J. ENVIRONMENTAL SYSTEMS, Vol. 16(1), 1986-87

INDIVIDUAL AND INSTITUTIONAL BEHAVIOR RELATED TO ENERGY EFFICIENCY IN BULDINGS*

ERIC HIRST
Oak Ridge National Laboratory
Oak Ridge, Tennessee

ABSTRACT

Energy consumption and energy efficiency in residential and commerical buildings are functions of both technology and people. Although improvements in efficiencies of buildings, appliances, and equipment are important, utlimately it is people who purchase, install, operate, and maintain these technologies. This article reviews recent research on the behavior of individuals and organizations relative to energy use and efficiency in buildings. Household purchase and operating behavior are discussed, as are the behaviors of designers and builders, appliance manufacturers, and financial institutions.

An oft-repeated truism among energy conservation analysts is "Buildings don't use energy, people do!" Although much of the research and policy attention on energy efficiency in building concerns the technical performance of various energy conservation devices and designs, it is essential to remember that people decide what, when, where, and how much energy is consumed. Obviously, building occupants influence energy use through various behaviors, such as setting temperatures, opening and closing windows and doors, and using hot water. People also affect energy use in other ways—as individuals and as members of organizations that commission, design, construct, and manage buildings and equipment.

* This article is based on a chapter in *Energy Efficiency in Buildings: Progress and Promise*, published by the American Council for an Energy-Efficient Economy. The Oak Ridge National Laboratory is operated by Martin Marietta Energy Systems, Inc. under contract No. DE-AC05-84OR21400 with the U. S. Department of Energy.

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doi: 10.2190/P8H6-GJHK-WDDK-C14X
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The first part of this article discusses energy efficiency *purchase* decisions (e.g., the process of deciding between an energy efficient or an "electricity-guzzling" refrigerator). The second part discusses individual behavior related to *operation* of buildings. More is known about the behavior of individuals and households in residences than about building managers and occupants of commercial buildings. The final part deals with the behavior of organizations (such as builders and architects, equipment manufacturers and suppliers, financial institutions, and associations) involved with building design and construction.

CONSUMER PURCHASE BEHAVIOR

Choices between models or methods in the purchase of appliances, heating and air conditioning equipment, new homes, and retrofit measures for existing homes can influence future energy consumption.

The economically rational person, in choosing among various alternatives that meet the same end use (e.g., keeping food cold), will trade off the higher capital cost for a more efficient unit against the lower operating cost over the lifetime of that unit. That tradeoff can be quantified with the concept of the implicit discount rate. The higher the discount rate, the more the individual emphasizes initial costs relative to future savings. In other words, higher discount rates imply less investment in more expensive energy efficient systems. The term "implicit" refers to the fact that most analyses infer discount rates from household behavior; they do not rely on individual self-reports of discount rates.

Several econometric analyses have been conducted during the past several years to statistically examine this relationship. The seminal work by Hausman analyzed purchase of room air conditioners [1]. It showed a very high implicit discount rate for these purchases, about 24 percent. Interest rates varied inversely with household income: households with annual incomes below $10,000 had discount rates of 40 percent or more, whereas households with incomes about $35,000 had discount rates below 9 percent. Other economists have applied models similar to Hausman's to estimate implicit discount rates for purchase of energy efficient residential equipment [2, 3].

Analysis of aggregate data on appliance purchases from 1972 to 1980, based on national appliance shipment data, shows discount rates that are very high (ranging from 10 to 200%) and roughly constant over this period [4]. Such analyses, based either implicitly or explicitly on economically rational models of human behavior, generally show discount rates much higher than real interest rates or those commonly used in public decision making (see Figure 1). These findings indicate that households generally underinvest in new energy efficient space heating equipment and appliances. Several government and utility conservation programs encourage increased production and purchase of high efficiency equipment [6, Chapters 9 and 10].

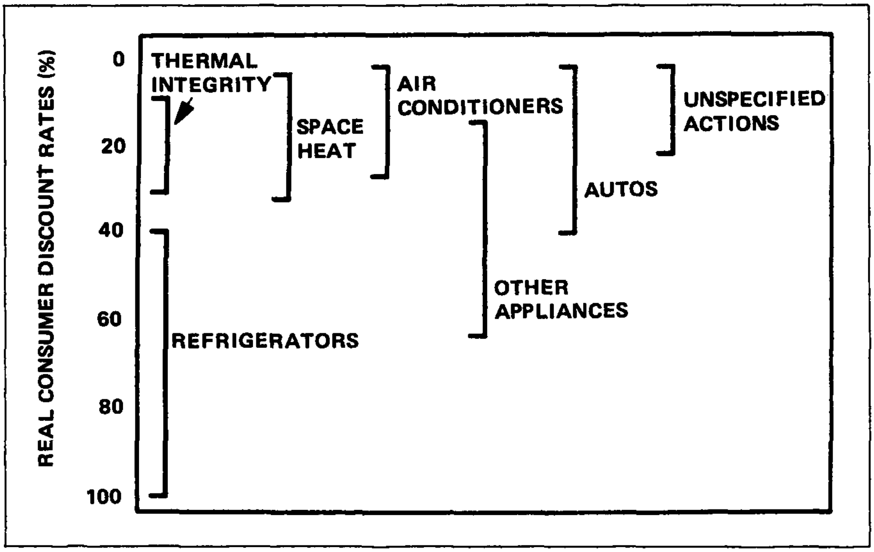

Figure 1. Estimates of average discount rates used by households in making energy-related purchase decisions [5].

Unfortunately, these analyses provide few insights into particular barriers that inhibit purchase of efficient equipment. Implicit discount rates reflect many factors: the types of products offered by manufacturers, the types and usefulness of information available to purchasers, the time required to obtain and process information, the availability of capital, and who makes the purchase (e.g., builder or homeowner). Stern concluded that to "subsume all these influences under a single index and call it the discount rate may be to misconceive the phenomena . . . such theoretical shorthand may lead analysts to think of some features of energy users' behavior as stable when they may in fact be changed by economic or institutional forces or by policy" [7].

In actuality, people do not think in terms of the time value of money [8]. When surveyed, most people knew, at least approximately, last year's inflation rate, but they were unable to determine "how money functions as a standard of deferred payment." When asked "how much they would have to spend today to get what one dollar bought a year ago [1983]," the median response "was an astounding $1.41," implying an inflation rate perception an order of magnitude greater than the actual inflation rate.

Surveys of households in Santa Cruz, California (a decidedly atypical sample of U. S. households) showed that the conservation actions taken vary "markedly between homeowners and renters, and across different types of conservation" [9]. Installation of conservation devices was positively related to socioeconomic status and to the availability of a household member able to do home repairs.

A similar survey conducted by Wilk and Wilhite in Santa Cruz examined why people do not caulk and weatherstrip doors and windows [10]. Because people viewed these measures more in the realm of home repair than in the realm of home improvement, these initiatives lacked the glamour of other more visible measures, such as storm windows and solar water heaters.

Households have inaccurate perceptions of the major energy users in their homes [11]. As a consequence, people overestimate the energy savings produced by management and curtailment practices (e.g., turning off lights) and underestimate the potential of energy efficiency investments. These incorrect perceptions of energy use and conservation options help explain why households "underinvest" in efficiency measures and why many government and utility conservation programs focus on encouraging such investments.

CONSUMER OPERATING BEHAVIOR

Human Factors

Many studies show that occupants have substantial effects on building energy use. For example, only about half the house-to-house variation in winter gas consumption for townhouses in Twin Rivers, New Jersey, could be explained by physical characteristics, such as the number of bedrooms and area of insulated glass. Almost three-fourths of the remaining variation was caused by "occupant-related consumption patterns" [12].

Indoor temperatures can have a considerable influence on residential energy consumption. A reduction in indoor temperature from 70° to 68°F will cut annual space heating energy use by 10 percent in locations with 5000 heating degree days (65°F base). Reducing the nighttime temperature from 68° to 60°F (for eight hours each night) increases the overall energy saving to 23 percent [13]. Many analysts believe that much of the post-embargo decline in per-household energy use was caused primarily by behavioral changes.

Although occupant behavior substantially affects energy use (see Figure 2), our understanding of the factors that influence such behavior is limited. In fact, conventional wisdom concerning the motivation for these behaviors is probably incorrect. According to Stern and Aronson, "Most analyses proceed from the simplifying assumption that energy producers and consumers are rational economic actors: that is, that they are motivated to maximize the value of some objective function, such as income, profit, or organizational size" [14]. Although in aggregate this assumption may be useful, it generally obscures the large variation across energy users.

Households might behave in apparently irrational ways because the majority of a typical household's energy use is automatically controlled and *invisible* to its members. Homeowners are therefore unaware of how much energy they use for which functions.

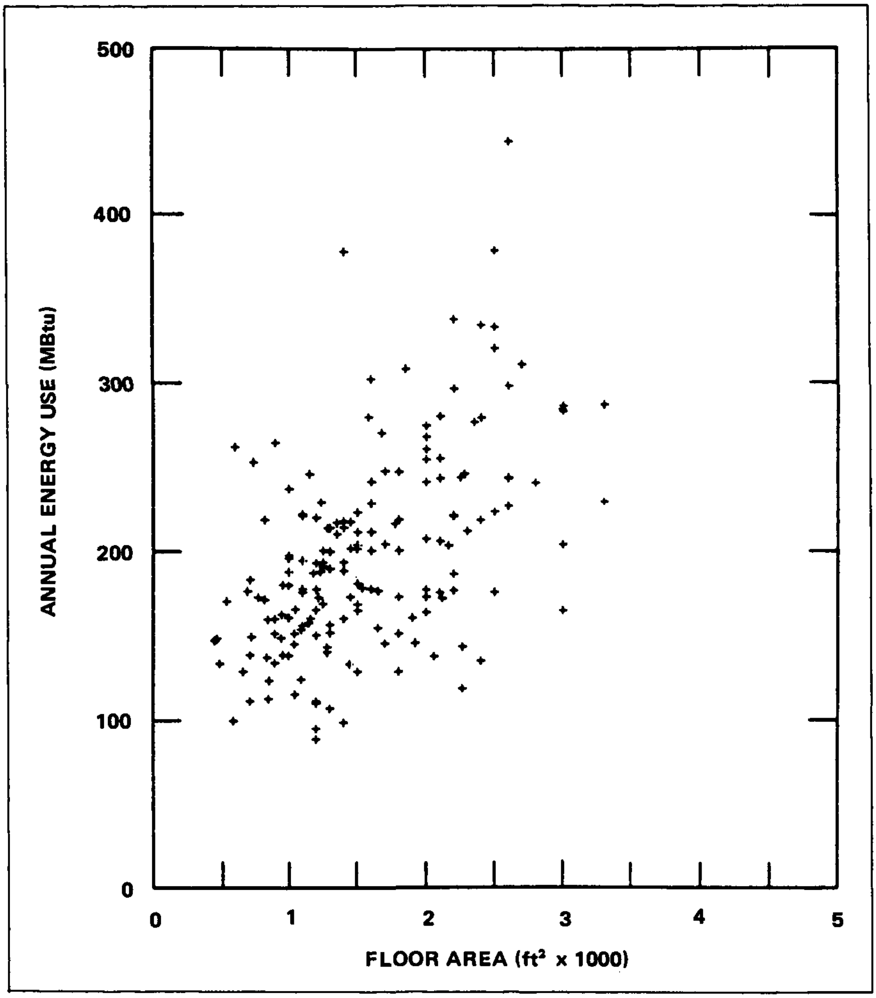

Figure 2. Energy use as a function of floor area for single-family homes heated with natural gas, built after 1950, in cold northern climates (6000 to 8000 HDD). Note the large variation across homes of similar size, probably due primarily to differences in occupant behavior.

In addition, households might adopt seemingly irrational behavior because they mistrust generalized information sources. Because people may realize that energy saving prescriptions appropriate for one house are not necessarily suitable in another, they may refuse to install some recommended measures.

The different ways in which people behave yield substantial diversity in energy use. Stern and Aronson offer five models of the individual as energy user [14]. The first is the conventional economically rational user—*the investor*—who makes appropriate tradeoffs between the operating and capital costs of various energy efficiency choices.

The second is the *consumer*, who thinks of energy using possessions as providers of necessities and pleasures, focusing primarily on the benefits obtained with little regard to the economics of ownership and use.

The third is the member of a *social group*. In this model, households are influenced primarily by friends and neighbors both in purchase decisions (e.g., the kind of car to buy) and in behaviors (e.g., at what temperature to set their thermostat).

The fourth relates energy use to *personal values*; energy consumption is a consequence of one's values and self-image. For example, those who are concerned about environmental quality may be frugal energy users, regardless of the direct economic benefit of saving energy. Those who are proud of a comfortable, affluent lifestyle may keep their houses cold in summer and hot in winter.

The final model is the *problem avoider* for whom attention is a scarce resource. Energy efficient investments are not made and energy conservation practices are not adopted until some threshold is reached (e.g., a particularly high heating bill).

Stern and Aronson concluded that none of these models is correct. Rather they all contain some elements of truth, the amount varying from household to household. These alternative models suggest that the economically rational model may not always be correct and—more important—may lead to policies and programs that are ineffective. For example, if one considers households as investors (the first model) whose supply of capital resources (money) is limited, then a tax credit for retrofit investments seems attractive. On the other hand, if one considers households as problem avoiders, then programs that offer convenient ways to improve the energy efficiency of their homes may be more effective than a tax credit.

System Factors

The physical systems in individual homes and the options that households actually face in managing these systems should be examined as well as household attitudes and demographic factors. Management of energy using systems depends at least partly on the systems themselves. Thermostat management (especially nighttime thermostat setback) is much easier to implement in a home with a central heating system and one thermostat than in a home with individual room heaters. Load research data from homes in Minnesota show lower electrical loads at night and higher loads in the morning for one-thermostat homes relative to a group of homes with individual room heaters (see Figure 3).

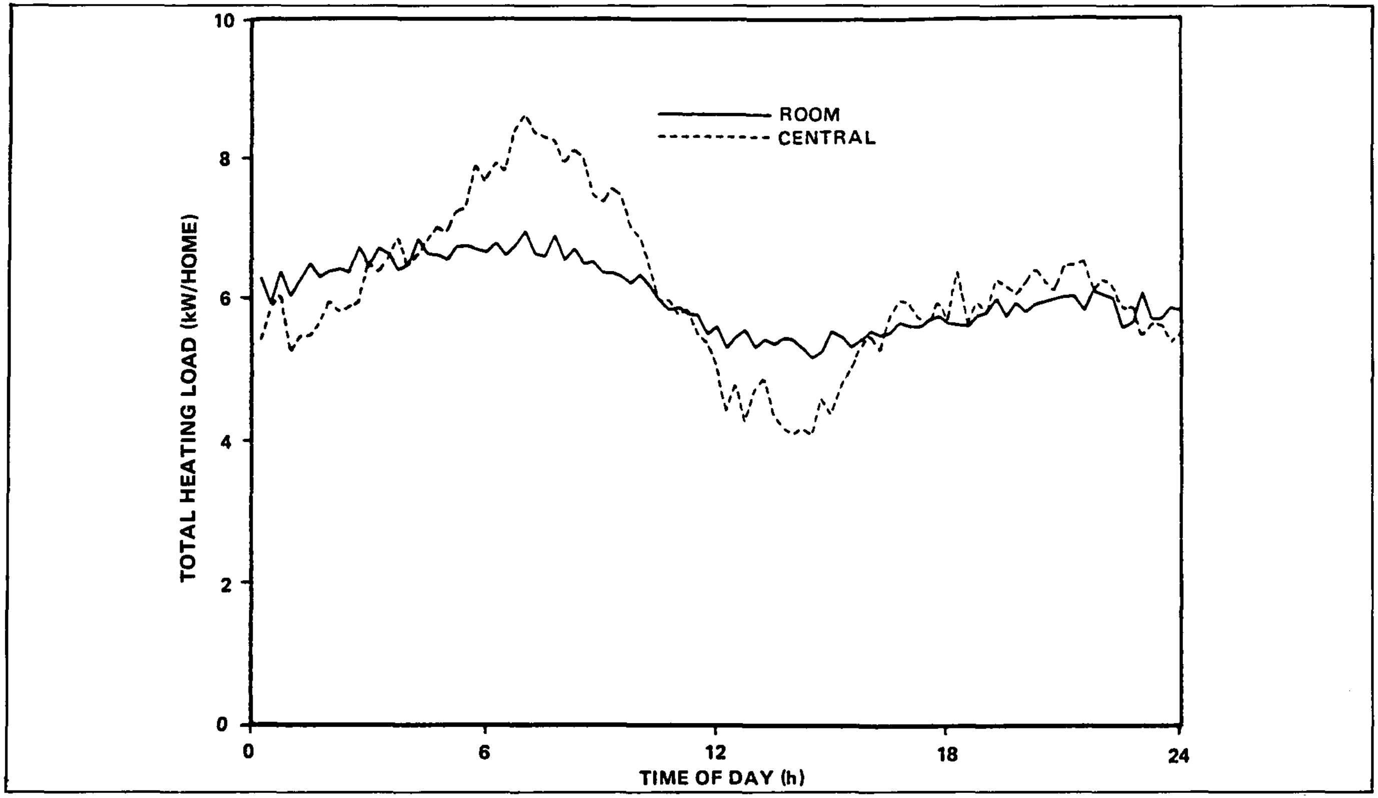

Figure 3. Total heating load for electrically heated homes with central heating vs. homes with individual room heaters [15]. The data strongly suggest that families with central heating systems reduce temperatures at night.

Fagerson's analysis of new energy efficient homes and retrofit homes, also in Minnesota, has similar findings [16]. In addition, thermostat settings were closely correlated with the amount of south-facing window area and with infiltration rates. Thus, people in leaky homes raise temperatures more than those in tighter homes do.

In multifamily buildings, the limitations of existing systems play a vital role in energy efficiency. Reports abound of households that open windows in winter if the central space heating system provides too much heat. They do so because it is the only way they can control temperatures within their apartment. On the other hand, some people use gas stoves to provide space heat when the central system does not provide sufficient heat.

Social Science Factors

One of the difficulties in assessing the importance of household behavior is the traditional reliance on self-reports. In many cases individuals either cannot or will not provide correct answers to questions concerning their behavior. A recent evaluation of a utility home energy audit plus zero-interest loan program found that 4 percent of the households that received both an audit and a loan claimed to have received neither; 16 percent of the households that received an audit only claimed not to have been audited; and households that took loans reported only 79 percent of the utility-certified retrofit measures that had been installed [17].

In part because of errors in household self-reports (as well as a desire to better understand the actual patterns and behavioral determinants of household energy use), a group at Michigan State University is collecting engineering data (thermostat settings, actual indoor temperatures, hot water consumption, etc.) and behavioral information (from household questionnaires and open-ended ethnographic interviews) [18-20]. Although the number of homes being monitored in this project (less than ten) is far too small to draw statistically valid conclusions, the research already points to some important findings. Energy use patterns

1. are different on weekends than on weekdays (particularly important with respect to electric utility peak loads);
2. depend on the coincidence of schedules for different family members (e.g., whether they eat meals together); and
3. depend more on the number of adults than on the number of children in the home.

Households that have few family members, that have regular bedtimes, and that are usually not home during the day have the most regular energy use schedules. The MSU researchers hope that careful examination of their detailed data will suggest which are the few key variables needed to understand household energy related behavior and to design effective conservation programs.

Analyses of summer air-conditioning use in two California communities focused on development of econometric models of household energy use [21, 22]. They developed a two-part model of summer electricity use. The first part estimated electricity use as a function of the physical factors that directly determine energy use: air conditioners and electric appliances. The other part estimated appliance ownership, house size, number of rooms closed, and frequency of air conditioner use as functions of economic and demographic factors and of household attitudes towards comfort, energy conservation, and environmental issues. Family income and the number of household members were the most important indirect determinants of energy use. The California approach is much less expensive and much easier to implement than the MSU approach, but is less likely to yield detailed understanding of household behavior and its interaction with residential energy using systems.

Communication Factors

A careful review of 200 evaluations of energy conservation programs conducted by California electric and gas utilities suggests that traditional generalized advertising approaches (e.g., leaflets and radio and TV ads) are likely to be ineffective ways to get people to change their patterns and to promote energy conservation [23]. Instead, existing social networks (e.g., community leaders and local nonprofit groups) should be used to spread information about effective conservation actions, and information should be made vivid and personalized. For example, having the energy auditor caulk one window is probably a much more effective way to encourage adoption of other measures than is a detailed written description of the likely economic benefits of different measures. Similarly, reference to the experience of other households in the same community is more effective than general statements about benefits.

One way to make energy savings visible and vivid is to provide feedback—regularly telling residents how much energy they use. A number of experiments, summarized by Sorenson, show that the amount of energy saving achieved depends on the frequency of feedback [24]. The studies also show that the combination of feedback and provision of energy conservation information is even more effective than either alone (see Table 1). Provision of daily feedback is probably not currently feasible without installation of new devices that monitor and present energy consumption information. However, current and emerging microprocessor technologies may soon permit installation of low-cost systems in homes. These systems may perform energy management functions (as do currently available, computerized, energy management systems for large commercial buildings). In addition to providing more cost efficient heating and cooling, these systems can provide feedback to households on their energy use (and cost). For the near term, gas and electric utility bills could be modified to provide feedback on changes in energy use

Table 1. Estimated Energy Savings From Information

Type of Information	Savings[a] (Percentage) Average	Range
Energy Savings Goals	1	0-1
Information	4	0-9
Feedback on Consumption	11	3-21
Financial Incentives	15	4-28
Combined Feedback and Information	14	13-17

Source: Sorensen [24].

[a] The large range in estimated energy savings for similar programs illustrates the variation in the implementation and consequent effects of these programs.

(from month-to-month, from this month to the same month last year, or from year-to-year) with little difficulty [25].

Improving operating practices in multifamily buildings is much more difficult than in single-family homes because it involves both owners (or their managers) and tenants. In addition, the central heating equipment and associated distribution system are more complicated in multifamily buildings, especially high-rise buildings. Wisconsin Gas Company's Voluntary Rental Unit Conservation Program includes two sets of energy audits, structural audits intended for building owners and personal energy audits intended for tenants [26].

INSTITUTIONAL BEHAVIOR

People affect building energy efficiency as members of organizations involved in the design, construction, financing, purchase, operation, and occupancy of buildings. This section summarizes the influences that various organizations and professionals have on energy use in buildings. The roles of designers, builders, appliance manufacturers, and financial institutions are discussed here. For discussions of government energy agencies and electric and gas utilities see [6, Chapters 9 and 10].

Designers and Builders

Many organizations make significant contributions to improved energy efficiency in buildings. Some are interested in whole-building performance while others focus on particular products or processes. These institutions represent various segments of the building industry: architects, engineers, building owners and managers, equipment manufacturers, and building-materials manufacturers. These organizations include:

- American Consulting Engineers Council;
- American Institute of Architects;
- American Planning Association;
- Air Conditioning and Refrigeration Institute;
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers;
- Building Owners and Managers Association;
- Building Thermal Envelope Coordinating Committee;
- Illuminating Engineering Society of North America;
- Masonry Industries Committee;
- Mineral Insulation Manufacturers Association;
- National Association of Home Builders;
- National Institute of Building Sciences;
- Passive Solar Industrial Council;
- Solar Energy Industries Association; and
- Urban Land Institute.

The recent energy efficiency-related activities of the American Institute of Architects (AIA) and the National Association of Home Builders (NAHB) are discussed here as examples.

The NAHB has 127,000 members that employ three million workers. When the economy is healthy, the average homebuilder produces twenty to twenty-five homes per year. In an economic slump, production may decrease to ten homes per year. The membership is organized into 780 local associations, each of which plans, organizes, and manages its own programs, such as energy conservation.

One of NAHB's major energy related activities was its 1979 development of voluntary energy guidelines. The "Thermal Performance Guidelines" were developed for 211 cities in all U. S. climatic regions. These guidelines were made available to local associations for voluntary use in their individual programs and projects. Pilot programs were organized around these guidelines; they involved seminars, workshops, and conferences. These guidelines have also been accepted by many lending institutions.

Both builders and home buyers alike are extremely sensitive to first cost and housing "affordability," producing some corner-cutting on quality including compromises in thermal integrity. Even though "energy efficiency" was viewed as very important by three-fourths of surveyed home buyers in 1983, efficiency depends on perceptions as well as on the structural characteristics of the house itself. Builders and buyers are largely concerned with readily observable features that provide status, sales appeal, and other amenities at the least cost. This clearly works against care in construction and the provision of hidden materials (e.g., wall insulation and vapor barriers) to save energy.

The AIA has 44,000 members working in approximately 12,000 firms. It sponsors numerous energy-conscious design programs and its *AIA Journal* often discusses energy-conscious projects. Its AIA Foundation helped develop the Building Energy Performance Standards (BEPS) for DOE.

A recent AIA effort has been its Energy in Design Workshop program for which it developed a multivolume set of design and redesign guidelines. These volumes present energy conscious guidelines from overview, schematic, and detailed perspectives. These volumes have been used in workshops held in various cities throughout the United States, open to all building-design professionals.

The AIA Foundation is involved in a series of workshops, sponsored by various government and private organizations. The goal is the formulation of a national agenda for research in energy efficiency and in building-related solar energy.

The AIA has no way of ensuring that its members design efficient buildings. However, evidence from its design awards program, publication of outstanding projects, and attraction of research funds through the AIA Foundation suggests that AIA is a significant force in stimulating progress in energy efficient architecture.

Appliance Manufacturers

The home appliance industry sells approximately thirty million major appliances and space-conditioning systems annually. Even though the appliance industry is concentrated among large domestic corporations (such as General Electric, Whirlpool, and White Consolidated Industries), it is very price competitive. Throughout the 1970s, appliance prices increased at less than half the inflation rate [27]. Appliance price rises were moderated by both competition and increasing productivity. Furthermore, appliance manufacturers typically spend only 1 to 2 percent of their sales revenues on R&D, compared to 4 to 7 percent of revenues in such industries as electronics and instrumentation [28].

Little information is available on how manufacturers treat energy efficiency in decisions regarding product offerings. Manufacturers regard such information as proprietory. From the products offered in the marketplace, it can be seen that manufacturers have made major advances in developing and introducing more-energy-efficient products during the past decade. Assessments of available highly efficient models show that they are still far from life cycle cost minimums. The emphasis in the United States appliance industry has been on minimizing price rather than on technological advancement [28].

Understanding how manufacturers view efficiency improvements (e.g., what paybacks are required to motivate production of more efficient products) would be useful. Another important manufacturing issue is the potential of Japanese and other foreign manufacturers to export efficient appliances to the United States.

Financial Institutions

Success in achieving energy efficiency often depends on the ability of building owners and users to put up the necessary funds or to link up with an outside party that provides financing. Unlike investments in utility power plants or major oil and natural gas projects, capital commitments to energy efficiency are made on a very small scale and by a myriad of individuals and organizations.

Sources of capital for energy efficiency investments in buildings include internal funds, banks and other conventional lending sources, utility loan programs, government financing programs, and third-party financing. The remainder of this section discusses the behavior of conventional financing sources (e.g., banks) and the expanding area of third parties who provide financing for conservation investments.

Banks and other conventional lending sources – Traditional guidelines for mortgage lending and housing appraisals discourage builders and homeowners from incorporating energy efficiency components into new housing [29]. Instead, these guidelines tend to limit home mortgages according to the income of the purchaser without considering operating costs (i.e., energy bills).

In recent years, interest has been shown in providing increased mortgages for highly efficient houses or in adding the cost of a retrofit to the mortgage for a less efficient house. The rationale for such efforts is that it is easier for the owner to make a larger mortgage payment if the home is energy efficient. This scheme has been successfully tried in Massachusetts and in Seattle [30]. Also, the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae) have embraced the concept [29]. However, the concept has not been widely implemented by local banks. A 1984 survey of 150 lending institutions showed that 88 percent do not give preferential loan treatment to people buying energy efficient homes [31]. Although most of these lenders sell loans in the secondary market, nearly 90 percent are not aware of the special underwriting guidelines for energy efficiency offered by Fannie Mae and Freddie Mac.

Because such mortgages can provide a major incentive for energy efficiency improvements in housing, additional efforts to change the policies of local banks are called for. Nearly half the lenders surveyed claimed that, in principle, they would be willing to change their debt-to-income ratio for energy efficient homes [31].

Bank loans are also used to finance residential energy retrofits and major equipment purchases (e.g., HVAC systems). However, interest rates for such loans are high, so consumers are reluctant to use them. Other borrowers may not be able to qualify under the restrictions placed by banks on these small loans.

Third-party financing – Third-party financing, which involves capital investment by someone other than the building owner or the supplier, is rapidly expanding. As of 1984, more than 100 energy service companies (ESCOs) were willing to install and provide financing for energy conservation measures in buildings [32]. By and large, ESCOs rely on outside investors to provide funds for their projects [33]. In many cases, ESCOs lease equipment to, operate equipment for, or enter into a "shared savings" plan with the building owner.

The possibility of third-party ESCOs making efficiency improvements in commercial or multifamily residential buildings overcomes a number of the traditional barriers to conservation in larger buildings. These barriers include a low level of awareness and skepticism regarding conservation options, lack of motivation, lack of capital, high required rate of return, and low priority for conservation investments [34].

Still, several issues and challenges confront ESCOs [32]. ESCOs will have to build credibility through demonstrated "success stories" and through information dissemination. So far, third-party financing has mainly occurred in large buildings where conservation measures cost at least $50,000 [32]. Further work is needed to reach smaller buildings in a practical and cost-effective manner. In addition, the problem of "cream skimming" (i.e., making only very-short-payback investments, the investments with the least risk) is a concern.

At the institutional level, standard arrangements for energy service agreements and for measuring energy savings need to be developed. Also, the status of tax benefits for third-party financing for conservation investments is uncertain and needs to be stabilized [32, 35].

On the positive side, third-party financed efficiency investments are beginning to penetrate hard-to-reach markets, such as public housing, schools, hospitals, and government buildings. Experiences have shown that while negotiations and implementation can be difficult, state and local governments are well-suited for using third-party financing arrangements [36-38]. The procedures for energy-service contracting by public sector organizations are expected to improve with time as this market expands.

More recently, the shared savings/energy service idea has been extended to single-family homes on a demonstration basis. Sentinel Energy, a private company, provides energy audits and retrofits in Hennepin County, Minnesota, at no cost to homeowners [39]. Sentinel then keeps 60 percent of the actual energy savings for five years to repay its capital investment in these houses.

Whether or not this strategy works and leads to substantial energy savings is yet to be determined.

SUMMARY

The purchase and operation actions of individuals have substantial effects on energy use in residential and commercial buildings. The evidence on household purchase behavior with respect to energy-efficiency improvements suggests that these decisions implicitly incorporate very high discount rates. In other words, substantial energy-efficiency opportunities are being foregone. Unfortunately, little is known about the reasons for these underinvestments in efficient equipment, appliances, and buildings.

A variety of government and utility programs exist to overcome barriers related to purchase of high-efficiency systems. These programs include information (e.g., home energy audits), financial incentives (e.g., rebates for purchase of high-efficiency refrigerators), and regulations (e.g., minimum performance standards for new homes and certain appliances).

Household operation of existing homes (i.e., fixed capital stock) also has substantial effects on energy use. Typically, energy use in "identical" homes can vary by a factor of two because of differences in household composition (number and ages of household members), attitudes, and behaviors. These differences are especially important with respect to energy use for space heating, water heating, and air conditioning.

Organizations that "supply" energy-efficient buildings and their equipment also have large effects on energy use. Building designers and contractors affect the performance of new and renovated structures. Appliance and equipment manufacturers decide on the efficiency levels to incorporate in their products and the prices to charge. Finally, financial institutions (both conventional banks and unconventional funding sources such as third-party organizations) provide the money to pay for new equipment and buildings. Information on the roles of these organizations and on ways in which they can further increase energy efficiency is particularly scanty.

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Direct reprint requests to:

Eric Hirst
Energy Division
Oak Ridge National Laboratory
Oak Ridge, TN 37831