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Authors
Levine, M.D.
Hirst, E.
Koomey, J.G.
et al.

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Mark D. Levine, Eric Hirst, Jonathan G. Koomey,
James E. McMahon, Alan H. Sanstad

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Energy Analysis Program
Energy and Environment Division
Lawrence Berkeley Laboratory
Berkeley, California 94720

Energy Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

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Mark D. Levine,* Eric Hirst,# Jonathan G. Koomey,*
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*Energy Analysis Program, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720

#Energy Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

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ABSTRACT

This paper presents a framework for evaluating engineering-economic evidence on the diffusion of energy efficiency improvements. Four examples are evaluated within this framework. The analysis provides evidence of market failures related to energy efficiency. Specific market failures that may impede the adoption of cost-effective energy efficiency are discussed. Two programs that have had a major impact in overcoming these market failures, utility DSM programs and appliance standards, are described.

I. INTRODUCTION

Can improvements in energy efficiency substantially reduce fuel use and energy bills in the United States with no reductions in services or amenities? If so, are government and utility programs necessary to promote efficiency measures yielding cost-effective savings? Or should we rely on the normal workings of the marketplace to select levels of energy efficiency?

We use the term "energy efficiency gap" to describe the difference between the actual energy efficiency of many purchased products and the level of energy efficiency that can be provided cost effectively for the same products. There are at least two schools of thought about this "energy efficiency gap". Many economists believe that the gap is either small or non-existent, and question policies that promote energy efficiency. Many technologists, on the other hand, believe that policies aimed at promoting energy efficiency can yield substantial economic benefits.

There is a spectrum of views within both groups. Some economists believe there is virtually no cost-effective energy efficiency to be acquired. They maintain that if individuals wanted that energy efficiency – instead of energy – they would have purchased it. Other economists acknowledge significant imperfections in markets for energy efficiency. Even here, there is room for disagreement about whether these market failures are sufficient to justify government intervention. There is also a range of views among technologists on how much energy efficiency can be obtained, and with what degree of difficulty.

The Energy Modeling Forum (organized by Stanford University) is currently addressing the "energy efficiency gap". Several recent papers address one or more aspects of this issue (Sutherland 1991; Sutherland 1994; Nichols 1993; Joskow and Marron 1993a and 1993b). Sutherland (1994) suggests that energy efficiency and economic efficiency are often competing goals, based in part on his belief that markets make good choices on energy efficiency. Nichols (1993) uses economic theory to suggest that utility programs (especially customer rebates) are misguided because the market would have adopted the efficiency measures if their costs were truly lower than their benefits. Joskow and Marron (1993a and 1993b) use data from ten utilities to suggest that utility demand-side management (DSM) programs may not be cost-effective. Their conclusions have been challenged by a number of others. (See, for example, Lovins 1993, Blumstein and Harris 1993, Miller 1993, and Hirst and Brown, 1990).

It is our judgment that resolution of this debate depends upon the careful quantitative analysis of the engineering and economic characteristics of specific technologies as well as an assessment of data on adoption of the technologies in the market and of policies directed toward energy efficiency. Accordingly, our primary objective in this paper is to focus attention on the empirical basis for skepticism about the effectiveness of the market mechanism in yielding cost-effective energy efficiency improvements. We present a framework for evaluating engineering-economic evidence on the diffusion of energy efficiency improvements. We then present a series of examples within this framework that, in our view, provide evidence for market failures related to energy efficiency. We go on to discuss several specific market failures that may impede the adoption of cost-effective energy efficiency. Next, we discuss two programs that have a major impact in reducing the gap, utility DSM programs and appliance standards. We conclude with a summary and suggestions for further research.

Specifically, we make the following points:

- There is a gap between the energy efficiency of many products that are purchased and the cost-effective levels of energy efficiency for these products. We present specific examples to show that this "efficiency gap" exists. We especially focus on cases where there is little or no evidence for the economist's assumed "hidden costs."

- This gap is a significant one, in the sense that closing it would have a major impact on U.S. energy use and the U.S. energy bill.

- There are undoubtedly many reasons that such a gap exists. We identify some of these market imperfections, while acknowledging the paucity of data detailed enough to indicate which of them yield what impacts.

- Given the discrepancy between the observed and the achievable levels of energy efficiency — and the beneficial impacts of cost-effective energy efficiency — government policy to promote energy efficiency is desirable. We discuss two of the major energy efficiency programs, appliance standards and utility DSM programs, to clarify the features of the programs that have led to their success.

- We identify research needed to refine our understanding of these important issues as well as to be able to better design and implement programs to increase cost-effective energy efficiency in the economy.

The information provided to support the points above yields a basis for commenting on the following economist's questions about the energy efficiency gap:

- Aren't technologists ignoring certain "hidden costs" in their calculations that, if included, would show that many energy efficiency investments are in fact *not* cost-effective?

- Aren't these hidden costs "irreducible," that is, not subject to reduction or elimination by policies?

- In any case, aren't these hidden costs "normal" to many markets, not just markets for energy efficiency? If not, what distinguishes energy markets?

- Even if these costs can be reduced, why can't these opportunities be exploited by private firms? That is, why do government and utilities need to intervene?

These questions are especially relevant in the 1990s. The extent to which efficiency improvements are less expensive than new energy sources will influence decisions concerning the best ways to reduce greenhouse gas emissions, cut energy-related air pollution, and promote competition in the electricity and gas industries.

II. EXAMPLES OF THE GAP BETWEEN COST-MINIMIZING AND OBSERVED LEVELS OF ENERGY EFFICIENCY

A. Background

Consumers and firms demand fuels and electricity not for their own sake but rather for the services they can provide, such as lighting, heating and cooling, and refrigeration. At any given time a range of technological options is commercially available to deliver these services, distinguished by energy-efficiency and thus by the cost of the services delivered.

Typically, the more efficient devices have higher initial purchase prices but lower operating costs. When two types of device provide equivalent energy services, an internal rate-of-return for the incremental investment in the more efficient device can be calculated provided that data on both purchase prices and operating costs are available. This rate-of-return can then be compared with social discount rates and with the borrowing or savings rates of the purchaser. When the rate-of-return exceeds the social discount rate but the less efficient device is purchased, we infer that energy services are not being obtained at minimum cost from a *societal* perspective. When the rate-of-return also exceeds market interest rates but the less efficient device is purchased, we infer that energy services are not being obtained at minimum cost from a *private* perspective.

A variation on this approach is to compare the annualized incremental cost of investment in the more efficient device with the price of energy. This requires the exogenous specification of a discount rate.

Cost minimization is a necessary condition for economically efficient allocations of resources (Varian 1984). Analyses of many commercial energy-using products, however, have found failure to obtain energy services at minimum cost, implying the existence of *market failures* for energy efficiency.

B. Conditions for Identifying Market Imperfections

What are the conditions under which untapped energy efficiency implies the existence of market failures? If a cost-effective efficiency investment is readily available, yet is not being used in many or most suitable applications, there are either (1) *hidden costs* that have not been included in the calculations, or (2) incorrect *parameter specification* in the calculations, or (3) *time lags* between the introduction and the acceptance of this technology, or (4) *market failures* inhibiting the adoption of this option (Koomey 1990).

In this section we provide an analysis of four examples of purchase or use decisions made between two products that are identical in customer utility, but that have different levels of energy efficiency. While examples in this case are electricity-using equipment, we believe that the conclusions outlined below hold for gas and oil end uses as well. We emphasize that the approach we have outlined here is firmly rooted in economic theory. When correctly applied, the type of analysis we describe above provides solid economic information on the performance of the market for energy efficiency and energy services.

Hidden costs: There are several categories of potentially "hidden" costs that may affect the analysis. First, there is the potential for a reduced level of energy service (e.g., quality of lighting or temperature and comfort levels with heating systems). Second, there may be irreducible private costs (such as the inconvenience associated with installation of the efficient equipment). Finally, other costs may not be included in the calculations including sales, income, and property taxes and additional maintenance costs for the efficient measure.

Parameter Specification: The input parameters in each analysis must capture the range of possible physical situations and usage characteristics existing throughout the economy. The examples that follow are based on engineering calculations using *typical* buildings or appliances. Engineering calculations may overstate the benefits of energy efficiency by calculating energy savings with respect to a base case building or device that is less efficient than currently designed new buildings or new devices. Building prototypes based on average characteristics may submerge important details and may not contain all available efficiency technologies. Incorrect estimation of operating hours may also affect these calculations.

Time Lags: New technologies take time to reach the market and to be understood and accepted by the design community. (The time and effort needed to learn about new technologies is another hidden cost, which is likely to be greatest when these new technologies are introduced rapidly.) In some cases, manufacturers may need years to produce a new technology on sufficient scale to saturate the market. This aspect of technology diffusion raises analytical and empirical problems that are difficult to address in the standard engineering-economic framework. Thus, in the examples described below, we concentrate on technologies that are readily available and whose characteristics minimize the barriers to diffusion.

Market Failures: If there are no hidden costs or time lags, and parameters have been correctly specified, then we conclude that market failures such as information problems, decision-making problems, transactions costs, and capital market imperfections must be inhibiting the adoption of the more efficient technology. We discuss each of these market failures in the next section.

C. Examples Indicating the Existence of Market Imperfections

In this section we provide examples of purchase or use decisions made between two models that are identical in customer utility, but that have different levels of energy efficiency for four technologies: commercial fluorescent ballasts, residential refrigerator/freezers, personal computers and office equipment, and color TV standby power. We conclude by summarizing the policy implications of these examples.

1. *Standard core-coil versus efficient core-coil commercial fluorescent ballasts*

Table 1 shows the market share and energy-related characteristics of standard core-coil and efficient core-coil fluorescent ballasts. After correcting for efficiency standards in five states that prohibited the sale of inefficient ballasts, standard core-coil ballasts would have accounted for about 90% of all fluorescent ballast sales in 1987 (Geller and Miller 1988). The table shows that the efficient core-coil ballast offered energy savings at a cost of conserved energy (CCE) of 1.4¢/kWh.[1]

Table 1. Characteristics of Standard Core-Coil and Efficient Core-Coil Fluorescent Ballasts

Ballast type	Approximate Adjusted Market Share ca 1987	Capital Cost 1989 $	Power Savings W	Energy Savings kWh/yr	Marginal CCE 89¢/kWh	Implied Marginal real IRR
Standard core-coil	90%	11.0	0	0	-	-
Efficient core-coil	9%	15.4	11	29	1.4	60.3%

Assumptions: Operation time for offices = 2600 hrs/yr, ballast lifetime=45,000 hrs=17.3 yrs, discount rate=6% real, capital recovery factor (CRF)=0.0917, and 1988 U.S. average commercial sector electricity price of 7.4¢/kWh. Capital costs are from Geller and Miller (1988), and have been adjusted from 1987-$ to 1989-$ using the consumer price index.

Market shares were adjusted by Geller and Miller to represent market shares if state standards did not exist in 1987. By the end of 1987, standards prohibiting sale of inefficient core-coil ballasts existed in five states representing about one quarter of the U.S. population (California, New York, Massachusetts, Connecticut, and Florida). Installation and maintenance costs are equivalent for all types of ballasts. Even more efficient electronic ballasts would have made up the remaining 1% of sales in 1987 (they have a capital cost of 33.4, power savings of 33 W, energy savings of 86 kWh/yr, a marginal CCE of 2.8, and an implied marginal real IRR of 26.3%).

This example assumes operating hours that are lower than those in almost all commercial buildings (Piette et al. 1988). The resultant CCE implies a real market discount rate of about 60% for those who purchase the standard core-coil ballasts. Since the efficient core-coil ballasts are identical to the standard

1. At a 15% real discount rate, the CCE would be 74% higher, or $0.025/kWh, which is still significantly cheaper than the price of electricity.

models except that the core winding is more efficient, we conclude that the market is acting as if purchasers of standard ballasts are using high discount rates.[2]

Hidden costs: The efficient core-coil ballast provides equivalent amenity and longer lifetime than its inefficient counterpart. It is widely available and is based on well-known, proven technology. The similarity between this device and the one it replaces ensures that hidden costs associated with difference in energy service are not important.

Parameter Specification: The only parameter that could be improperly specified in this comparison is operating hours. However, we know that efficient core-coil ballasts are cost effective when operated more than 600 hours/year, and we know that the lights in all types of commercial buildings operate for thousands of hours every year. Thus, we can conclude that incorrect specification of operating hours (within reasonable bounds) will not affect the results from this calculation.[3] The other parameters are irrelevant because efficient core-coil ballasts are perfect substitutes for inefficient ballasts (except with respect to energy savings and lifetime, where they are superior substitutes).

Time Lags: Efficient core-coil ballasts were on the market for many years before 1987, so time lags are not relevant in this example.

Conclusions: This example describes a case in which there are no hidden costs or time lags affecting the purchase decision for ballasts. Parameters have been specified correctly in the analysis. Even though this ballast saves energy at a cost below the price of electricity, we found that most consumers still purchased the less efficient standard core-coil ballast. We conclude that market failures must have inhibited the adoption of the more efficient core-coil ballasts.[4] Since fluorescent ballasts are found in almost every commercial building, this finding suggests that market failures affecting the adoption of efficient core-coil ballasts are widespread and may affect the adoption of other cost-effective devices as well.

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2. The fact that consumers purchased the less efficient model does not mean that they actually performed a life-cycle cost calculation using a high discount rate. It strongly suggests that cost-effective efficiency measures are ignored by many purchasers.
3. The lowest plausible number of annual operating hours for commercial buildings is around 1300, which would yield a cost of conserved energy of 2.8¢/kWh, still 1/2 of the electricity price. These calculations assume a real discount rate of 6% and other parameters as specified in Table 1.
4. As of January 1990, only efficient core-coil and electronic ballasts may be sold in the U.S. The inefficient core-coil ballasts were outlawed by an 1988 amendment to the National Appliance Energy Conservation Act of 1987.

2. *High efficiency versus low efficiency residential refrigerator/freezers*

Meier and Whittier (1983) present data on sales of a pair of refrigerator models differing only in energy efficiency. They were able to estimate the discount rate implicit in the purchases of the less efficient model in each of several regions. Their study is revealing in that it used very specific data and a simple technique: the incremental price of the more efficient model was compared with its reduced operating cost to compute a rate-of-return on the investment in the efficient model. Purchase of the less efficient model then implies an implicit discount rate exceeding this rate-of-return.

The two refrigerators were displayed next to each other and sold by the same national retailer between 1977 and 1979. Both models were top-mount, auto-defrost, roughly 17 cubic feet in volume, and had the same features. The price of the higher efficiency model was $60 more than the less efficient one, and it used 410 kWh/year less electricity. The absolute difference in prices for the refrigerators was constant over the analysis period, even though purchase price for both models was reduced by rebates at various times. The high efficiency model was advertised widely, and a prominent consumer magazine recommended it and even calculated the monthly savings in electric bills. (There were no federally mandated appliance efficiency labels in place at that time.) The efficient and inefficient models together accounted for significant fractions of total unit sales of all models of that particular brand (roughly 20% to 80%, depending on the region).

Using a 6% real discount rate and a lifetime of 20 years, the more efficient refrigerator saved energy at a cost of 1.3¢/kWh (1979$), cheaper than the electricity prices prevailing in every state at that time. Prices in 1979 were lowest in Washington (1.5¢/kWh), while the national average was about 5.4¢/kWh. Using a 15% real discount rate, the CCE is 2.4¢/kWh, still less than half the U.S. average price of electricity in 1979.

During 1977 through 1979, the inefficient model was purchased by around 45% of purchasers of either refrigerator in the Midwest (i.e., 55% purchased the efficient model), 35-40% in the East, 54-69% in the South, and 57-67% in the Pacific Region. These purchasing patterns reflect the influence of electricity price, at least qualitatively: in 1979, the Pacific and Southern region had prices of 3.4¢/kWh and 4.0¢/kWh, respectively, and the Midwest and East had prices of 5.5¢/kWh. Even noting this qualitative difference, however, it is impossible to ignore the fact that 35% to 70% of the purchasers of these two models chose the inefficient model, in spite of the low cost of conserved energy.

The results of Meier and Whittier's calculation of the real implicit discount rate are:

- In the Pacific region, over 60% of buyers revealed discount rates exceeding 34%;
- In the South, 59% of buyers revealed discount rates exceeding 41%;
- In the Midwest, 45% of buyers revealed discount rates exceeding 56%;
- In the East, 40% of buyers revealed discount rates exceeding 58%.

These implicit rates of return are significantly higher than those prevailing in the capital markets (typically 4-12% real).

Hidden Costs: The only hidden cost that might affect this comparison would be a result of having no standardized rating system for energy use, which might have made it more difficult for consumers to verify the energy savings that the salesperson claimed. This factor was probably mitigated by the recommendation of the consumer magazine and the accompanying estimate of monthly dollar savings for the more efficient model.

Parameter Specification: Refrigerator usage does not vary by more than 10-20% over the year or between users, so errors in characterizing usage are not a factor in this calculation. Geographical variation in electricity prices does not affect the results, because we compared the estimated cost of conserved energy (using a 6% real discount rate) to the electricity prices prevailing in the state that had the lowest electricity price in 1979 and found the efficient model to be cost effective even in this extreme case.

Time Lags: Time lags are not relevant here, because both models were widely available (and displayed next to one another) at the same time.

Conclusions: This example describes a case in which there were no hidden costs or time lags affecting the purchase decision for a refrigerator. Parameters have been specified correctly in the analysis. The energy efficient refrigerator saves energy at a cost below the price of electricity, yet many consumers purchased the inefficient model in spite of the efficient model's economic advantage. We conclude that this indicates that market failures affected the market for efficiency in refrigerators. Many consumers rejected investments that yield returns much greater than their cost of capital. The appliance efficiency standards that went into effect in 1990 and 1993 have significantly changed the market for refrigerators, but many of the same factors affecting consumers' efficiency choices in 1977-79 probably still exist for other products.

3. *Energy Star computers*

The Environmental Protection Agency's (EPA's) Energy Star Computer program is a voluntary program that includes all the major U.S. computer manufacturers (Johnson and Zoi 1992). The manufacturers agreed to produce computers, monitors, and printers that switch to low-power states after a specified period of inactivity (the low power state of 30W for the CPU represents a reduction of about 70%, with comparable reductions for monitors and printers). When the user starts working again, the computer springs back to life instantly. Because even heavily used personal computers sit idle for significant parts of the day, energy use can be substantially reduced (Fig. 1).

Extensive discussions with manufacturers showed that these features could be added at *negligible cost* to the purchaser, and that consumer utility would hardly be affected. Manufacturers who meet the Energy Star criteria are eligible to display the Energy Star Logo, which brands their product as energy efficient, on their product literature.

We cite this example not to advocate regulating the computer industry, which we emphatically do not favor, but to describe how electricity use was essentially ignored by this highly competitive and technologically advanced industry prior to the EPA's program. For example, during one meeting with representative divisions of a major computer manufacturer, a product development specialist remarked that they once considered incorporating lower-power states into their mainstream product line, but that the marketing department advised them that it would not be worth the effort.

The fact that energy is only a small part of the total costs of owning and operating a computer may contribute to the previous lack of interest on the part of customers in efficiency improvements. However, in businesses where computers are widely used, wiring constraints in older buildings can force costly renovations if the capacity of the wiring is not able to meet the demand for power. These constraints may have increased the awareness of such customers to the amount of energy their computers used.

Saving energy in the use of personal computers may seem like it would have relatively minor impacts nationally. This is not the case. The rapid proliferation of personal computers and associated printers has resulted in significant increases in electricity use in commercial buildings. Harris et al. (1988) projected office equipment electricity use of 65 TWh to 115 TWh by 1995, which would imply that office equipment would account for between 6% and 12% of total commercial sector electricity use as forecast by US DOE (1994).

Hidden Costs: There are no hidden costs in this example. The level of service remains virtually unchanged.

Parameter Specification: The manufacturers, the ones most equipped to know, say these measures will have negligible costs. Incorrect parameter specification is therefore not an issue.

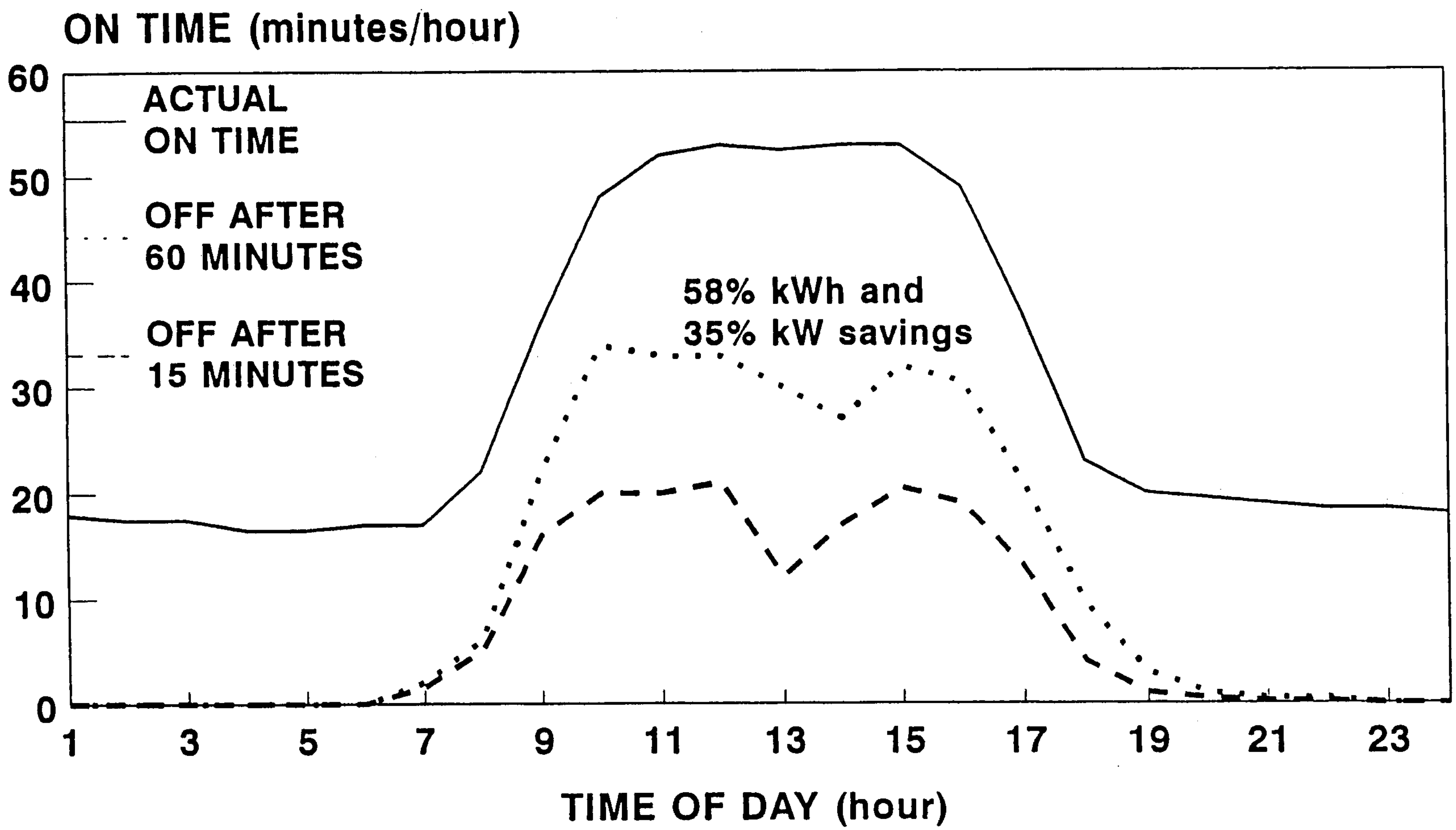

Fig. 1. Mean on-times for 94 personal computers in a Canadian office building (Ross 1992). The lower two curves indicate the energy and demand savings that could be achieved if the computers were automatically turned off after 60 minutes or 15 minutes of non-use.

Time Lags: The technology involved in Energy Star Computers has existed for years. Time lags are therefore not an issue in this case.

Conclusions: This example describes features that can be added to computers, monitors, and printers to make them more energy efficient. The resulting technologies have no hidden costs and no time lags. Parameters have been specified correctly in the analysis. Adding the features saves energy at a cost below the price of electricity, but we found that even in the competitive computer industry, this highly cost-effective energy savings option would not have been captured without the cooperation between EPA and the manufacturers. Therefore, we conclude that market failures must have inhibited its adoption.

4. Standby power in color televisions

The U.S. Department of Energy describes options for improving the efficiency of color television sets, including the option of reducing standby power (US DOE 1988). A small amount of power is needed at all times to allow the remote control to turn the TV on and off. Even when the TV is operating, this power is used to allow the remote control to adjust volume and change channels. In a survey of 25 19" and 20" color TV models, DOE found that more than 70% had standby power of greater than or equal to 2 W. The average standby power for the entire sample of TV models was 4.4 W.

Televisions with standby losses greater than 2 W typically feed power to the tuner using a resistor. By replacing this resistor with a transformer, the standby power can be reduced to 2 W. The additional manufacturing cost associated with the transformer is $2.15 (in 1987$). The cost of the resistor is subtracted from that of the transformer, and markups are applied to calculate the consumer price. The consumer price of reducing this standby power was estimated to be $4.30. This investment would save 21 kWh/year.

Using a real discount rate of 6% and a lifetime of 11.5 years, these costs and energy savings translate into a cost of conserved energy of 2.5¢/kWh. This CCE is about a factor of three lower than the average price of electricity, yet more than 70% of televisions had not adopted this simple technology as of 1987. At a 15% real discount rate, the CCE becomes 3.8¢/kWh, which is about half the U.S. average price of electricity.

Approximately 18 million color televisions were sold in the U.S. in 1986. Changes of a few watts in standby power may sound small for individual televisions, but with hundreds of millions of televisions in existence and the standby power being consumed every hour of the day, 2.4 W savings per TV would (after 20 years) add up to approximately 450 megawatts and 3.2 TWh of annual savings. Such savings would be worth about $240 million per year if evaluated at national average electricity prices.

Hidden Costs: There are no hidden costs in this example. The consumer would see no difference in performance, and reliability would not be affected.

Parameter Specification: Standby power use is constant, so there are no usage-related variations. The cost of reducing standby losses is based on well-known, simple technology, so this parameter has been specified accurately.

Time Lags: The technology to reduce standby losses to 2W or less is well within the capabilities of all television manufacturers.

Conclusions: This example describes a cost effective improvement in television efficiency that has no hidden costs and no time lags. Parameters have been specified correctly in the analysis. Reducing standby power saves energy at a cost below the price of electricity, yet most manufacturers choose not to add this option. We conclude that market failures have inhibited the adoption of this cost effective, energy-saving option.

5. *Implications*

The four examples described above are not isolated ones. They were chosen to illustrate specific cases where equipment purchasers chose less energy efficient products over more efficient ones, even though the more efficient ones were cost effective. Or, in the cases of television sets and computers, they illustrate the fact that consumers did not have the choice of saving energy because the manufacturers did not make the measure available, even though its application was straightforward and highly cost-effective.

Dozens of studies have indicated the potential for achieving substantial cost-effective energy savings in buildings and equipment, generally in the range of 20 to 40% for new equipment and buildings compared with what is otherwise chosen. For an extensive discussion of the measures that can be applied to new and existing residential buildings, including costs and energy savings, see Koomey et al. (1991).[5]

These examples show that the technology choices made by manufacturers and consumers are often far from the economic optimum. However, such calculations are only the first step in assessing the existence of market failures. They do not indicate precisely what those failures are, only that some failure exists. We now turn to examples of markets failures that may be present in energy markets.

5. For a summary of the results of a number of estimates of national energy savings that could be obtained through cost effective investments in energy efficiency, see Fickett, Gellings, and Lovins (1990) and Rosenfeld, et. al. (1993).

III: FACTORS ACCOUNTING FOR THE ENERGY-EFFICIENCY GAP

A. Background

We presented evidence above that consumers and firms often fail to minimize their costs of obtaining specific energy services. Since, as we discussed above, cost minimization is a necessary condition for economically efficient allocations of resources, these examples provide *prima facie* evidence of economic inefficiency in energy markets. What market imperfections might impede economic efficiency in markets for energy services and be correctable through well-designed policies?

In a "first-best" world, consumers and firms would make decisions regarding energy services that were both privately and socially optimal. The theory of welfare economics, however, provides a list of stringent conditions for decentralized markets to achieve efficient allocations, including:

- prices that fully reflect both private and social costs;
- complete and identical information on the part of consumers and firms;
- perfect capital markets;
- no transaction costs.

Each of these conditions fails to one degree or another to be satisfied in markets for energy services. That is, the "energy efficiency gap" reflects an "economic efficiency gap" that is amenable to correction by appropriate policies. These market imperfections can be used to interpret the evidence we presented above and can guide the design of policies (Sanstad and Howarth 1994).

B. Market Imperfections Related to Energy Efficiency

1. *Existing price distortions*

It is universally recognized that electricity prices do not reflect environmental costs. It is important to recognize, however, that price reform is by no means a panacea for correcting market imperfections related to energy. First, simply determining correct prices (i.e., prices that internalize all social costs) is itself a difficult and possibly insurmountable policy hurdle. The magnitudes of environmental externalities are site-specific and typically quite controversial (ECO Northwest 1993). Estimates of the costs associated with carbon dioxide (CO_2) emissions range from \$1 to more than \$20 per ton, reflecting different and not easily reconciled assumptions about the damages related to global climate change and the most efficient ways of reducing CO_2 emissions (Ottinger et al. 1990). Beyond this, there are substantial political and institutional barriers to energy price reform as illustrated by the recent failed effort to impose a Btu tax.

Second, the examples we presented above show that existing markets at *current* prices are not performing efficiently since cost-effective measures are not being adopted, so that market imperfections arising independently of price distortions must be addressed.

2. *Information problems*

Consumers often lack information regarding both their current energy consumption patterns and ways to reduce this consumption. In the residential sector, this problem occurs because consumers get a monthly bill that provides no breakdown on the contributions of individual end-uses to that bill. This is analogous to shopping in a supermarket that has no individual prices; because one receives only a total bill at the checkout counter, one has no idea what individual items cost. Kempton and Layne (1989) suggest that utilities need to provide considerably more information on the monthly bills if consumers are to have the necessary information to make "rational" decisions on energy use.

Komor et al. (1989) show that small commercial customers are often just as ignorant about their monthly electricity bills as residential customers. They interviewed owners and managers of 40 small commercial establishments and found that they knew little about energy use in their facilities. For example, not one of the interviewees was aware of the electricity demand charge ($/kW-month), even though this component accounted for almost half of the typical electric bill!

Asymmetric information is a market imperfection in landlord/tenant or building/occupant situations.[6] A significant difference in energy efficiency investment between owners and renters was empirically documented by Brechling and Smith (1992) in a rigorous econometric study of the British housing market. This problem arises from different levels of information between owners and renters. If tenants pay utility bills, they could gain (in the form of lower utility bills) from the installation of efficiency measures by building owners. Owners would wish to earn a return on such investments in the form of higher rents. Owners cannot easily overcome, however, the problem of informing current and prospective tenants (who are unknown) of the benefits available from increased efficiency. Hence, in a competitive rental market, the opportunity for mutual gains from improved energy efficiency can go unexploited.

If the landlord pays utility bills, he or she could again benefit from the installation of efficiency measures to lower tenants' energy consumption. In

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6. That different levels of information among market participants can have significant consequences for economic efficiency is one of the central insights of the field of information economics. This problem was first examined by Akerlof (1970).

this case, however, the tenant pays nothing for energy and thus has no incentive to use it efficiently (Kempton et al. 1992). Thus, the circumstance that favors efficient use of energy (tenant pays utility bills) leads to a disincentive for the purchase of energy-efficient equipment. The case that favors the purchase of efficient equipment (landlord pays bill) leads to a disincentive for the tenant to use energy efficiently.

Similar problems may occur in the markets for new homes and for energy-efficiency improvements in single-family homes (Dubin 1992; Stoft 1993). Because of information gaps, customers often must use energy technologies selected by others. Builders frequently buy furnaces, water heaters, and appliances for new homes. Not surprisingly, builders focus more on initial cost and less on operating cost than homeowners would. The same situation occurs in construction of commercial buildings. Owner-occupied buildings are much more likely to have energy-efficient technologies than are tenant-occupied buildings, as shown in a survey of new construction practices in Washington, D.C. (Hines 1990). This difference, which is rather dramatic in the case examined, was true for almost all the lighting, building shell, HVAC, motor, and control measures examined (Fig. 2).

3. *Decision-making problems*

Behavioral research studies the decision rules consumers use in making energy-related choices. Humans have limited or "bounded" rationality, since they can only process limited amounts of information (March and Simon 1959). The time it takes to process information is an information cost, while humans' inability to analyze and understand every issue is an indication of bounded rationality. For example, technical information related to energy is not "transparent" to consumers but is subject to psychological processes that may distort its content (Stern and Aronson 1984, Yates and Aronson 1983). In addition, consumers appear to use heuristics in making energy decisions that deviate systematically from those that would be employed in expert calculations (Kempton and Montgomery 1982). The result of such factors is often sub-optimal decisions relative to the specific set of choices available to the individual consumer (Howarth and Andersson 1993).

While firms typically have greater technical expertise available to them, intra-firm complexities of decision-making may result in deviations from the classical hypothesis of profit maximization in the case of energy investment decisions (DeCanio 1993, Ross 1986). These factors can result in firms' internal hurdle rates exceeding their cost of capital, so that even profitable energy efficiency investments are passed up. For example, principal agency problems between managers and technical personnel, or between shareholders and management, may result in biases against energy-efficiency investments (DeCanio 1993). This would explain the seeming "paradox" of firms failing to optimally invest in energy efficiency.

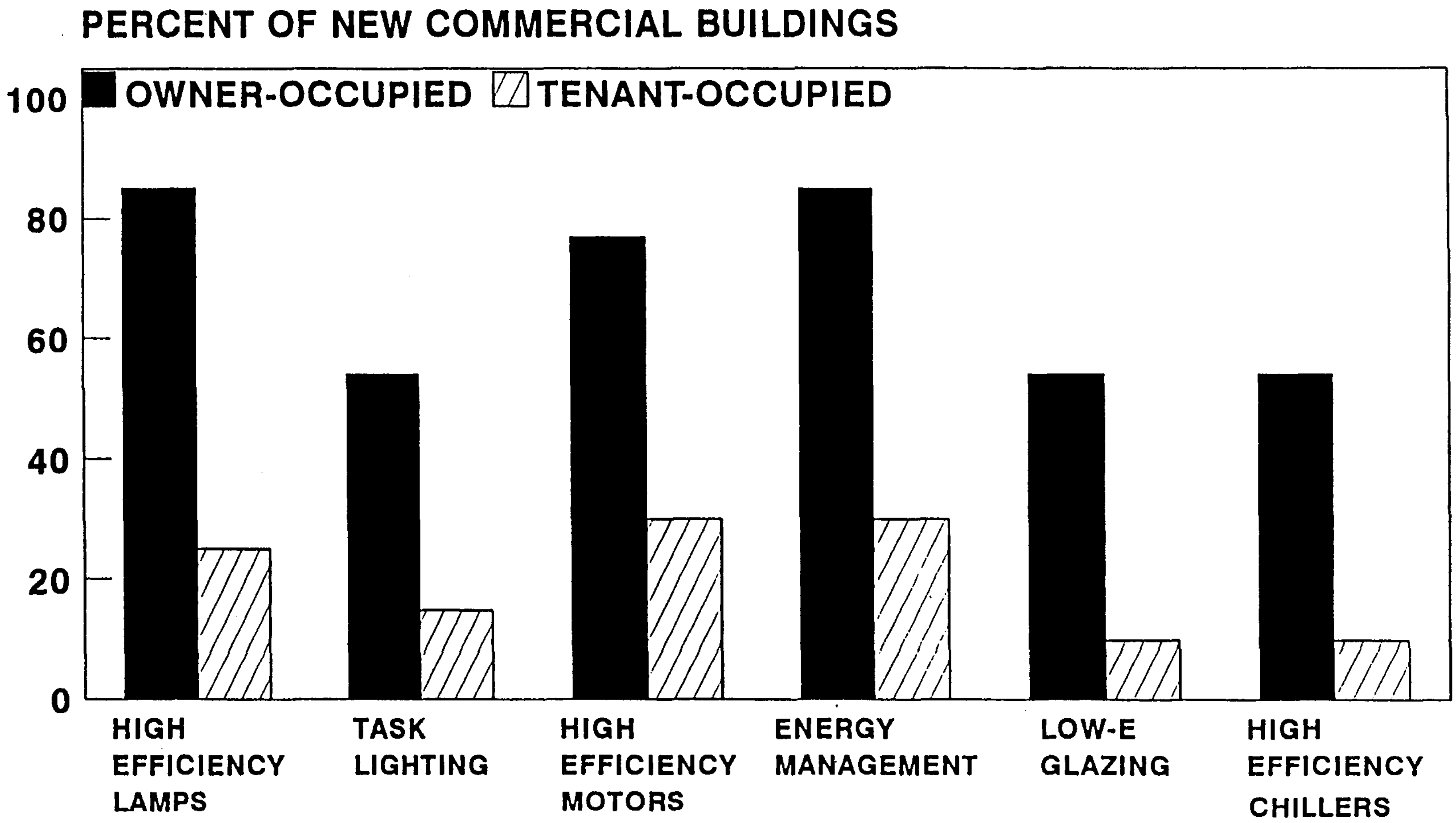

Fig. 2. Percentages of new commercial buildings in Washington, D.C. with various energy-efficiency measures, by building occupancy (Hines 1990).

4. Transaction costs

These problems related to information and decision-making can also be viewed in terms of transaction costs, including the costs of gathering and processing information, making decisions, and designing and enforcing contracts relating to the purchase and installation of energy-using technology. These are sometimes referred to as "hidden costs" associated with energy efficiency, with the implication that their inclusion in engineering calculations would close the "efficiency gap."

From a theoretical perspective, the suggestion that transaction costs have no implications for economic efficiency is incorrect (Sanstad and Howarth 1993). These costs associated with making energy choices are "real" costs that must be taken into account in policy and program analysis.

For policy purposes, however, the question is whether there are interventions that can overcome specific types of costs in a manner not available to consumers acting individually. From this perspective, different "hidden" costs have different implications. For example, the amount of time and effort required to find a refrigerator that has a cost-effective level of energy efficiency can be very high. The typical consumer will seek a refrigerator that has important features such as size, color, design, a respected brand, correct type of ice maker, etc. One of these features may be cost-effective levels of energy efficiency (or more likely "high" energy efficiency, as the consumer is not likely to have enough information or knowledge to perform even a simple payback calculation on energy efficiency). The time and inconvenience needed to obtain the energy efficient refrigerator – transaction costs – may be prohibitive.

In this case, appliance standards may remove all inefficient refrigerators from the market or even induce more efficient ones to appear. (We discuss appliance standards in section IV). Such standards are a policy intervention that (among other things) eliminates the transaction costs that prevent the purchase of energy-efficient appliances. In the case of appliance efficiency, we suspect that these transaction costs are the largest reason that high efficiency products were not purchased prior to appliance standards; to the extent that this is the case, the appliance standards reduce imperfections in the market.

5. Capital market imperfections

Electric and gas utilities are able to borrow money at a real cost of capital of about 6%. The market for energy efficiency, determined by the decisions of millions of individual investors, operates at much higher discount rates. Indeed, in most cases the decision on efficiency choice is made with a discount rate several times greater than the utility cost of capital. To the extent that energy efficiency substitutes well for new energy supplies, this disparity in the decision criteria for investment in efficiency and in new supply means that capital will be preferentially allocated to supply. The large differences between the cost of capital for utilities and the effective discount rate that is typically used in the purchase of energy efficiency results in a very large misallocation of capital.

One of the best examples of this problem is residential appliances. Prior to appliance standards, Ruderman, et al. determined that the market behaved as if the real discount rate for energy efficiency was 15 to more than 100% (Ruderman, et al. 1987). Except for air conditioners, the market discount rates were in the upper end of this range. This analysis implicitly considered factors beyond the control of the purchaser (e.g., unavailability of the efficient appliance, bundling of efficiency with other high-cost items, differential markups for high efficiency items, etc.). The calculation was performed for the typical efficiency of a new appliance in the late 1970's through the mid-1980's (prior to appliance standards).

Knowledge of the cost and benefits of efficiency measures not purchased provided a basis for estimating the discount rate (applied to the market as a whole) of the average efficiency choice for each of the millions of products sold. Thus, new power plants are built instead of investing in appliance efficiency because the centralized decision maker borrows at 6% real while the complex end-use market for appliances typically declines investments yielding returns that are five to ten times greater.

C. A Practical Illustration: The Design and Construction of Commercial Buildings

In a recent attempt to understand why buildings are not designed as efficiently as they could be, Lovins (1992) interviewed more than fifty design professionals and analysts of the design process and found a market rife with inefficiency and "perverse" incentives. These inefficiencies are driven mainly by the difficulty of creating optimized, custom-built buildings systems in the face of persistent institutional failures.

As an example of such an institutional failure, Lovins cites the prevailing fee structures of building design engineers, which are explicitly or implicitly based on a percentage of the capital cost of the project. The reason that fee structures like this one are pernicious is because good design for heating, ventilation, and air-conditioning (HVAC) systems can often allow substantial reductions in capital costs *and* operating costs. Such design requires additional expenditures beyond the typical "rule-of-thumb" equipment sizing that most engineers do, which results in a net penalty for designers of efficient systems.

HVAC systems are typically oversized by factors of two or three, which is a major source of unnecessary capital expenditures as well as less efficient delivery of energy services. Such oversizing is typically justified because of uncertainty about the plug loads of individual tenants who may not even be signed up to lease the space when the mechanical equipment is specified. The systemic benefits from optimizing mechanical systems cannot be captured by such a linear, piecemeal approach.

Cross-subsidies and incorrect price signals are commonplace in commercial buildings. Managers of master-metered buildings often charge their tenants based on floorspace, failing to reward more efficient tenants.

Lovins explores a variety of other institutional failings, including nonexistent or faulty operation, monitoring, post-occupancy evaluation, maintenance, and building commissioning. He explores every step in the design process, documents how this process fails, and suggests ways to fix it. This study is an important example of the kinds of empirical work that are crucial to understanding the extent of market failures affecting efficiency in buildings.

D. Observations

Our discussion shows that factors preventing the adoption of cost-effective energy efficiency measures can be framed in terms of the standard economic theory of market imperfections. Further research is needed to clarify the theoretical analysis of energy-related market imperfections, to guide empirical research on this set of issues, and to apply theory and empirics to the design of effective energy policies.

IV. POLICIES TO PROMOTE COST-EFFECTIVE ENERGY EFFICIENCY

Two major energy-saving policies have been pursued aggressively during the past decade. The first involves utility promotion of energy efficiency among their customers through demand-side management (DSM) programs. U.S. utilities are presently spending more than $2 billion annually on such programs. This represents more than 14% of total investment in new generation (including non-utility generators) (Energy Information Administration 1994). The second energy-saving policy is appliance efficiency standards. These standards result in a projected savings equivalent to the output of more than 20 1,000-MW power plants after 20 to 25 years.

A. The Role of Utilities in Promoting Energy Efficiency

During the past several years, U.S. electric utilities have played an increasingly important role in encouraging their customers to improve energy efficiency.[8] As shown in Fig. 3, utility expenditures on demand-side management (DSM) programs and their effects (energy savings and reductions in demand at the time of system peak) increased sharply between 1989 and 1991; utility plans show continued increases during the coming decade (Energy Information Administration 1993).

What factors led utilities to get involved on the "customer side of the meter," given their long tradition of focusing only on the provision of electricity (i.e., generation, transmission, distribution, and customer billing)? These factors included:

- Growing interest in integrated resource planning (IRP), which involves explicit consideration of DSM programs as cost-effective alternatives to some new power plants;

- Provision of financial incentives to utility shareholders for implementing cost-effective DSM programs;

- Increasing concern about the environmental effects of electricity production and transmission, especially global warming and acid rain; and

- Growing recognition of the powerful role that utilities can play in overcoming market imperfections that impede adoption of cost-effective energy-efficiency opportunities (Hirst 1991).

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8. Natural-gas utilities, after considerable activity during the 1970s, reduced their energy-efficiency programs sharply in the 1980s. During the past few years, however, gas utilities are once again beginning to promote customer energy efficiency. A controversial issue, not addressed here, concerns the role of gas or electric utilities in encouraging customers to switch from one fuel to another (e.g., from electricity to gas for residential water heating, or from gas to electricity for industrial drying).

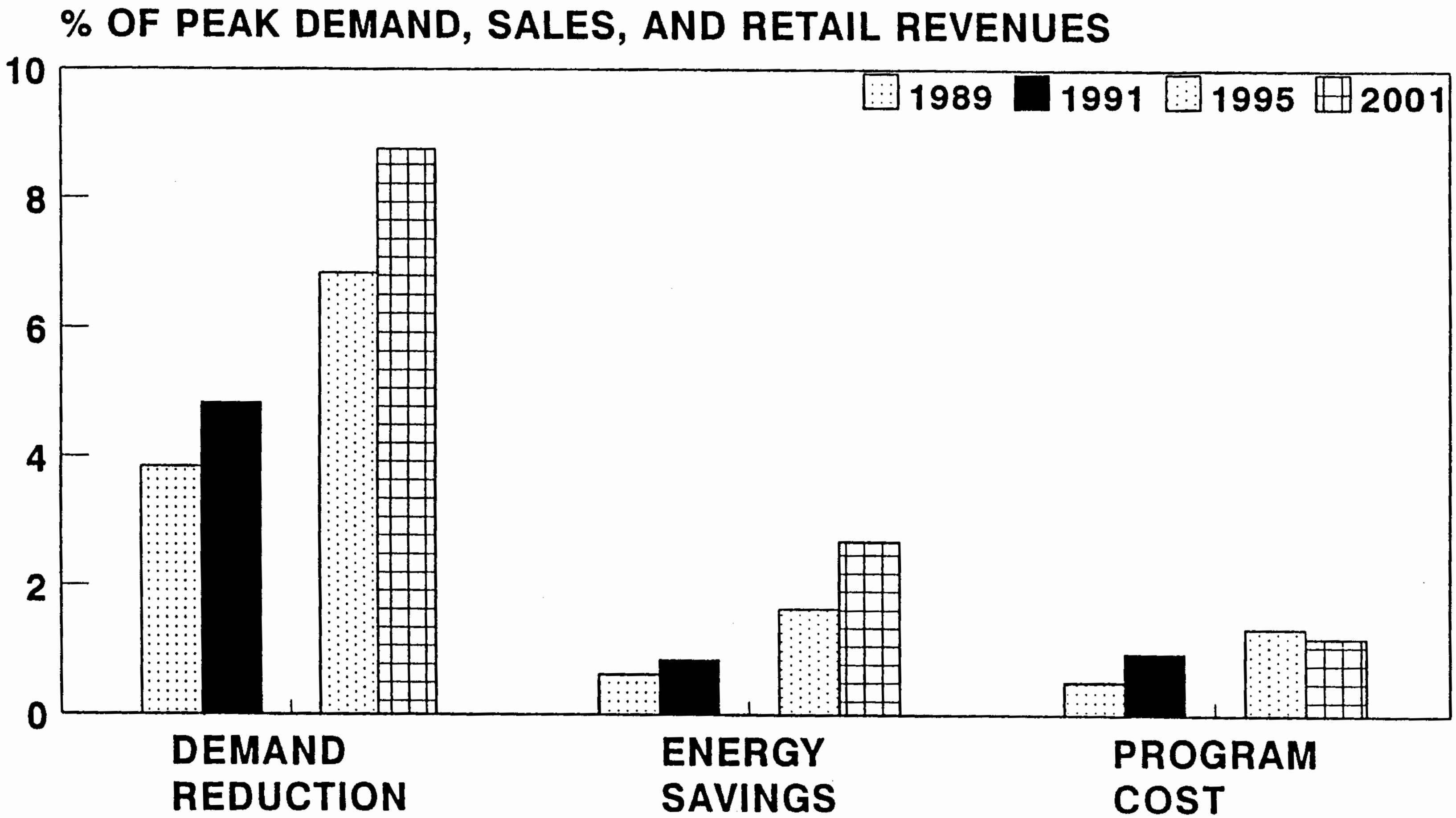

Fig. 3. The costs and effects of electric-utility DSM programs, 1989 through 1991 and plans to the year 2001

In essence, electric utilities and their regulators now recognize that utilities can be providers of energy *services* not just of kWh and kW *products*. For purposes of this paper, the key factor is the last one, the role of utilities in overcoming market imperfections.

As discussed earlier, customers face market failures which impede the adoption of what would otherwise be cost-effective energy efficiency actions. Utilities have important characteristics that position them to help customers overcome these failures. Utilities have monthly contact with all their customers through meter reading and billing. Utilities have long-standing and generally good relationships with their customers and with the communities they serve. Utilities are widely recognized for their technical competence. Utilities have large field organizations that can deliver DSM programs to customers. Utilities have ready access to capital, leading to a low cost of capital and steady cash flows, enabling them to offer loans and rebates for customer purchase of energy-efficient systems. And many utilities are increasingly knowledgeable about the energy service needs and wants of their customers, primarily because of their DSM programs. All these factors make it easier and more efficient for utilities than for other organizations to design and implement DSM programs.

Utilities can also help overcome infrastructure limitations. For example, various energy-efficient technologies (e.g., low-emissivity windows and other advanced glazings, and compact florescent lamps and other new lighting systems) are not available in many parts of the country. Utility programs that promote these devices can transform the market so that wholesalers and retailers will routinely stock, advertise, and sell these products. According to *Energy User News*, "[m]uch of the recent demand for compact fluorescent products has been fostered by utilities. Since April [1990], utilities in California, Washington, Oregon, Massachusetts and Connecticut have expanded investments in conservation programs, all of which help foster compact fluorescent technology" (Bryant 1990).

Utilities can provide credible, site-specific information to customers on the applicability, costs, and benefits of different DSM technologies. Residential and commercial energy audits, offered by many utilities, are an effective way to provide such information. Because research has demonstrated the importance of credibility and follow-up in successfully conveying energy information (Katzev and Johnson 1987; Winett and Neale 1979), utilities are especially well-placed to undertake these types of interventions. Utilities can also provide appropriate design and financial incentives for installation of DSM measures in new buildings. In many cases, no other institution appears to be as effective in providing such site-specific information, especially when it is combined with incentive programs that boost consumer adoption of the DSM technology.

Finally, expanding utility DSM programs is consistent with industry trends toward greater attention to customer service and satisfaction. DSM programs allow utilities to expand the range of services they provide to customers beyond selling a single-dimension product, electricity. As electricity markets become more competitive, utilities will increasingly use their DSM programs to enhance their customer services. For example, an industrial audit might uncover various measures that, upon installation, cut the customer's electric bill, boost productivity, and make that customer more competitive in its markets.

1. Performance of DSM programs

A key issue for DSM is its actual performance, i.e., the measured energy and demand reductions relative to program costs. Considerable evidence shows that, in general, the *a priori* engineering estimates of the amounts of energy to be saved by particular measures and programs are optimistic (Nadel and Keating 1991; Joskow and Marron 1993a and 1993b).

The more important issue is whether, given actual savings less than predicted, the programs are still cost-effective. Here the evidence is mixed. Some programs are clearly cost-effective, based on rigorous accounting of all program costs and measurement of electricity savings (Nadel 1992). Others are not. New England Electric System (1993), which has a history of successful program design, implementation, and evaluation, found that most of its programs were cost-effective for both 1991 and 1992 (Fig. 4). On the other hand, the Bonneville Power Administration Residential Weatherization Program was highly cost-effective in its early years, but by 1989 decreased levels of electricity savings caused the program's costs to exceed its benefits (Brown and White 1992)

In general, electric utilities (and their regulators) are becoming more conscientious about carefully measuring the energy savings and load reductions caused by DSM programs. These efforts are reflected in various conference proceedings, protocols for evaluating DSM programs, and the increased availability of data on the costs and savings of DSM measures and programs.[9]

9. See the conference proceedings from the Evaluation panel of the biennial Summer Study on Energy Efficiency in Buildings, sponsored by the American Council for an Energy-Efficient Economy and the proceedings from the biennial conferences on Energy Program Evaluation, sponsored by the National Energy Program Evaluation Conference. Evaluation protocols have been developed by the U.S. Environmental Protection Agency and the states of California and New Jersey. The Northeast Region Demand-Side Management Data Exchange, IRT Environment, Electric Power Research Institute, and Lawrence Berkeley Laboratory all collect, analyze, and publish information on the performance of utility DSM programs.

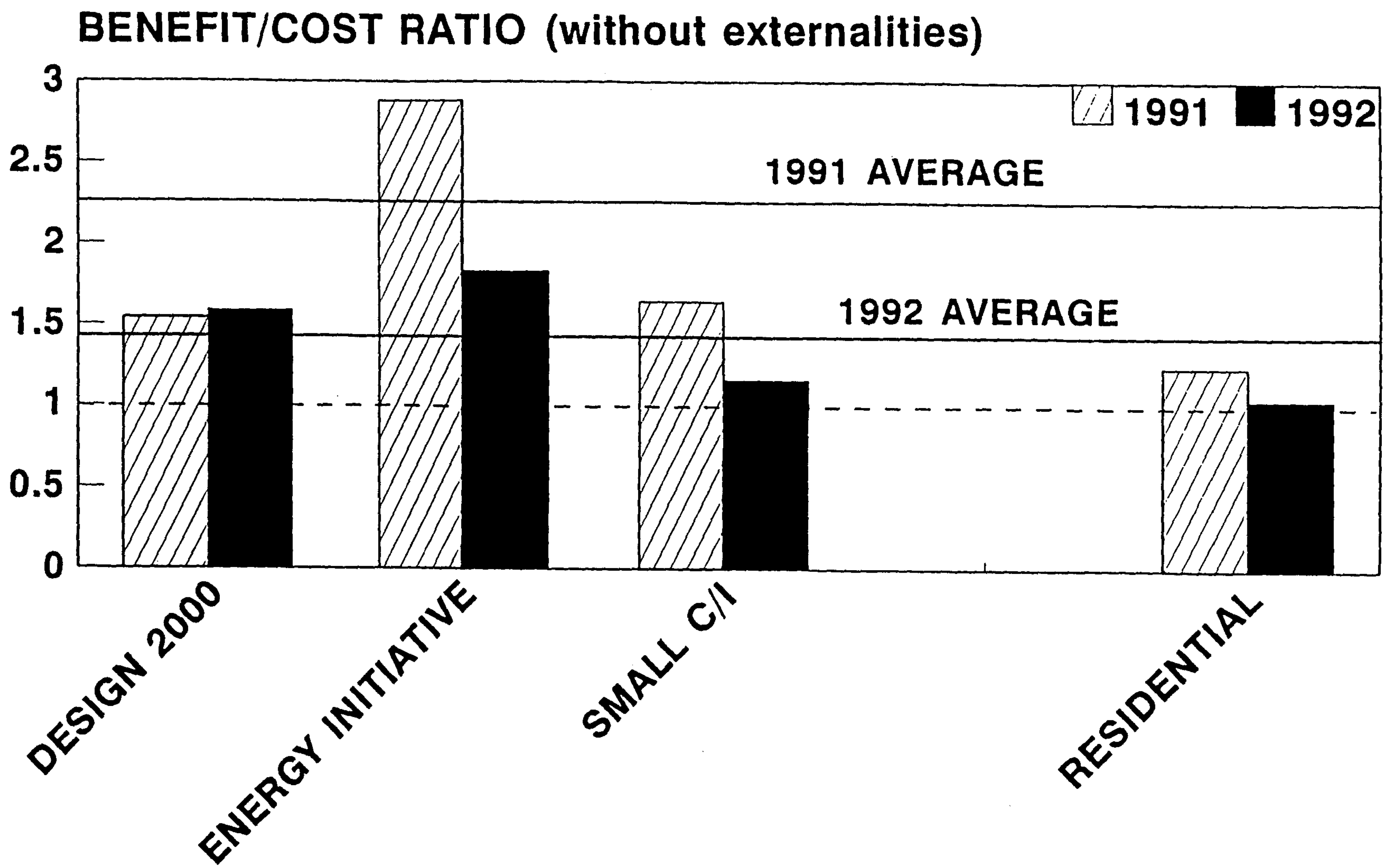

Fig. 4. NEES estimates of DSM-program benefit/cost ratios, based primarily on measured electricity consumption. Design 2000 is aimed at new commercial/industrial construction, while Energy Initiative focuses on retrofit. In 1992, NEES made Energy Initiative much more comprehensive; the reduced focus on lighting, which is very cost effective, lowered the program's overall cost effectiveness in 1992.

2. *Market transformation*

Utilities can increase the benefits and reduce the costs of their DSM programs by working closely with trade allies and by moving upstream from retail customers. These efforts are called market-transformation programs, because their intent is to change the operation of markets, not just to stimulate one-time changes in customer behavior.

Utilities are increasingly designing their DSM programs to work with government programs and standards, as well as manufacturer and other trade-ally efforts. For example, rather than encouraging individual customers to purchase high-efficiency appliances, utilities can work with manufacturers, wholesalers, and dealers to be sure that only efficient appliances are sold.

The Super Efficient Refrigerator Program (often called the Golden Carrot) is a example of market transformation. Roughly 25 utilities pooled a $30 million incentive, which was offered to refrigerator manufacturers to design and build units that do not use CFCs and that exceed the 1993 federal efficiency standard by at least 25%. Whirlpool was selected as the winner of this competition for development of a 22 cubic foot side-by-side refrigerator freezer than consumes 30% less than the 1993 standards. The company expects to start marketing these high-efficiency units in the service areas of the sponsoring utilities in 1994. The utilities will pay Whirlpool as the units are delivered in their areas (Demand-Side Report 1993).

The Model Conservation Standards provide another example of market transformation. The Bonneville Power Administration has run programs for several years intended to encourage builders to construct, households to purchase, and local governments to require energy-efficient new homes. These efforts to educate and motivate different stakeholders, coordinated with those of the Northwest Power Planning Council, several utilities, and other organizations, led to passage of tougher building codes in the Pacific Northwest states. These new codes require construction that meets the Model Conservation Standards and reduces the need for Bonneville participation in new-home construction markets.

Market transformation requires the utility to move upstream from its customers to retailers, wholesalers, distributors, manufacturers, as well as the organizations that install, service, and finance equipment and structures (Hammarlund 1993). Working with these "trade allies" within their existing infrastructures should yield larger energy savings, lower costs, and more permanent changes than programs aimed at individual customers. In addition, market transformation requires integration of utility efforts with those of government organizations, such as energy-efficiency standards and government programs.

To the extent that utility market transformation programs are successful, the role of utilities in promoting customer energy efficiency is temporary. That is, if utilities can work with trade allies to change "standard operating procedures," to adopt and implement stricter building and appliance energy-efficiency standards, and to make energy efficiency the norm rather than the exception, then the need for additional utility intervention is greatly diminished. For example, passage of tough building standards in Washington and Oregon means that the Bonneville Power Administration (as well as other utilities in the Pacific Northwest) can reduce the rebates it offers builders to construct energy-efficient homes and devote its resources to training code officials and builders on how best to administer and comply with the new codes.

3. *Future prospects*

Market research can help utilities to identify market failures and to understand better the energy-related attitudes, interests, and needs of different market segments among their customers. This information, in turn, can be used to design DSM programs that attract more customers and do so at lower cost. For instance, National Analysts (1990) developed computer models that help utilities identify appropriate market segments among their residential customers and assess the likely response of these segments to different types of DSM programs. Much of this research can be done inexpensively. Pacific Power & Light (now PacifiCorp) spent about $50,000 on a residential lighting pilot effort to identify likely participation rates and potential energy savings.

Because the utility industry is becoming more competitive, the focus of DSM programs will likely shift away from resource acquisition to improved customer service. Energy efficiency will continue to be a key driver for such programs as utilities seek to help their customers become more competitive. In such an atmosphere, utilities can continue to use their unique position to help customers overcome market failures and adopt cost-effective energy-saving technologies.

B. Appliance Efficiency Standards

1. *Background*

The State of California was the first to promulgate energy efficiency regulations for residential appliances, which limited the sale of refrigerators to those with energy consumption less than a specified maximum. The range of other appliances legally permitted to be sold was similarly restricted, based upon their energy efficiency or annual energy consumption. In 1986, after several states had adopted different energy efficiency regulations, manufacturers and environmental groups negotiated a set of national efficiency standards (California Energy Commission, 1983). These national appliance standards were encoded in the *National Appliance Energy Conservation Act of 1987.* Since then, the U.S. Department of Energy has updated those standards for refrigerators, freezers, and some other products, and continues to study updates for possible future rulemakings (McMahon et al. 1990)

Cumulative expenditures by the federal government for the appliance-efficiency program total about $50 million from 1979 to 1993 (Adams 1993). These expenses included development of test procedures for measuring efficiencies, technical analyses to provide an engineering and economic basis for the standard levels selected, administrative costs associated with public hearings, publication of laws and supporting technical documents, and management of the program.

2. *Benefits of appliance standards*

The benefits of the program have been determined by using end-use forecasting models, which account for the primary effect (increased efficiency of new appliances) and important secondary effects (more expensive appliances, fuel switching, and changes in operating practices). The results suggest a cumulative net benefit to the nation for appliances sold from 1990-2015 of $46 billion. This consists of a net present cost of $32 billion for higher priced appliances and a net present savings of $78 billion. These benefits as well as the cumulative energy savings of the standards to date (those already promulgated) are shown in Fig. 5. Figure 6, which shows the effects of standards that have been promulgated, shows substantial reductions in residential energy demand growth due to the standards. Proposed standards for eight products will cause significant additional declines in residential energy demand if adopted. The two lower curves in Fig. 6 show the impact of the standards proposed by the U.S. DOE in March 1994 for eight products. The lower curve is for implementation of the standards in 1996; the curve above it is for implementation in 1998.

Included in this accounting are the projected increased costs passed on to consumers, and the value of energy savings (calculated at average energy prices). The costs to manufacturers are accounted for and (mostly) passed on to consumers. However, the benefits accounted for do not include the value of decreased emissions of air pollutants and carbon dioxide. (The quantities saved represent 1.5 to 2% of total national emissions of SOx, NOx, and CO_2). The benefits also fail to assign a value to the deferral of new electricity generating plants beyond the average price of energy paid by the consumer (McMahon et al. 1990).

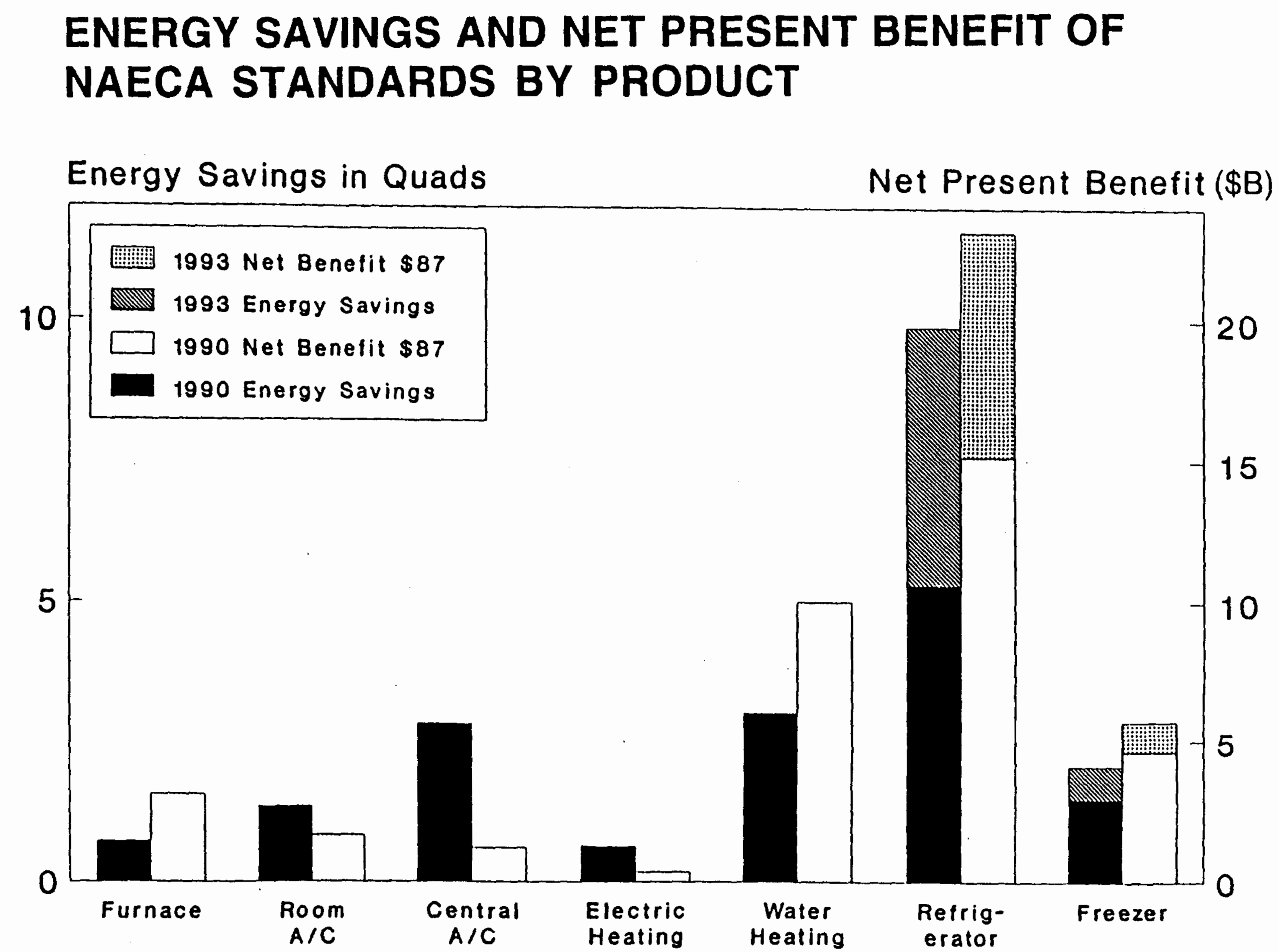

Fig. 5. Projected energy savings and net present benefits of appliance efficiency standards promulgated in 1990 and 1993.

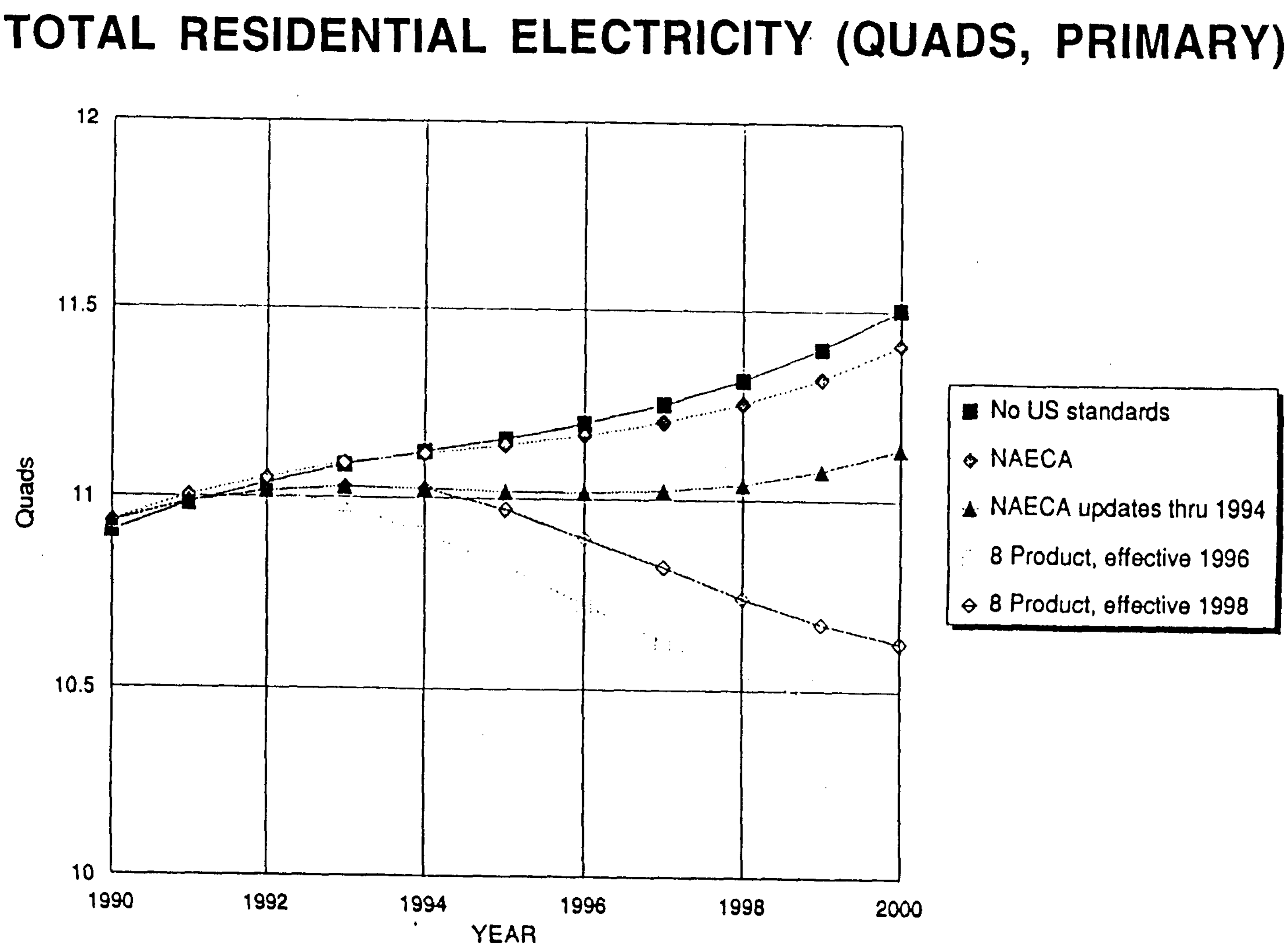

Fig. 6. Projected residential electricity demand in five cases: (1) no appliance standards, (2) standards set by the National Appliance Energy Conservation Act (NAECA), (3) NAECA with updates through 1994, (4) recently proposed eight product rulemaking, assuming implementation in 1996, and (5) recently proposed rulemaking with implementation in 1998.

3. Possible criticisms

It has been suggested that the consumer's choice in appliance models may be restricted as a result of the standards, thereby creating a hidden cost. Considering refrigerators as an example, however, there were more models available after the regulations became effective in 1990 than were available in 1986 (McMahon 1991). Moreover, real prices of refrigerators have declined from 1986 to 1991 (AHAM 1993a). The average refrigerator purchased after efficiency standards is larger than before and more likely to be a "side-by-side" than another type (AHAM 1993b). The engineering cost data, when manufacturer and dealer markups are added, suggest that the more efficient appliances required by the federal standards pay back their incremental investment in three years or less (US DOE 1989); using actual price data on refrigerators before and after the standards, it is difficult to detect any significant post-standard price increases.

Another potential criticism of the standards is that they may cause a sacrifice in some amenity that the consumer values. In fact, as noted above, such a criticism is largely ruled out by defining different standards for various classes of appliances which differ in the features offered. Thus for refrigerators, some of the different classes include freezing compartments that are top-mounted, side-mounted, and bottom-mounted. For purposes of rulemaking, each class of refrigerator, as well as each size, must meet a different standard. (In practice, an equation specifies the size-dependence of the standard level within each refrigerator class.)

We believe that the large cost-effective energy savings resulting from appliance standards — amounting to 0.1 quadrillion Btu (almost $1 billion) per year at present and growing to eight times this amount in 15 to 20 years — itself provides evidence of market failure related to energy efficiency. First, there is no evidence that these substantial energy-efficiency gains would have come about in the absence of standards. Second, while there has been no definitive research on what constitutes the imperfections in the market, we speculate that there are variety of factors, few of which actually relate to consumer interest in energy efficiency. In particular, we believe that consumers are interested in a variety of features, of which energy efficiency is not primary. As we noted earlier, the transaction costs of seeking out energy-efficient models that have all the other desired features are likely to be high. The manufacturers know that consumers value attributes other than energy efficiency, and undoubtedly also believe that consumers may not be able to evaluate the true energy cost savings of greater efficiency. In a competitive market, manufacturers are motivated to minimize costs. Thus, given a choice between proliferating models (an expensive proposition) and choosing one efficiency level for each set of features, manufacturers chose the latter. This does not mean that the consumer does not value or benefit from cost-effective levels of efficiency. It means that, until standards, most consumers were poorly informed about these benefits and could only avoid purchasing lower efficiency by investing considerable time and effort.

4. Alternative approaches

Considering the magnitude of the benefits of high appliance efficiency, the question is what alternative role the government could have played that would have been more economically efficient. Prior to standards, some suggested that information and labeling programs could achieve significant energy efficiency gains. Such programs were in place for many years before the NAECA standards went into effect, with only limited impact (McMahon 1991).

Could the $50 million spent by the government for efficiency standards have been spent in some other way to achieve equal or greater benefits? We are unable to propose a program with a $2 to 4 million annual budget (over 15 years) that could have effectively achieved the benefits of the appliance efficiency standards program. Each year the 100 million households in the U.S. spend about $67 billion for residential appliances (including heating and cooling equipment) to purchase about 55 million major appliances and 12 million heating and air conditioning systems. If the $2 to 4 million that the government spent on appliance standards were spent on consumer education, this would amount to about $0.02 to 0.04 per household per year. It is hard to believe that such expenditures would affect many purchase decisions and it is inconceivable that the impact would be in any way comparable to that of the standards.

5. Summary

We believe that appliance standards have had a large beneficial impact on residential energy expenditures. The standards yield a benefit to cost ratio of almost 2.5 (at a real discount rate of 7%) without counting the value of environmental externalities, will reduce power plant construction by more than 40 500-MW units over the next 20 years, have not reduced the choice of appliances or the service they provide, and have occasioned almost no objection from consumers. While some may argue on theoretical grounds that such a policy ought to have major flaws (or hidden costs), the evidence indicates otherwise. The positive experience with appliance standards itself is additional evidence for substantial imperfections in the market that have made possible such large savings.

V. SUMMARY AND CONCLUSIONS

We have presented a methodology for identifying technical evidence of market failures related to energy efficiency, and applied this framework to several examples of cost-effective energy-efficient technologies whose adoption in the market has been impeded. These efficient technologies offer consumer services identical (or, indeed, superior) to those provided by less efficient technologies and their adoption clearly yields economic benefits. Although we cannot say exactly why these technologies have not been adopted, these examples demonstrate the existence of market failures. We reviewed several market imperfections that may account for the energy efficiency gap.

We have also discussed utility demand-side management programs and appliance standards regulations, two major initiatives aimed at overcoming market failures to improve energy efficiency. We have argued that sizable economic benefits are accruing from these program, and that, without these interventions, these benefits would go uncaptured in the marketplace.

We can now summarize our answers to the questions raised in the Introduction:

- **Aren't technologists ignoring certain "hidden costs" in their calculations that, if included, would show that many energy efficiency investments are in fact *not* cost-effective?**

We have provided four examples in which there are either no hidden costs or these costs are minimized and thus cannot be used *a priori* to explain why consumers still failed to purchase the cost-effective, more efficient product.

- **Aren't these hidden costs "irreducible," that is, not subject to reduction or elimination by policies?**

When hidden costs do appear in other cases, they are to a large extent subject to reduction or elimination by policies. Government and utility programs can substantially reduce these costs by taking actions once on behalf of thousands or millions of customers. For example, federal appliance efficiency standards involve a great deal of technical analysis. However, this analysis is done only once, and is used to eliminate all appliances that do not meet economically-based energy-efficiency criteria. Similarly, utility DSM programs that provide financial incentives to purchase and install energy-efficient devices reduce the capital market dichotomy of the high cost of money that consumers face and the much lower cost of money that utilities enjoy.

- In any case, aren't these hidden costs "normal" to many markets, not just markets for energy efficiency? If not, what distinguishes energy markets?

Like all markets, markets related to energy have some unique characteristics. Energy consumption has very significant societal implications, including very large environmental impacts and potential significant effects on national security. Additionally, because the nation's consumers and industry are both vitally dependent on its availability and affordability – and because a sizable portion of GNP is spent on energy – the proper functioning of energy markets is widely recognized as critical to economic well-being. However, we make no general claim that markets related to energy efficiency are intrinsically "special," nor is such a claim required for the case we are making. If evidence of market imperfection is present, as we believe it is in this case, then in principle intervention is warranted, in energy as well as other markets.

• Even if these costs can be reduced, why can't these opportunities be exploited by private firms? That is, why do government and utilities need to intervene?

A defining characteristic of market imperfections is that they *cannot* be overcome by consumers or firms acting independently; this is equally true of markets related to energy as well as other markets. We fully recognize the problem of "government failure" and the fact that not all problems can be overcome through public or utility policies. As we have shown, however, there is ample reason to conclude that policies to reduce market imperfections related to energy efficiency can be and have been successful.

Additional behavioral research is needed. In particular, utilities, EPRI, and DOE should sponsor projects to pinpoint and quantify the various market failures related to energy efficiency. These projects need to examine failures at a disaggregate level — by market segment (e.g., multifamily tenants vs. owner-occupied medium-size office buildings), by end use, by technology, and by type of decision (purchase or operation). These projects will quantify the importance of different failures in different circumstances.

Utilities and government can then use the results of these projects to analyze program and policy options to address the most important failures. If, for example, lack of capital is the problem, then rebates may be the solution. If, on the other hand, uncertainty about the likely energy savings of a new technology is the barrier, then a performance guarantee may be the solution. In other words, programs need to be designed to address specific, documented failures.

Such empirical research could provide two benefits. The primary benefit will be better programs that provide more savings at lower cost. A secondary benefit will be the resolution of controversies over the role of governments and utilities in promoting energy efficiency.

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