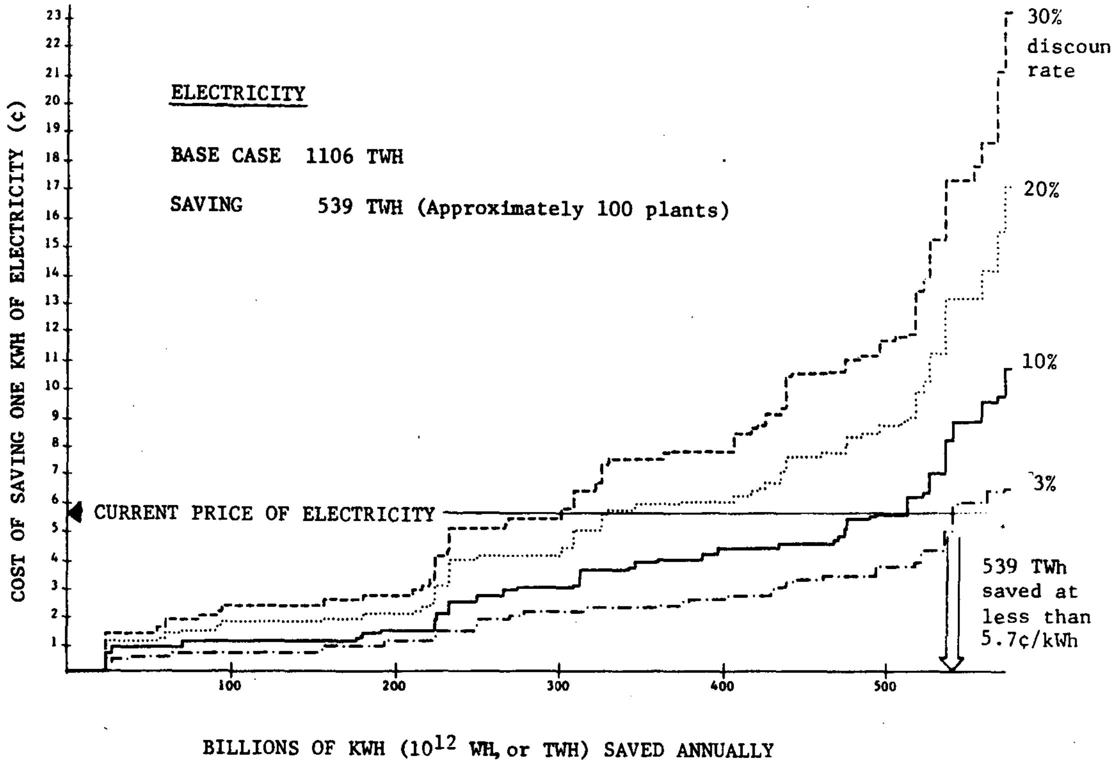

Figure 6(a) Supply curves of conserved electricity for the US residential sector (retrofit of stock, plus 20 years of construction) in the year 2000. Four curves are plotted, each corresponding to a different real discount rate. LBL-11300

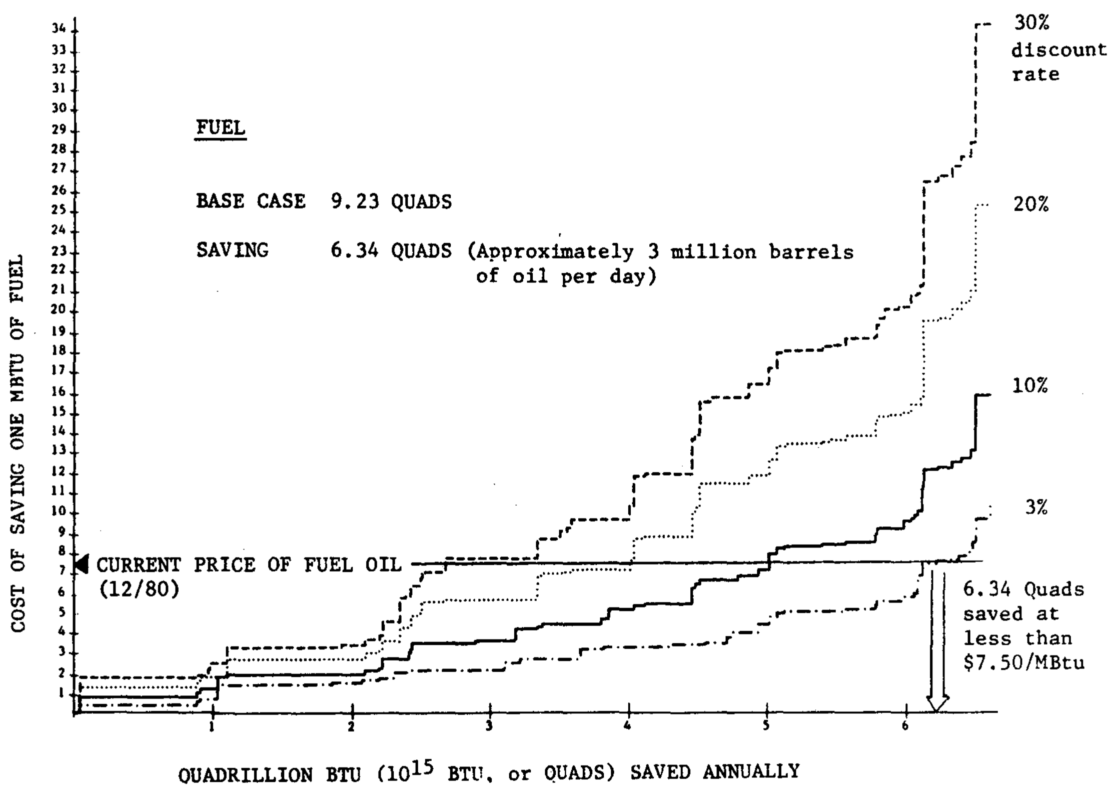

Figure 6(b) Supply curves of conserved fuel for the US residential sector (retrofit of stock plus 20 years of construction) in the year 2000. Four curves are plotted, each corresponding to a different real discount rate. Source: LBL/SERI Buildings Study, LBL-11300, April, 1981.

Figures 6(a), 6(b) are "supply curves" of conserved energy for U.S. residences in 2000 AD. The curve indicates how much it would cost to save a given amount of energy. Implicit in the calculation is a discount rate. The rate used by different homeowners will vary; the higher the market imperfections drive the consumer discount rate, the lower the available conserved energy will be for any given energy price. To illustrate this effect, let us look at the effect of going from a 20% real discount rate to a 3% real discount rate for fuel conservation. At a 20% rate and fuel for $7.50/MBtu, the homeowners would invest in conservation up to 4 quads. If all the market imperfections were corrected, the homeowner would invest up to 6.3 quads, saving more energy and more money. The picture for electricity is similar; savings in 2000 are 320 and 540 TWh respectively. Although these numbers are only illustrative, it is clear that there is great potential to reduce U.S. expenditures on energy by reducing the discount rate that the consumer perceives.

We contend that a federal infrastructure of research, labelling information, test and inspection procedures would achieve this aim, and that such a program would be high pay-off, anti-inflationary, and wise.

CATEGORY B2. RESEARCH THAT SPEEDS THE MARKET, BUT IS NON-CAPTURABLE AND NON-PATENTABLE

As an example of this common type of research, we site the development of the "blower door" by Princeton and NBS, and the use of this technique to discover the importance of attic bypasses and to pioneer the whole field of House Doctoring.

Over the next few years, thousands of house doctors will use relatively primitive tools (window fans to pressurize a home, "punk" to smoke) to detect and plug air leaks. The fruits of the research are a new trade, but there is no way for the developer of the technique to patent his findings.

Example 3

Fan Pressurization Detects Air Leakage

Air leakage is expensive. In the US, the natural infiltration of outside air into houses causes, on the average, a complete change of air every one and a half hours; this is called 2/3 air changes per hour, or 2/3 ach. To heat this air all winter takes 200 gals of fuel oil or 250 therms of gas.

In 1975 the CEES at Princeton University under Professor Socolow started to investigate methodically the sources of this infiltration, since leak plugging seemed an obvious and cheap way of cutting home heating bills. They caulked windows and weatherstripped doors, but found that they had hardly reduced infiltration at all. This was amazing, since all engineering manuals showed windows and doors to be the major sources of infiltration.

To find where the leaks really were they developed a "blower door", a replacement front door with a fan set in it. Using this door they blew air into houses and traced where it leaked out; the tools they used were simple smoke sticks and expensive infra-red cameras. They found that the major leakage sources in houses included gaps where pipes enter walls and ceilings, gaps around recessed light fixtures, dropped ceilings above bathtubs, and built-in cupboards. They also discovered that the spaces inside both interior and exterior walls can act as a chimney, leading warm inside air to the outside. They called all these newly discovered leakage sites "bypasses", since they bypass insulation.

This discovery explained why insulation often performed far below expectations; the warm air was simply going around it. Therefore the bypasses must be fixed before you insulate. The Princeton researchers have shown that a two-person team of "house-doctors", trained in the use of the blower door and infrared camera, can reduce air leakage by 20% to 40% in half a day's work.

Researchers at Lawrence Berkeley Laboratory have developed a model that related the pressures and flow rates obtained from the blower door to infiltration rates. The air leakage is expressed as an area, a measure roughly equivalent to the sum of the areas of the individual leaks. For example the equivalent leakage area of a typical house is approximately one square foot - roughly the same as a two inch high opening of two 3 ft. wide windows on opposite sides of the house. Retrofitting reduces the leakage area. The LBL model predicts the reduction in infiltration is proportional to reduction in leakage area. Thus the 20% to 40% reduction seen by house doctors on the East and West coasts translates into a saving of 75 gals of fuel oil, or 100 therms of gas. On a national basis, that becomes half a million barrels of oil a day, or $5 billion a year.

Further savings can be obtained by fixing leaks in air ducting. Both LBL and Princeton have found that as much as 20% of the hot air fed into ducts leaks out into unheated attics and crawl spaces. The same has been shown to be true for cold air in central air-conditioning systems.

The parallel efforts at Berkeley and Princeton have shown an interesting effect: house doctoring seems to be just as cost effective in warm climates as in cold ones, though the precise measures are sometimes different. It should be noted that the research which has led to the identification of the ways to save $5 billion a year cost the Department of Energy a mere $1 million a year.

CATEGORY B3. DEVELOPMENT OF NEAR-TERM TECHNOLOGIES.

CASE a) No US Manufacturer Exists.

Hirst et al.[1] present as exhibit No. 12 Electric Heat Pump Water Heaters. Two more examples are gas-fired heat pumps and residential air-to-air heat exchangers.

In the case of the heat exchangers, no US manufacturer is yet in production, but LBL set up a test facility in 1978. We tested the foreign models and found one that was not suited to severe American / Canadian winters. These tests helped pioneering builders of energy efficient homes to choose the appropriate units.

When the first American prototype arrived in 1980, it worked badly, but we were able to suggest modifications which were quickly adopted by the manufacturer, who now plans to become the first US producer.

CASE b) Industrial Inertia.

There are cases where large manufacturers, quite capable of introducing an innovation do nothing because no single manufacturer wants to "shake the boat". An example was the high-frequency fluorescent ballast, described in our last example.

Example 4

Mechanical Ventilation and Heat Exchangers for New Homes

To assure good indoor air quality, homes should probably have about 2/3 of an air change per hour (ach). We have mentioned several times in this report that to heat 2/3 ach all winter takes 200 gallons of fuel oil, or 250 therms of gas.

If new homes are built with a carefully installed vapor barrier, natural infiltration is reduced to about 1/10 ach, and can be replaced with mechanical ventilation through a heat exchanger with an effectiveness of about 75%. Such devices retail from $250 for a window model (the price should come down with mass production) to $500 for a central unit. They use only 50 to 150 watts of electric power, and save over 100 gallons, perhaps 125 therms, per year.

By 1990, we should have at least 10 million new dwellings. We consider the savings from heat exchanger both in winter and summer.

In winter the savings is 15 million Btu x 10 million homes = 0.15 quad, worth nearly $1 billion per year, about 3 million per day.

In summer, a water-permeable heat exchanger can turn around outdoor water vapor as well as outdoor heat, and it is the water vapor that puts 2/3 of the load on an air conditioner in the humid southeast of the U.S. A permeable exchanger can save about 1/2 kw of peak power in the warm, damp parts of the U.S., where perhaps 2.5 million new homes will be built by 1990. That represents an additional savings of 1.3 GW of peak power, which costs our utilities about $1 per installed watt. The capital savings is then another 1.3 billion.

The federal effort so far in heat exchanger testing facilities has cost less than $1 million. For every year that full market acceptance of heat exchangers is accelerated, the nation gains $100 million. This is an excellent rate of return on a modest federal investment.

Example 5

HIGH-FREQUENCY SOLID-STATE BALLAST FOR FLUORESCENT LAMPS

There are two ways in which the efficacy of fluorescent lamps can be improved. First, it has been known since 1950 that if the lamps are driven at high-frequency instead of 60 HZ power from the utility, their lumen output per watt (efficacy) improves 15%.

Secondly, for every 100 watts input into a typical conventional fluorescent fixture, 16 watts goes to heating the steel and iron "ballast" and never gets to the lamp.

By the late 1970's, advanced electronic technology made it possible to design a solid-state high-frequency oscillator which could power the lamps and have internal losses of only a few watts instead of the typical 16 watts. The lamp becomes more efficient because it does not turn off every half a cycle at the high frequencies (no flicker) and the ballasting is done at high frequencies which use smaller components that have less heat losses. The combined savings for a typical 100-watt fixture are then 10 watts from the ballast and 15 watts from the lamps, totaling 25 watts. As to price, the normal ballasts cost about $6.00 wholesale, and tend to be noisy; the new ballasts will sell for about $20.00; both sorts last about 15 years.

The favorable economics for each lamp are as follows: over 15 years, the extra $14 investment will save 1300 KWH, worth about $65.00. Using a 10% real interest rate (in constant 1980 dollars) the cost of conserved electricity is 2.1 ¢/KWH, much cheaper than the average commercial-sector price of 6¢/KWH. In addition, the new ballasts are capable fo continuous dimming, both to take advantage of daylight, and to keep a constant light level on the task below as the lamps degrade with time.

If economics (2.1 ¢/KWH) are so favorable, one wonders why the lighting industry waited for a federal incentive program, or how much this program advanced the inevitable development.

The ballast industry is very similar in structure to other sectors of the lighting industry, namely a very stable industry dominated by four to six large companies with many small companies comprising a very small percentage of sales. Because of the structure of the industry and the relative stability of the market share, it is very difficult for small companies to infiltrate the marketplace and be competitive. There is also little incentive for the large companies to rapidly innovate new technologies, especially when the innovation will require substantial investment on their part, since the results will probably be duplicated by the other companies at less cost, and market shares will not change drastically.

Box continued on next page

Example 5 (cont'd.)

Looking for cooperation with industry, LBL issued a competitive request for proposals four years ago to develop a solid-state ballast that would improve efficiency by 25%, offer continuous dimming capability, and be lighter/smaller in size. The large ballast companies not only refused to respond to the request for proposals, but published many statements that solid state ballasts would never make it due to first cost, technical problems, adverse affect on lamps, consumer acceptance, etc., etc. The LBL program worked with two small contractors to develop and test solid state ballasts. As a result of the successful tests, a large corporation, Beatrice Foods, purchased the rights to one of the ballast designs, conducted a large demonstration (cost-shared with DOE) of the ballasts, constructed a manufacturing plant, and is now taking orders for solid state ballasts. Since Beatrice Foods has the funds to impact market shares in the ballast industry, all companies were forced to reevaluate their position. Recently, seven manufacturers have announced the development of an energy saving solid state electronic ballast. At least two of these seven are large ballast manufacturers that did not respond to the original request for proposals. Total expenditure of public funds in this area has been less than $1.5M and the results have been the availability on the commercial market of a solid state ballast for fluorescent lamps and the acceptance by the ballast industry of this new energy saving technology.

In 1980 the electronic ballast systems were assessed for total performance; that is, we considered all of the improved attributes of the electronically ballasted system--the tighter system control brought about by improved voltage regulation, the regulation of light output, and the ability to dim lamps, in addition to the 25% "intrinsic" improvement in system efficiency. Among our findings, now being compiled for publication as an LBL report, we demonstrated that total energy savings can be as high as 40-70%.

Finally, we note that at present the U.S. consumes annually about 220 x 10^9 KWH in fluorescent lighting.* A market penetration of 25% with a 35% improvement in efficiency at .05 per KWH results in annual savings to consumers of $1 billion--not bad for a total DOE catalytic investment of $1.5 million!

* At 5¢/kWh, this costs more than $10 billion a year, or twice the entire non-military, non-strategic petroleum reserve budget of DOE.

REFERENCES and NOTES

1. E. Hirst; W. Fulkerson; R. Carlsmith; T. Wilbanks; "Improving Energy Efficiency: The case for Government Action", Oak Ridge National Laboratory, March 1981.

2. D.M. Moschandreas; H.E. Rector; P.O. Tierney; "A Survey Study of Residential Radon Levels," Geomet Technologies Inc. Report ES 877 to LBL Jan. 14, 1981.

3. M.D. Levine and J.E. McMahon; "Residential Energy Conservation and Market Behavior," LBL report in preparation.

4. To calculate the cost of conserved energy, we assume that the homeowner finances his investment in efficiency via a 20 - year loan at a real interest rate of 3% in 1980 dollars, and no fuel price escalation beyond general inflation. This corresponds to a capital recovery rate of 6.7% per year.

5. The resource energy associated with 1 kWh of electric sales is 11,500 Btu burned back at the power plant.

ACKNOWLEDGEMENT

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Appendix A

Improving Energy Efficiency: The Case for Government Action

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March, 1981

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ENERGY CONSERVATION HOME PG&E

Appendix B

ENERGY CONSERVATION HOME REQUIREMENTS AND AGREEMENT

For Individual or Multi-Family Dwellings

Pacific Gas and Electric Company

ENERGY CONSERVATION HOME PROGRAM
for Individual or Multi-Family Dwellings

Standards for Qualification

I. **General**

The purpose of these requirements is to improve the energy performance of residential dwellings.

II. **Minimum Standards**

A. To qualify as Energy Conservation Homes, dwelling units will be rated by a scoring system with points determined by the potential for annual energy savings of three therms of gas or 30 kilowatthours of electricity. Actual savings may be higher or lower depending on individual operation and locality. One point is also given for each 2,000 gallons/year of water savings.

B. All gas and electric appliances incorporated in the dwellings are to be approved and/or certified by the American Gas Association and/or the Underwriters Laboratories.

C. Qualification procedure will be as follows:

1. PG&E customer.
2. Minimum number of points per dwelling will be: .... 50 points

D. The partial list of energy conservation systems and devices which follows includes alternatives to be considered in the construction of dwellings to Energy Conservation Home standards. Unless otherwise specified, points will only be allowed *once* for any feature, AND WILL NOT BE ALLOWED FOR FEATURES MANDATED BY STATE OR FEDERAL CODES.

A builder may desire to incorporate other energy conserving features in lieu of those listed or may wish to make a specific points calculation for listed items to fit the particular climate zone. See Paragraph II-A when making such calculations. Figures are subject to PGandE verification and approval.

MEMBER NATIONAL ENERGY WATCH

62-7205 (1/80)

	Points Allowed	Score	Incremental cost ($)
(1) Major Appliances:			
Gas Range	13	13	-
Oven with light and window	1		
Microwave oven	10		
Dishwasher with switch controllable drying cycle	5		
Gas dryer outlet	10	10	25
(2) Space Heating/Cooling			
Set-back or programmable thermostat (not for use with heat pump)	16	16	60
Clogged filter indicator	8	8	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	-
Fluorescent Application:			
– Exterior - Porch/Patio	3		
– Kitchen area	5	5	-
– Laundry area	1		
– Bathrooms (all)	7	7	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

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