SAVING MONEY AND REDUCING THE RISK OF CLIMATE CHANGE THROUGH GREATER ENERGY EFFICIENCY

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Abstract

Improving the efficiency of specific energy-using devices such as automobiles or appliances can save consumers and the country money while reducing emissions of carbon dioxide and other pollutants. In the case of automobiles, the efficiency improvements that occurred during 1975-89 saved consumers over $20 billion and cut U.S. energy consumption by nearly 5 Quads (6%) in 1989. The net cost of avoided carbon emissions was approximately negative $200 per metric ton. Improvements in the efficiency of refrigerators during the past 15 years were even more cost effective, with a social-cost benefit ratio of about 8 and net cost of avoided carbon emissions of approximately negative $300 per metric ton. For both end uses, a further doubling in efficiency is both technically feasible and cost effective.

Policies and programs aimed at increasing energy efficiency also can save money and reduce carbon dioxide emissions. Appliance efficiency standards and utility conservation programs are two examples of what can be done to capture the benefits of greater energy efficiency. Conservation and load management programs operated by the New England Electric System are expected to save consumers $88 million per year and lower carbon emissions over 5% by 1999. A broad set of new energy efficiency initiatives could further reduce energy service costs and carbon emissions in the U.S. The initiatives include new financial incentives, minimum efficiency standards, R&D ventures, and information programs. Adopting the initiatives could cut U.S. energy demand in 2000 by 15-20% from levels otherwise projected, provide consumers with a net savings of $75 billion per year, and reduce carbon emissions in 2000 to 90% of the level in 1988. The policies are needed to overcome barriers inhibiting widespread efficiency improvements.

Acknowledgement

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Introduction

Some recent studies profess to show that there are economic penalties associated with achieving a substantial reduction in carbon dioxide emissions in the United States or in the world (1, 2). These studies utilize macroeconomic models and apply carbon or energy taxes as the means for reducing carbon dioxide emissions. Higher energy taxes and prices, without compensating reductions in other taxes, lead to loss of income, less economic activity, and a lower GNP.

The macroeconomic studies are flawed on a number of counts. As pointed out by Williams (3), they fail to adequately account for ongoing reductions in the energy intensity of industrialized countries. Falling energy intensities, which have been occurring for decades, are related to structural changes (e.g., less dependence on energy-intensive materials) and technological innovations. Both of these factors are likely to continue to have a large impact on energy use in the United States and elsewhere (4). Technological innovations in another area, renewable energy technologies, could greatly reduce dependence on carbon-based fossil fuels. This is important since the economic studies extend 20-110 years in the future, a time period when a variety of renewable energy technologies are expected to become cost-competitive and widely implemented (5).

Another serious flaw in the economic models is their simplistic treatment of economic costs and benefits. The models ignore the complex environmental impacts associated with climate change, for example. Global warming is expected to intensify hazards such as tropical pests, hurricanes, and urban air pollution (6). Regional variations in impacts also could lead to major economic and human dislocations. Ignoring these difficult to quantify but important effects limits the value of the economic projections.

Of greatest relevence to this chapter, the economic models fail to account for the full impact of end-use energy efficiency measures such as more efficient automobiles, buildings, appliances, or industrial processes. End-use efficiency improvements usually provide energy savings of greater present value than the initial cost for the conservation measures; i.e., saving energy usually costs less than supplying energy. Consequently, there is a net economic savings for consumers and the economy while energy use and corresponding pollutant emissions decline. When energy is obtained from fossil fuels, there is a reduction in carbon dioxide emissions at a negative economic cost to society. End-use efficiency improvements can be stimulated through market mechanisms such as revenue-neutral fees and rebates, efficiency regulations, or other means.

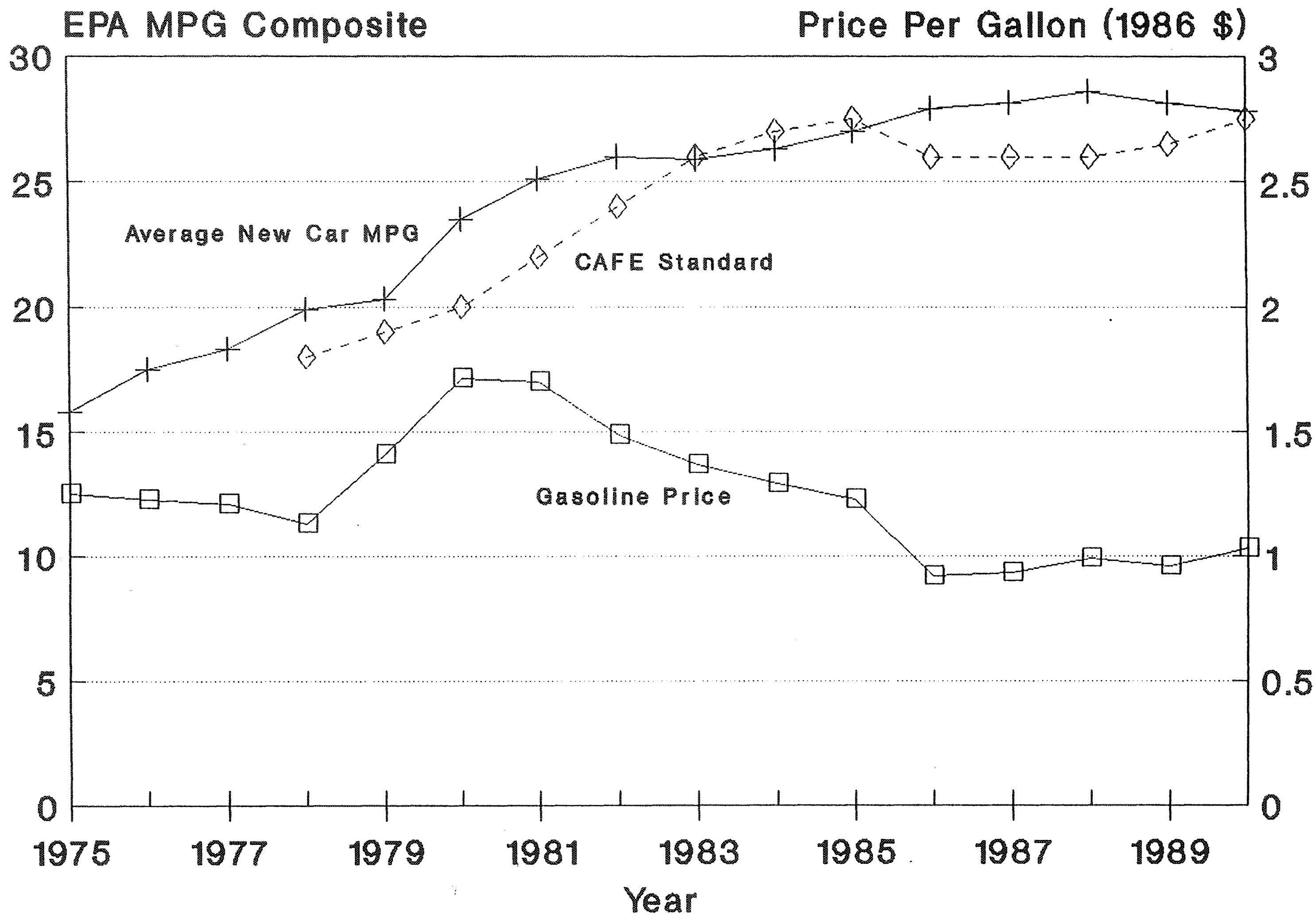
Technologies for Improving Energy Efficiency

Two examples of the technological possibilities for cost-effective end-use efficiency improvements are presented in this section. Both past accomplishments and near-term opportunities for improving the efficiency of automobiles and refrigerators are addressed. In addition, a few comprehensive studies of energy conservation potential are summarized.

Automobiles

The average fuel economy of new cars sold in the U.S. increased from 15.8 miles-per-gallon (MPG) in 1975 to 28.6 MPG in 1988 based on the Environmental Protection Agency's (EPA) combined city-highway test procedure (Figure 1).

Figure 1 -- Trends in Automobile Fuel Economy and Gasoline Price



(1990 data are estimates)

Efficiency gains resulted from a wide range of technical modifications including engine improvements, the shift to front-wheel drive, better aerodynamics, and use of lighter materials (7). Starting in 1978, efficiency gains were achieved without significant reductions in average car size (as measured by interior volume) or performance (as measured by acceleration).

Fuel economy rose during the early 1980s in spite of a steady declines in gasoline price. Corrected for inflation, the average price of gasoline in 1988 was at the lowest level in 40 years (8). The Corporate Average Fuel Economy (CAFE) standards established by the U.S. Congress and Ford Administration in 1975 were the main impetus for fuel economy improvements during 1975-88 (9). The fuel economy of cars produced by U.S. manufacturers stayed especially close to the CAFE standards during the 1980s.

It is possible to calculate the energy, economic, and carbon savings associated with previous automobile efficiency improvements (Table 1). Automobile efficiency experts estimate a cost in the range of $200-400 per car at the retail level for the cumulative fuel economy improvements made between 1978 and 1985 when domestic cars increased from 18.7 to 25.8 MPG on average (10). Also, U.S. auto manufacturers have estimated the average cost for fuel economy improvements during this period by size class. Averaging across companies and size classes, the manufacturers estimate an average cost premium of $397 (10). Based on a car being driven 10,400 miles per year on average (11) and a 15% penalty between the EPA composite rating and on-road efficiency (12), fuel economy improvements between 1978 and 1985 on average saved 180 gallons of gasoline per year.

With estimates of the extra first cost and annual energy savings for the efficiency improvements during 1978-85, it is possible to calculate a "cost of saved energy" (CSE) using the following formula:

$$CSE = (FC \times CRF + AOC)/AES$$

where FC is the extra first cost for the conservation measures, CRF is the capital recovery factor, AOC is any additional non-energy operating cost due to the conservation measures on a yearly basis, and AES is the annual energy savings. The capital recovery factor is given by:

$$CRF = ((1 + D)^L \times D)/((1 + D)^L - 1)$$

where D is the real discount rate and L is the lifetime of the conservation measures. In effect, CSE is the average cost for saving a unit of energy over the lifetime of the efficiency measures.

In this example, assuming a cost premium of $400, no additional non-energy operating cost because of the conservation measures, a real discount rate of 6% (approximately the interest rate or opportunity cost for consumers), and a ten year lifetime, the cost of saved energy equals $0.30/gal. For comparison, gasoline typically cost consumers in the U.S. $0.86/gal as of 1989 excluding taxes (11). Using this gasoline price, the efficiency improvements show a benefit-cost ratio of 2.9.

Regarding aggregate energy savings, the average on-road fuel economy for the entire passenger car fleet in 1989 was approximately 20.5 MPG (11). For comparison, the fleet-average fuel economy in 1975 was 13.5 MPG. If the entire passenger car fleet in 1989 (143 million vehicles) had only achieved 13.5 MPG, total gasoline

Table 1

ENERGY, ECONOMIC, AND CARBON SAVINGS ASSOCIATED WITH PREVIOUS AUTO EFFICIENCY IMPROVEMENTS

INITIAL COST FOR INCREASING FUEL ECONOMY FROM 18.7 TO 25.8 MPG:

Duleep - $200-400
U.S. auto companies - $397 on average

AVERAGE GASOLINE SAVINGS FROM INCREASING FUEL ECONOMY FROM 18.7 TO 25.8 MPG:

180 gallons per year

OTHER ASSUMPTIONS:

Discount Rate - 6% real
Lifetime - 10 years

COST OF SAVED ENERGY (based on $400 cost premium):

$0.30/gal = $2.40/MBtu

1989 AVERAGE GASOLINE PRICE (excluding taxes):

$0.86/gal

SOCIETAL BENEFIT-COST RATIO:

$0.86/$0.30 = 2.9

TOTAL GASOLINE SAVINGS IN 1989 FROM AUTO EFFICIENCY IMPROVEMENTS DURING 1975-89:

37.6 billion gallons = 2.45 MBD = 4.7 Quads

NET ECONOMIC SAVINGS IN 1989 DUE TO EFFICIENCY IMPROVEMENTS DURING 1975-89:

$32.3 billion - $11.3 billion = $21.0 billion

AVOIDED CARBON EMISSIONS IN 1989 FROM AUTO EFFICIENCY IMPROVEMENTS DURING 1975-89:

102 million metric tons

NET COST OF AVOIDED CARBON EMISSIONS:

- $206 per ton

consumption would have increased by 37.6 gallons assuming no change in miles driven. This savings is equivalent to 2.45 million barrels of oil per day (MBD), more oil than the U.S. imported from Arab OPEC nations in 1989. The aggregate energy savings, 4.7 Quads, also equalled 21% of transportation sector energy use and 6% of total U.S. energy use in 1989. Moreover, the energy savings will grow as older, less efficient cars are removed from the vehicle fleet.

If all gasoline savings in 1989 resulted from efficiency improvements with a cost of conserved energy of $0.30/gal, then the total annualized cost for efficiency improvements in the 1989 car fleet was $11.3 billion. Since the value of the gasoline savings was $32.3 billion (excluding taxes), consumers realized a net economic savings of $21 billion in 1989. This estimate is conservative in that it assumes no change in energy price as a function of gasoline use. In fact if U.S. gasoline use was 2.45 MBD higher than the actual value in 1989, there would have been upward pressure on world oil markets and higher oil and gasoline prices.

Regarding carbon dioxide emissions, the direct reduction in emissions associated with reducing gasoline use by 2.45 MBD in 1989 was about 102 million metric tons (expressed in terms of carbon). This is equivalent to about 7% of actual carbon emissions from fossil fuel combustion in the U.S. that year. Based on a net economic savings of $21 billion, the net "cost" for avoiding this amount of carbon emissions was about negative $206 per metric ton.

Manufacturers have by no means exhausted all cost-effective options for improving automobile efficiency. There are number of proven technologies such as front-wheel drive, use of four valves per engine cylinder, and better aerodynamics which have been used in some but certainly not all vehicle models. There are other efficiency measures such as new intake valve control systems and continuously variable transmissions which are just starting to be implemented. Table 2 lists a host of technologies that are available for increasing the efficiency of new cars during the 1990s. All of these measures increase efficiency without reducing vehicle performance or comfort.

Ledbetter and Ross analyzed the savings potential and cost effectiveness of these efficiency measures (13). The results are presented in terms of a "conservation supply curve", where individual measures are displayed according to their cost of saved energy and potential efficiency improvement (Figure 2). Each horizontal line in Figure 2 is a separate conservation measure. The efficiency improvements account for the fraction of new vehicles still eligible for each measure. Widespread adoption of cost-effective measures, i.e., measures with a cost of saved energy that is less than the projected gasoline price, could increase the average rated fuel economy of the new car fleet in 2000 to about 44 MPG. Compared to a scenario with no efficiency improvements, total energy use would drop 2.1 Quads (1.1 MBD) by 2000 and 4.9 Quads (2.6 MBD) by 2010. The average cost of saved energy for all the cost-effective efficiency measures is only about $0.55 per gallon. Since the average cost of saved energy is still much less than the projected cost of fuel, carbon dioxide emissions continue to be reduced at a negative net cost.

Even greater efficiency improvements are possible with more advanced technologies such as direct-injection diesel engines, two-stroke engines, engine shut-off during deceleration, and aluminum engines or bodies. Prototype vehicles with these features have EPA combined fuel economy ratings of 65-100 MPG (14). Although these prototype vehicles are yet not suitable for mass production, they demonstrate that much higher efficiencies can be achieved. As Ross has stated (15), "The cost

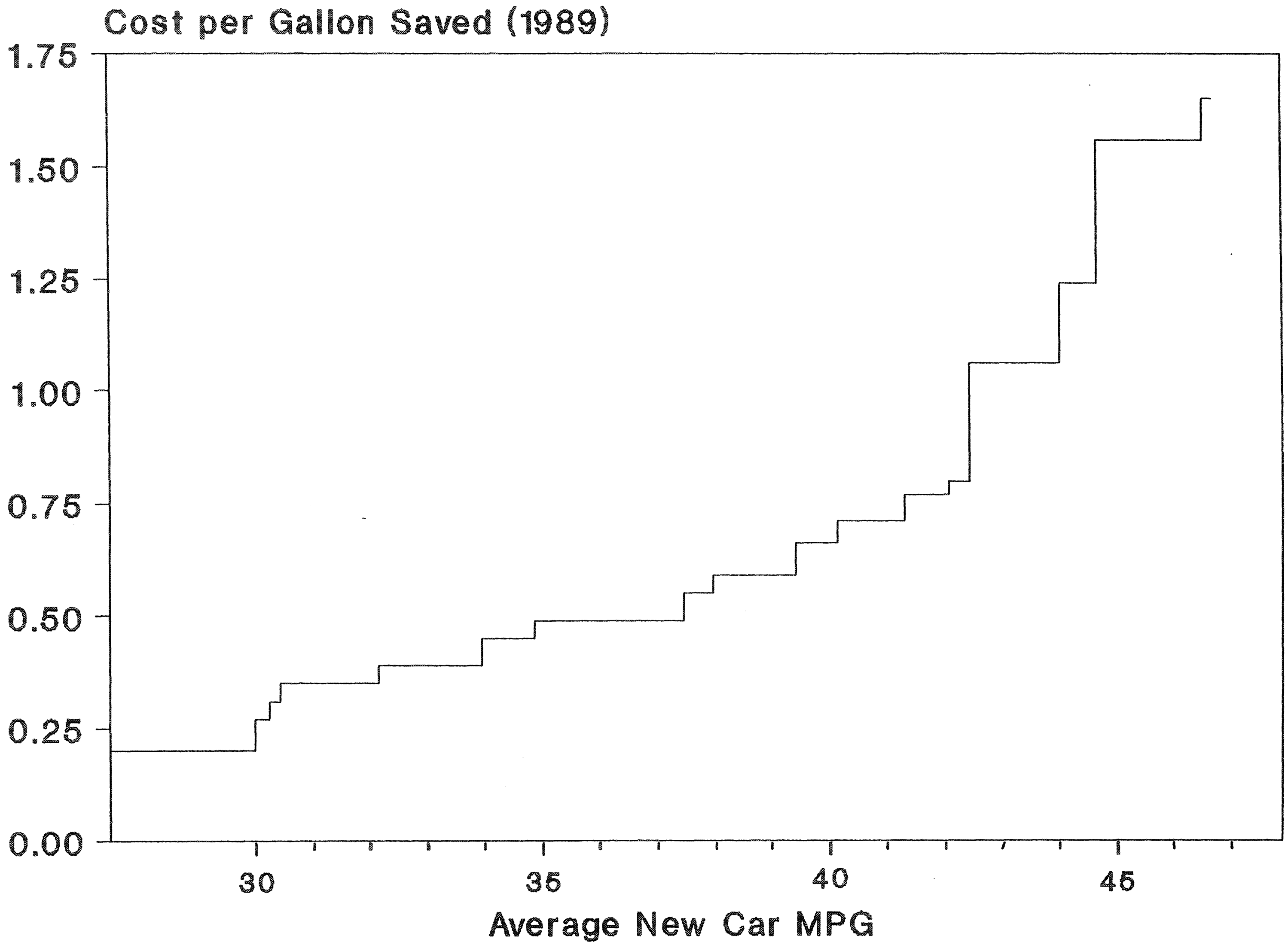
Table 2

SELECTED AUTOMOBILE FUEL ECONOMY TECHNOLOGIES

Technology	Potential Fuel Economy Improvement (%)
Roller cam followers	1.5
Overhead cam engines	6.0
Intake valve control	6.0
Front wheel drive	10.0
Four valves per cylinder	6.8
Improved aerodynamics	4.6
Improved engine accessories	1.7
Torque-converter lock-up	3.0
Four-speed auto. transmission	4.5
Five-speed auto. transmission	2.5
Electronic transmission controls	1.5
Multi-point fuel injection	3.0
Advanced friction reduction	2.0
Continuously variable transmission	2.5
Improved lubricants and tires	1.0
Aggressive transmission management	8.0
Engine idle off	9.0

Source: Ledbetter and Ross, 1990 (Ref. 13).

Figure 2 -- Conservation Supply Curve
Auto Fuel Efficiency, Year 2000



performance that cars like these would have if designed for the market and mass produced remain to be determined. There is, however, every expectation that cars with very high fuel economy and good space and performance characteristics can be built, perhaps without a substantial cost penalty beyond the manufacturer's initial tooling investment."

Refrigerators

Total energy use per household fell approximately 24% during 1973-87 (16), indicating significant conservation of fuels and electricity in the residential sector. Refrigerators, which account for about 15% of electricity use in housing, provide a good example of the technological changes and energy efficiency improvements in this sector. The typical new refrigerator sold in 1989 consumed about 930 kWh/year according to the official test procedure, 46% less than that for the typical new refrigerator sold in 1972 (Figure 3). In addition, today's mix of new refrigerators are larger and have more features such as greater use of automatic defrost. In terms of "energy factor" (a measure of efficiency based on adjusted volume per unit of electricity use), refrigerators sold in 1989 were over twice as efficient as those sold in 1972 (17).

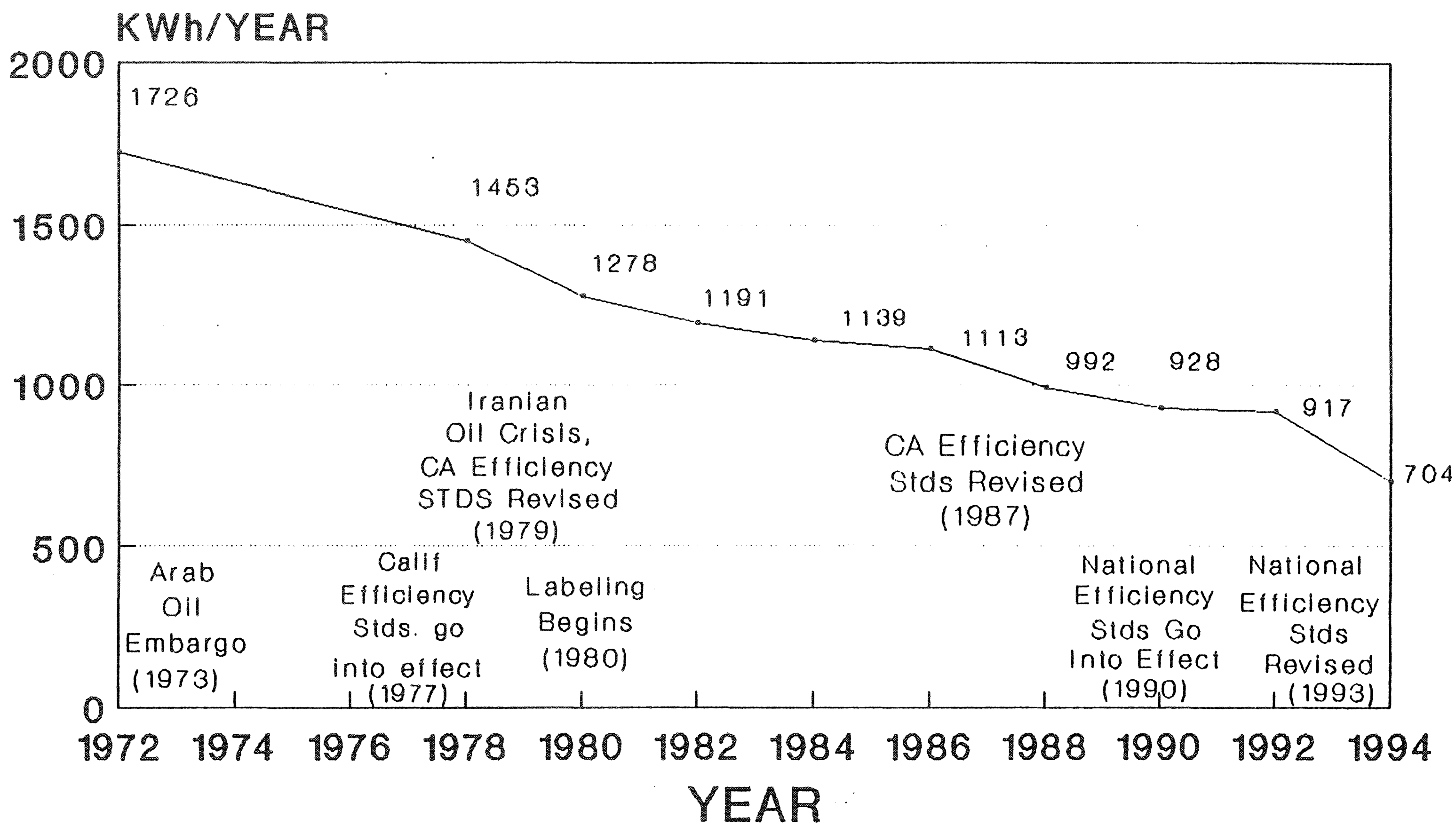
In order to improve energy performance, refrigerator manufacturers switched from fiberglass to polyurethane foam insulation, increased the efficiency of motors and compressors, used larger heat exchangers, reduced internal heat sources, and made other changes (18). The doubling in efficiency occurred without major innovations or radical product redesign. Efficiency gains in refrigerators and other appliances were stimulated by market forces as well as minimum efficiency standards. Standards were first adopted in California in the mid-1970s. After California strengthened its standards and other states passed similar legislation, consensus national appliance efficiency standards were adopted in 1987 (19). The national standards for refrigerators went into effect in 1990. As was the case for automobiles, the standards caused efficiencies to rise in spite of real energy prices falling in recent years.

Improving the efficiency of refrigerators is very cost effective (Table 3). Assessments by contractors for the Department of Energy (DOE) as well as independent analysts indicate that a one-third reduction in electricity use from commonplace efficiency measures costs about $40 at the retail level (20, 21). Using a 6% real discount rate, the cost of saved energy is only $0.009/kWh. Based on the 1989 average residential electricity price of $0.076/kWh (11), efficiency improvements adopted in recent years show a societal benefit-cost ratio of 8.4. With these values, consumers realized a net economic savings of about $3.2 billion in 1989.

Around 48 billion kWhs were saved in 1989 due to efficiency improvements in new refrigerators during 1972-89. This equivalent to nearly 6% of total residential electricity use or the power supplied by about eleven very large (1000 MW) power plants. Splitting up avoided power generation in proportion to the total utility fuel and generation mix, refrigerator efficiency improvements led to approximately 10 million metric tons of avoided carbon emissions in 1989. Given the extreme cost effectiveness of these improvements, carbon emissions were reduced at a net cost of negative $308 per ton.

The electricity consumption of new refrigerators will continue to decline through greater implementation of available technologies, development of new technologies, and tightening of efficiency standards. Regarding new standards, DOE issued "second-tier" efficiency requirements for new refrigerators and freezers in 1989 (22). The new

Figure 3
Average Electricity Use of New Refrigerators Sold in the US



Source: Association of Home Appliance Manufacturer Historic Data, DOE Projections

Table 3

ENERGY, ECONOMIC, AND CARBON SAVINGS ASSOCIATED WITH REFRIGERATOR EFFICIENCY IMPROVEMENTS

INITIAL COST FOR REDUCING ELECTRICITY USE (1989 $):

DOE - $31 for 431 kWh/yr reduction
ACEEE - $54 for 414 kWh/yr reduction

AVERAGE ELECTRICITY SAVINGS BETWEEN NEW MODELS PRODUCED IN 1972 AND 1989:

Typical 1972 model - 1726 kWh/yr; 3.84 Energy factor
Typical 1989 model - 934 kWh/yr; 7.78 Energy factor
Savings - 792 kWh/yr

OTHER ASSUMPTIONS:

Discount Rate - 6% real
Lifetime - 19 years

COST OF SAVED ENERGY (based on $0.101/kWh/yr cost premium):

$0.009/kWh = $0.78/MBtu

1989 AVERAGE RESIDENTIAL ELECTRICITY PRICE:

$0.076/kWh

SOCIETAL BENEFIT-COST RATIO:

$0.076/$0.009 = 8.4

TOTAL ELECTRICITY SAVINGS IN 1989 FROM REFRIGERATOR EFFICIENCY IMPROVEMENTS DURING 1972-89:

48.3 billion kWhs = 0.56 Quads

NET ECONOMIC SAVINGS IN 1989 DUE TO EFFICIENCY IMPROVEMENTS DURING 1972-89:

$3.67 billion - $0.44 billion = $3.23 billion

AVOIDED CARBON EMISSIONS IN 1989 FROM REFRIGERATOR EFFICIENCY IMPROVEMENTS DURING 1972-89:

10.4 million metric tons

NET COST OF AVOIDED CARBON EMISSIONS:

- $308 per ton

standards, which take effect in 1993, will ensure a further reduction in average electricity use of around 25% (see Figure 3). In addition, DOE is required to evaluate the technical and economic feasibility of tougher standards in the future.

The 1993 standards do not represent the upper limit on refrigerator efficiency. New insulating materials are under development that, unlike polyurethane foam, do not contain chlorofluorocarbons (CFCs). In particular, various vacuum insulation concepts provide greater resistance to heat flow without use of CFCs (23). Researchers at the Natural Resources Defense Council have estimated the energy savings and cost effectiveness of one type of vacuum insulation material along with other advanced efficiency measures (Table 4). Their analysis starts at the level of efficiency and electricity use mandated by the 1993 standards. Use of the aerogel vacuum insulation material and other measures could lower total electricity use for a typical two-door refrigerator-freezer to around 200 kWh/yr. It is estimated that electricity use of around 260 kWh/yr could be achieved up to a marginal cost of saved energy of $0.075/kWh (24).

Other Technologies

Analysis of a wide range of energy-efficiency measures yields the same results as those portrayed above -- saving energy costs less than supplying energy and carbon dioxide emissions are reduced at a negative net cost. A study of the electricity conservation potential in New York State found that it is technically and economically feasible to reduce total electricity demand by 35% (25). The conservation measures that can yield the largest savings include heating, ventilation, and air conditioning system retrofits in the commercial sector, more efficient refrigerators and freezers, reflectors for fluorescent light fixtures, compact and other high-efficiency fluorescent lamps, and variable speed motor drives (Table 5). The average cost of saved energy for all conservation measures considered in this study is $0.025/kWh. For comparison, the statewide average electricity price is about $0.090/kWh.

Researchers from Lawrence Berkeley Laboratory have shown that efficiency improvements in all major end uses in buildings can cut carbon emissions at a negative net cost (26). The electricity savings potential and conservation measure costs in this analysis were derived primarily from a study sponsored by the Electric Power Research Institute (27). The analysis indicates that electricity use in U.S. buildings and corresponding carbon dioxide emissions can be cut by 45% (Table 6). All twelve major conservation measures are cost effective and reduce carbon emissions at a negative net cost based on a cost-effectiveness threshold of $0.075/kWh, the average cost of electricity in buildings.

Energy efficiency improvements in the industrial sector tend to be very economical as well. One study of conservation opportunities in 15 major manufacturing companies found that the cost of saved energy was typically in the range of $1-2/MBtu (28). The conservation measures included boiler improvements, heat recovery equipment, control systems, cogeneration projects, recovery of waste gases, and process modifications. For comparison, industrial consumers typically pay about $3/MBtu for natural gas and $4.70/MBtu for petroleum products (11).

Barriers Inhibiting Implementation

If energy-efficiency measures are so cost effective, it is reasonable to ask why they are not more widely implemented and why policies and programs are needed to

Table 4

REFRIGERATOR CONSERVATION SUPPLY CURVE (1)

Efficiency Measure	Elect. Use (kWh/yr)	Elect. Savings (kWh/yr)	Cost of Saved Energy Marginal (c/kWh)	Cost of Saved Energy Average (c/kWh)
Baseline	677	--	--	--
Condensor anti-sweat heater	572	195	1.3	1.3
Adaptive defrost	487	85	3.0	2.0
EER=5.3 compressor	466	21	6.4	2.5
0.75" aerogel insulation	374	92	6.8	3.8
1.00" aerogel insulation	320	54	3.5	3.8
1.25" aerogel insulation	285	35	5.4	3.9
1.50" aerogel insulation	260	25	7.5	4.1
1.75" aerogel insulation	242	18	10.5	4.4
2.00" aerogel insulation	228	14	13.4	4.7
Two-compressor system	188	40	20.0	5.9

(1) 18 cubic foot refrigerator/freezer with automatic defrost.

Source: Goldstein, et al., 1990 (Ref. 24).

Table 5

COST-EFFECTIVE ELECTRICITY CONSERVATION POTENTIAL IN NEW YORK STATE

Conservation Measure	Savings Potential (GWh/yr)	Cost of Saved Energy ($/KWh)
Reflectors for fluorescent fixtures	4140	0.010
High eff. refrigerators and freezers	5280	0.011
Residential infiltration reduction	590	0.017
HVAC retrofits in commercial buildings	6850	0.020
Commercial bldg. variable speed drives	3473	0.024
Energy saving incandescent lamps	880	0.028
High eff. industrial lighting	470	0.028
Occupancy sensors in comm. buildings	500	0.033
High eff. commercial fluor. lighting	2190	0.036
Industrial variable speed drives	2550	0.040
Compact fluorescent lamps	2020	0.040
Infrared reflecting lamps	810	0.044
Daylighting in commercial buildings	1660	0.047
Heat pump clothes dryer	860	0.065
Other	2070	--
All measures	34,340 (1)	0.025

(1) The savings potential refers to 1986, when total electricity consumption in the region under study equalled about 99,000 GWh.

Source: Miller, Eto, and Geller, 1989 (Ref. 25).

Table 6

COST OF SAVED ELECTRICITY AND CARBON DIOXIDE THROUGH GREATER ENERGY EFFICIENCY IN BUILDINGS

Conservation Measure (1)	Cost of Saved Energy (c/kWh)	Potential Elect. Savings (TWh/yr)	Potential Carbon Savings (Mton/yr)	Net Cost of Saved Carbon (2) ($/ton)
Reducing urban heat islands	0.5	45	8.7	–362
Residential lighting	0.9	56	10.6	–349
Residential water heating	1.3	38	7.1	–332
Commercial water heating	1.4	10	1.9	–321
Commercial lighting	1.5	166	31.9	–312
Commercial cooking	1.5	7	1.3	–310
Commercial cooling	1.9	115	22.1	–291
Commercial refrigeration	2.2	22	4.1	–284
Residential appliances	3.3	103	19.6	–221
Residential space heating	3.7	105	20.2	–198
Commercial space heating	4.0	22	4.1	–188
Commercial ventilation	6.8	45	8.7	– 36
All measures (3)	2.4	734	140.3	–265

(1) Specific conservation measures are aggregated for each major end use.

(2) The net cost of saved carbon is calculated using the 1989 average electricity price for the buildings, $0.075/kWh.

(3) For reference, the buildings sector consumed 1627 TWh of electricity in 1989 and generating this power resulted in about 311 million metric tons of carbon emissions.

Source: Rosenfeld, et al., 1990 (Ref. 26).

encourage greater adoption. The answer to these questions is that a variety of structural and behavioral factors inhibit full exploitation of cost-effective energy-efficiency measures (29). As evidence of these barriers, consumers in all sectors **implicitly** require paybacks of three years or less when making tradeoffs between initial costs and reduced operating costs. The resulting problem, often referred to as the "payback gap", is that there is a large difference in the investment criteria used for energy efficiency and energy supply investments. For the latter, paybacks of ten years or more are accepted. The following factors contribute to the payback gap.

Lack of Information

Consumers often lack credible information on the performance of energy-efficient technologies. Consumers usually do not know how much energy is used and how much it costs to operate different pieces of equipment. Although the MPG rating of automobiles is well understood, there is inadequate information about the energy-use characteristics of other products. Even if the energy efficiency ratings of new products are readily available, most consumers do not know how to evaluate the return associated with purchasing an energy-efficient, higher first cost product.

Lack of Experience and Availability

Many energy-efficient technologies were developed and commercialized within the past decade. Consumers may view them as risky investments with uncertain savings. There may be questions about non-energy-related performance. Also, there may be a lack of vendors and limited availability of relatively new energy-efficient technologies.

Limited Capital

Certain types of consumers such as low-income households and cash-constrained businesses often lack money for investing in energy conservation measures. Businesses tend to devote investment capital to improving their products or expanding their market share, not to reducing operating costs. One study found that even energy-intensive industries typically require a payback of two years or less for cost-saving investments (28).

Misplaced Incentives

In some cases, those who select and purchase energy-consuming equipment do not pay the operating cost. This is often the case for buildings under construction and for rental properties. In large companies, those in charge of specifying and purchasing equipment are often disconnected from those paying the operating costs. Where split incentives exist, equipment purchasers tend to minimize first cost, which leaves the user with inefficient buildings, appliances, etc.

Weak Incentives

Outside of some energy-intensive industries, energy represents a small fraction of the total cost of owning and operating a household, business, or vehicle. In office buildings, for example, the annual cost to an employer for a typical worker is approximately $150 per square foot, while energy costs are typically $1 to $2 per square foot (30). Low relative costs along with competing demands on decision makers' time limit consideration of energy efficiency opportunities.

Government Policies

Government spending, tax, and regulatory policies are strongly tilted in favor of energy production as opposed to greater efficiency. In the mid-80s, energy supply industries received tax breaks and other subsidies totalling around $40 billion per year (31). And over 90% of the federal government's energy R&D budget is devoted to supply options. At the state level, regulation of electric utilities usually makes it more profitable for utilities to promote electricity consumption rather than conservation in the short run.

Price Distortions

In addition to the payback gap problem, energy prices do not fully reflect the environmental, security-related, and social costs associated with energy production and use. For example, the costs of acid rain, urban smog, and protecting oil imports are not reflected in the prices of fossil fuels or electricity. One study estimates that the environmental costs related to electricity production from fossil fuels are in the range of $0.01-0.07/kWh, depending on fuel source and power plant type (32). Also, electricity and fuel prices are normally based on average costs, not marginal costs. Average-cost pricing and the failure to incorporate "externalities" into energy prices contribute to underinvestment in energy efficiency from the perspective of minimizing the total cost society pays for energy services.

Policy Instruments

A wide range of policies and programs can be adopted to overcome the barriers described above (33). This section examines two such efforts, appliance efficiency standards and the electricity conservation programs conducted by one particular utility. In addition, a broad set of policies for reducing energy use, economic costs, and carbon dioxide emissions in the United States are presented.

Appliance Efficiency Standards

As mentioned above, the National Appliance Energy Conservation Act of 1987 (NAECA) set minimum efficiency requirements for major residential products and required DOE to consider tightening the standards in the future (19). The legislation was developed jointly by conservation advocates and appliance manufacturers with support from utilities, consumer advocates, and environmental groups. The standards were virtually unopposed because consumers save money, manufacturers sell better-quality products and face uniform regulations, utilities need to construct fewer power plants, and less fuel is burned by eliminating the production, purchase, and use of inefficient appliances. It is truly a "win-win" proposition.

The appliance standards cover a wide range of products including furnaces, air conditioners, water heaters, refrigerators, freezers, and ranges. It is estimated that the initial appliance standards along with "second tier" standards on refrigerators and freezers will reduce electricity use by 54 TWh and total primary energy use by nearly 1.0 Quads in 2000 (34). These estimates are based on comparing a standards scenario to a market forces scenario. In the latter, efficiencies improve more gradually. Saving 1 Quad in 2000 is equivalent to about 5% of projected primary energy use by the residential sector that year (35). Assuming electricity savings are in the same proportion as total utility fuel shares, direct and indirect fuel savings from the appliance standards lower carbon emissions in 2000 by about 16 million metric tons.

The appliance standards are expected to increase the initial cost of affected products slightly, but on average the operating cost savings will be three times as great as the increase in first cost (34). Consumers should save about $2.7 billion per year on a net basis by 2000 and realize a total savings of $28 billion (nearly $300 per household) over the lifetime of products sold through 2000. Thus the appliance standards should reduce carbon emissions at a net cost of around negative $170 per metric ton.

Additional energy and carbon savings would result by strengthening the efficiency requirements on products already covered by NAECA as well as by adopting efficiency requirements on other products. In 1988, national efficiency standards on fluorescent lighting ballasts were added. The initial requirements, which took effect in 1990, are expected to reduce electricity use by about 28 TWh/yr and save businesses nearly $11 billion by 2000 (36). The benefit-cost ratio for these standards is around five. Other products for which minimum efficiency requirements are technically and economically feasible include lamps, light fixtures, and motors. Total electricity savings of about 72 TWh/yr could occur ten years after the adoption of efficiency standards on these products (37).

Utility Conservation Programs

A growing number of utilities in the United States are investing in end-use efficiency, thereby cutting load growth and reducing the need to build new power plants. The most aggressive utilities are spending around 2-4% of their gross revenues on conservation and load management (C&LM) programs (38). Utilities that invested large sums in C&LM during the 1980s experienced load growth that was about 1%/yr below that of other utilities (39).

In the late-1980s, the New England Electric System (NEES) developed one of the most comprehensive and well-funded electricity conservation programs in the nation. NEES spent about $65 million on C&LM programs in 1990 (about 4% of its revenues) and plans to increase its budget to $85 million in 1991 (40). NEES offers rebates and other financial incentives to stimulate the adoption of conservation measures by all types of consumers. NEES's 1990 program was expected to reduce peak demand by 105 MW and power production costs by $150 million.

Regulatory commissions in states where NEES operates (MA, RI, and NH) have provided the utility with incentives for achieving the maximum electricity savings as cost-effectively as possible. If NEES meets its 1990 savings and cost targets, its shareholders will get to keep about 10% of the net benefits to society from its C&LM programs after recovery of program costs (40). Over a twenty-year period starting in 1990, NEES expects to reduce its peak demand by about 1250 MW and obtain 32% of its "new resources" from C&LM (Figure 4) (41).

Fossil fuels provide about two-thirds of the power generated by NEES. It is possible to estimate the avoided carbon emissions and the cost effectiveness of carbon avoidance due to NEES's C&LM programs (Table 7). This analysis is based on the total cost for the conservation measures, i.e., the cost to the utility as well as the consumers. The average cost of saved energy for the C&LM programs was $0.037/kWh in recent years and is projected to reach about $0.052/kWh in the future. In both cases, the cost of saved energy is less than half the avoided cost of power (41). A net economic savings of about $850 million is projected as a result of all C&LM efforts through 1999.

Figure 4

NEESPLAN 1990 Resource Plan

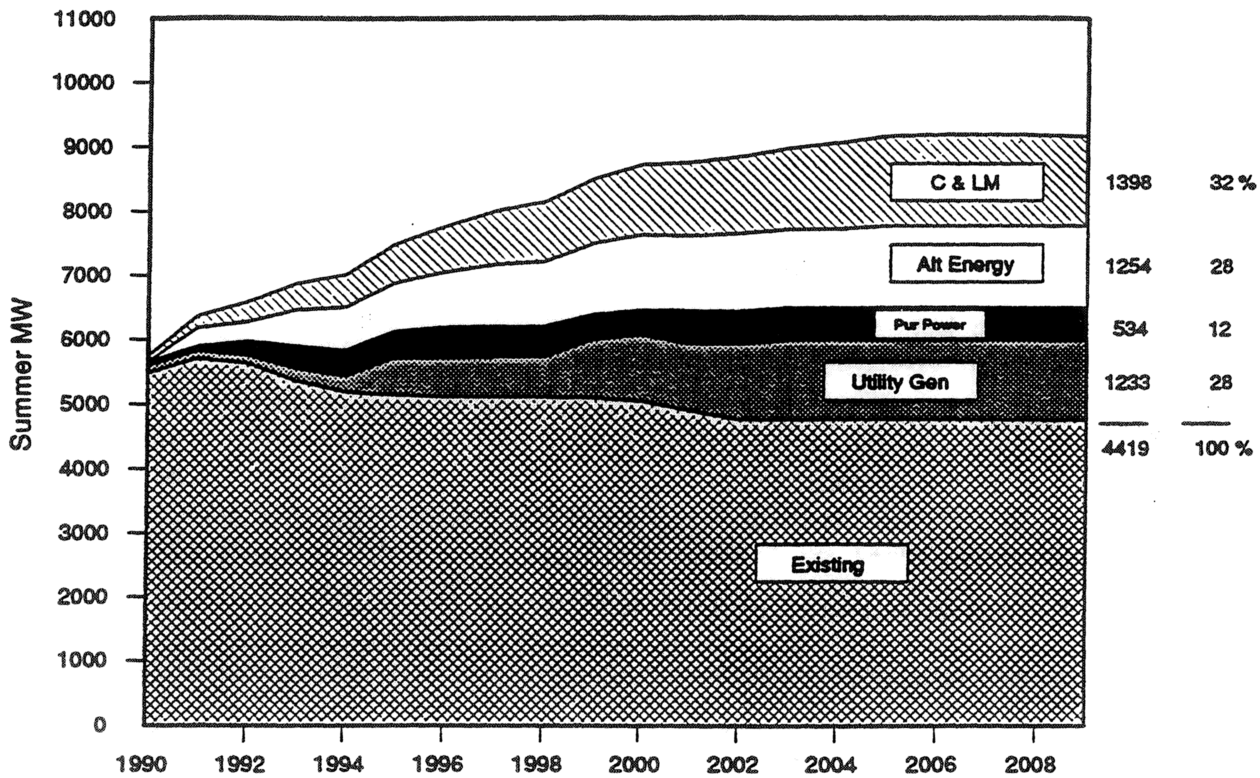


Table 7

ELECTRICITY SAVINGS, COST EFFECTIVENESS, AND AVOIDED CARBON EMISSIONS FROM CONSERVATION PROGRAMS SPONSORED BY THE NEW ENGLAND ELECTRIC SYSTEM (NEES)

Parameter	1987-89 Program	Projected 1987-99 Program
Electricity savings in last year (GWh/yr)	182.8	1,292.5
Electricity savings in last year as a fraction of electricity sales (%)	0.8	4.5
Conservation program cost (Million $)		
Utility	56.2	560.0
Society (i.e., utility plus consumers)	65.2	647.9
Average cost of saved energy for society ($/kWh)	0.037	0.052
Average avoided cost in last year (1989 $/kWh)	0.079	0.120
Societal benefit-cost ratio	2.15	2.32
Net economic savings in last year (Million $)	7.7	87.9
Net economic savings over the lifetime of the conservation measures (Million $)	75.0	855.2
Avoided carbon emissions in last year (Ktons)	34.9	246.9
Avoided carbon emissions in last year as a fraction of total carbon emissions (%)	0.9	5.3
Net cost of avoided carbon emissions ($/ton)	- 143	- 231

Source: New England Electric System, 1990 (Refs. 41 and 42).

C&LM programs underway at NEES are expected to cut NEES's carbon emissions in 1999 by about 250,000 metric tons, equivalent to over 5% of projected carbon emissions that year. The net cost of avoided carbon emissions, negative $140–230 per ton, is similar to that for other types of conservation measures and programs. In 1990, NEES was in the process of increasing its long-run electricity savings targets (42). Boosting energy savings efforts should lead to even greater carbon avoidance.

National Energy Efficiency Platform — Description

The 74.3 Quads of energy consumed in the United States in 1986 was almost identical to the amount of energy use in 1973. GNP rose 36% during this period, so national energy intensity declined 2.3%/yr on average. About three-quarters of the reduction in energy intensity was due to efficiency improvements, the remainder was due to structural change and interfuel substitution (16). Since 1986, however, energy use and carbon emissions have increased nearly as fast as GNP. Both U.S. energy use and carbon emissions in 1989 were 9% higher than in 1986 (11). Considering automobiles, for example, the average efficiency of new cars began to decline in 1989 (Figure 1).

In order to get the U.S. back on the "energy efficiency track", a national energy efficiency platform was developed in 1989 by four energy conservation research and advocacy organizations (43). The platform combines economic incentives, efficiency standards, R&D initiatives, and information programs (Table 8). Of course, the list is not exhaustive. Other policies such as a carbon-based fuels tax or additional efficiency standards could be adopted in order to achieve even further savings. The energy efficiency initiatives are briefly described and analyzed below.

Raise the Fuel Economy Standards for Cars and Light Trucks

The original fuel economy standards are now ineffective and outdated. The standards could be gradually increased to 45 MPG for cars and 35 MPG for light trucks over the next ten years. New standards could either require each manufacturer to achieve a specified overall average efficiency (i.e., an extension of the current approach), require equal percentage efficiency improvements from all manufacturers, or require specified average efficiency levels for each size class.

Expand the Gas Guzzler Tax and Establish Gas Sipper Rebates

Only very low fuel economy luxury cars are now subject to the federal gas guzzler tax. The tax could be extended to other inefficient cars (in proportion to MPG rating) and the new tax revenue could be used to provide rebates to purchasers of highly efficient cars. Rebates could be offered for the best cars in each size class.

Raise the Federal Gasoline Tax

The market price for gasoline does not reflect its real cost to the nation, i.e., considering externalities such as environmental impacts and national security costs associated with oil imports. Furthermore, the gasoline tax in the U.S. is far below that in most other industrialized nations. Substantially raising the gasoline tax would rekindle consumer interest in fuel economy, complement new fuel economy standards, and help to limit growth in vehicle usage.

Table 8

ENERGY EFFICIENCY PLATFORM FOR THE UNITED STATES

1. Raise car and light truck fuel economy standards, expand the gas guzzler tax, and establish gas sipper rebates so that new cars average 45 mpg and new light trucks average 35 mpg by 2000.

2. Raise the federal gasoline tax by 50 cents per gallon within five years and spend part of the revenue on mass transit and energy efficiency programs.

3. Reform federal utility regulation to foster investment in end-use energy efficiency and cogeneration systems.

4. Increase the efficiency of electricity supply through development, demonstration, and promotion of advanced generating technologies.

5. Implement new acid rain legislation that encourages more efficient production and use of electricity.

6. Strengthen federal appliance efficiency standards and adopt new efficiency standards on lamps, light fixtures, showerheads, and motors.

7. Reduce energy use in residential and commercial buildings through home energy ratings, mortgage-based incentive programs, and new building standards.

8. Reduce federal energy use through life-cycle cost-based purchasing.

9. Reduce industrial energy use through research, demonstration, and reporting programs.

10. Increase government-sponsored energy efficiency R&D and reinstitute demonstration programs.

Source: Geller, 1989 (Ref. 43).

Reform Federal and State Regulation So That Utilities Are Rewarded for Promoting Energy Efficiency

Most utilities are penalized when they operate successful energy efficiency programs due to the loss of sales revenue in the short run. To remedy this problem, energy efficiency measures could be allowed to compete fairly with energy supply options under the Public Utility Regulatory Policies Act (PURPA). Also, state regulatory authorities could provide utilities with financial incentives for pursuing energy efficiency and least-cost energy services.

Increase the Efficiency of Electricity Supply

New power production and distribution technologies such as combined-cycle power plants, advanced steam-injected gas turbines, and amorphous-alloy distribution transformers are more efficient than conventional technologies. Utilities could be given financial and regulatory incentives such as accelerated depreciation in order to stimulate the adoption of these new technologies. Also, R&D and demonstration programs related to electricity supply could emphasize options that increase overall efficiency.

Implement New Acid Rain Legislation

Acid rain legislation adopted in 1990 caps total emissions of sulfur dioxide by providing each affected utility with an annual emissions allowance. An individual utility can sell some of its allowances should its actual emissions fall below its emissions cap. Also, utilities can receive extra allowances for early emissions reductions due to investments in energy efficiency and renewable energy technologies. This legislation, if rigorously implemented, will give utilities in the Midwest and elsewhere an incentive to increase the efficiency of electricity supply and end use.

Strengthen and Expand Equipment Efficiency Standards

The Department of Energy is required to review the appliance efficiency standards on a regular basis and promulgate more stringent standards if deemed technically and economically feasible. DOE could tighten the minimum efficiency requirements on air conditioners, water heaters, and other products covered in the original NAECA law. Also, new efficiency standards could be adopted for incandescent lamps, fluorescent lamps, fluorescent light fixtures, heating and air conditioning equipment used in commercial buildings, showerheads, and motors.

Require Home Energy Ratings and Labels

Home energy rating and labeling programs have been successfully implemented in some parts of the country (44). Ratings and labels could be required on all new homes. For existing homes, their use could be promoted at the time of sale. This will help consumers to identify an efficient home, encourage builders to exceed minimum building code requirements, and make it easier for lending agencies to offer larger mortgages for buyers of very efficient homes.

Offer Incentives to Buyers of Efficient Homes

The federal mortgage lending agencies (FHA, Fannie Mae, etc.) can offer larger mortgages to buyers of homes that meet strict efficiency guidelines because residents of such homes are able to afford a higher monthly loan payment. A program along these lines was started, but it has had little impact so far. The program needs to be streamlined, better promoted, and expanded.

Strengthen Efficiency Standards for New Residential and Commercial Buildings

The energy efficiency requirements in most state building codes are outdated and below cost-effective levels. DOE could encourage and assist states that are interested in upgrading their codes, using new standards that are mandatory for federally-owned building but voluntary for the private sector as a model (45). Also, new homes financed by the federal government (e.g., public housing and homes receiving for FHA loans) could be required to meet more stringent efficiency standards such as the Model Energy Code issued by the Council of American Building Officials in 1989 (46).

Require Federal Purchasing Agents To Buy Energy-Efficient Equipment

Without exception, the federal government should purchase energy-efficient lighting products, motors, heating and cooling equipment, etc. when the operating savings exceed the extra first cost. A large revolving fund could be established to finance such investments.

Increase Funding for Energy Efficiency R&D

DOE's conservation R&D program was cut by two-thirds during 1980-89 in spite of DOE advancing the development and commercialization of numerous energy-efficient technologies during the 1970s (47). Funding was modestly increased for 1990-91, but many worthwhile projects are still unfunded or underfunded. The program could be doubled within a few years through redirecting money from other parts of the agency. Also, DOE could reinstitute demonstration of new energy-conserving technologies and expand efforts to transfer new technologies to the private sector.

Collect Additional Data on Industrial Energy Use

The federal government has stopped collecting data on annual energy use from large industries. This limits awareness of energy use and energy efficiency trends. The Energy Information Administration could reinstitute an annual survey of energy use by major manufacturers. Also, data on the extent of implementation of efficiency measures could be collected.

Establish Special Research and Demonstration Programs for Industries

In order to encourage innovation in the industrial sector, joint government-industry research centers could be established for energy-intensive industrial processes. The centers could conduct basic and applied research, striving for advances that provide energy savings along with other benefits.

National Energy Efficiency Platform — Potential Impacts

Adopting the energy efficiency platform could dramatically lower national energy use, expenditures on energy services, and carbon emissions by 2000 (Table 9). The savings are calculated relative to the energy use forecast issued by DOE in 1989 (48). To avoid double counting, savings already assumed in the DOE forecast are excluded. To facilitate the analysis, some of the policy measures are grouped together. No energy savings are directly attributed to the R&D proposals.

Table 9

POTENTIAL BENEFITS FROM THE ENERGY EFFICIENCY PLATFORM

Policy Proposal	SAVINGS IN 2000 Energy (Quads)	Money (Billion $)	Carbon Emissions (1) (Megatons)
Raise vehicle efficiency standards and gas guzzler tax/sipper rebates	2.0	12	41
Increase the gasoline tax	0.9	10	19
Reform utility regulation	3.8	14	94
Increase the efficiency of electricity supply	0.9	--	20
Implement new acid rain legislation	1.9	9	48
Equipment efficiency standards			
existing standards	1.2	6	25
new standards	1.1	5	25
Reduce energy use in buildings through home energy ratings, mortgage programs, and standards	1.2	5	22
Reduce federal energy use through life-cycle cost-based purchasing	0.2	1	4
Reduce industrial energy use through R&D, demonstration, and reporting	2.7	13	58
Increase conservation R&D	--	--	--
TOTAL	15.9	75	356

(1) Units are million metric tons of carbon.

Source: Geller, 1989 (Ref. 43).

Adopting the entire platform could cut projected energy use in the year 2000 by nearly 16 Quads (18%). Consumers could realize a net savings of about $75 billion per year taking into account the initial cost of efficiency measures. Carbon emissions in 2000 could fall by over 350 million metric tons, with a net cost of carbon avoidance of negative $210 per metric ton on average. Additional energy, economic, and carbon savings will occur after the turn of the century as the full impact of the policies is felt.

Table 10 compares energy use, energy services cost, and carbon emissions in 1988 with the respective values in 2000 from a frozen efficiency scenario, the 1989 DOE forecast, and a high efficiency scenario represented by implementing the platform. In the high efficiency scenario, there would be a modest drop in absolute energy use between 1988 and 2000. Assuming GNP increases 2.5%/yr, national energy intensity (E/GNP) would fall 3.0%/yr on average during 1988-2000 in the high efficiency scenario. This rate of energy intensity reduction is moderately greater than the average rate that prevailed during 1973-86. With the energy efficiency initiatives, carbon emissions fall by 21% compared to the DOE forecast and 11% compared to actual emissions in 1988.

The potential reduction in carbon emissions from the proposed set of energy efficiency initiatives is consistent with the goal of achieving a 20% reduction in CO2 emissions from 1988 levels by 2000. Efficiency improvements provide most of but not all of the CO2 reductions necessary to meet this goal. A modest increase in renewable energy sources, shifting from more carbon-intensive fuels to natural gas, or further conservation will be needed in order to reduce CO2 emissions 20% by the turn of the century.

This analysis is consistent with other studies of the potential to cut national CO2 emissions through increasing energy efficiency. In Sweden, it is estimated that aggressive efficiency improvements can lower projected carbon emissions in 2010 by one-third or more while reducing the overall cost of energy services (49). In Canada, it is estimated that drastically reducing carbon emissions in 2005 from projected levels through efficiency improvements could provide a net economic benefit of about $60-110 billion (50). Both of these studies indicate that strong policy initiatives will be needed in order to realize such large savings.

Conclusion

Examination of specific energy end uses as well as conservation policies and programs indicates that it is possible to greatly reduce carbon dioxide emissions while reducing the cost of energy services and increasing economic growth. In fact, consumers and our nation can save money while taking actions to reduce the threat of global warming. The key to obtaining these benefits is to focus on increasing the efficiency of energy end use. Increasing the efficiency of energy supply can yield similar results (51). In other words, both environmental and economic benefits result from a more rational balance between investments in energy efficiency and energy supply.

Given the existence of cost-effective efficiency opportunities, any thorough analysis of the potential cost of carbon dioxide emissions avoidance should contain a negative cost portion (Figure 5). The challenge for analysts is to identify the maximum amount of energy and carbon that can be saved at a negative cost. Likewise, policymakers and those implementing energy policies should strive to

Table 10

OVERALL ENERGY USE, COST, AND CARBON EMISSIONS
FOR DIFFERENT EFFICIENCY SCENARIOS

Scenario	Energy Use (Quads)	Energy Services Cost (1) (Billion $)	Carbon Emissions (Megatons)
Actual 1988	80.2	416	1503
Frozen efficiency 2000	107.2	735	2010
EIA Base Case 2000	90.6	621	1699
High Efficiency 2000 (2)	74.7	546 (3)	1343

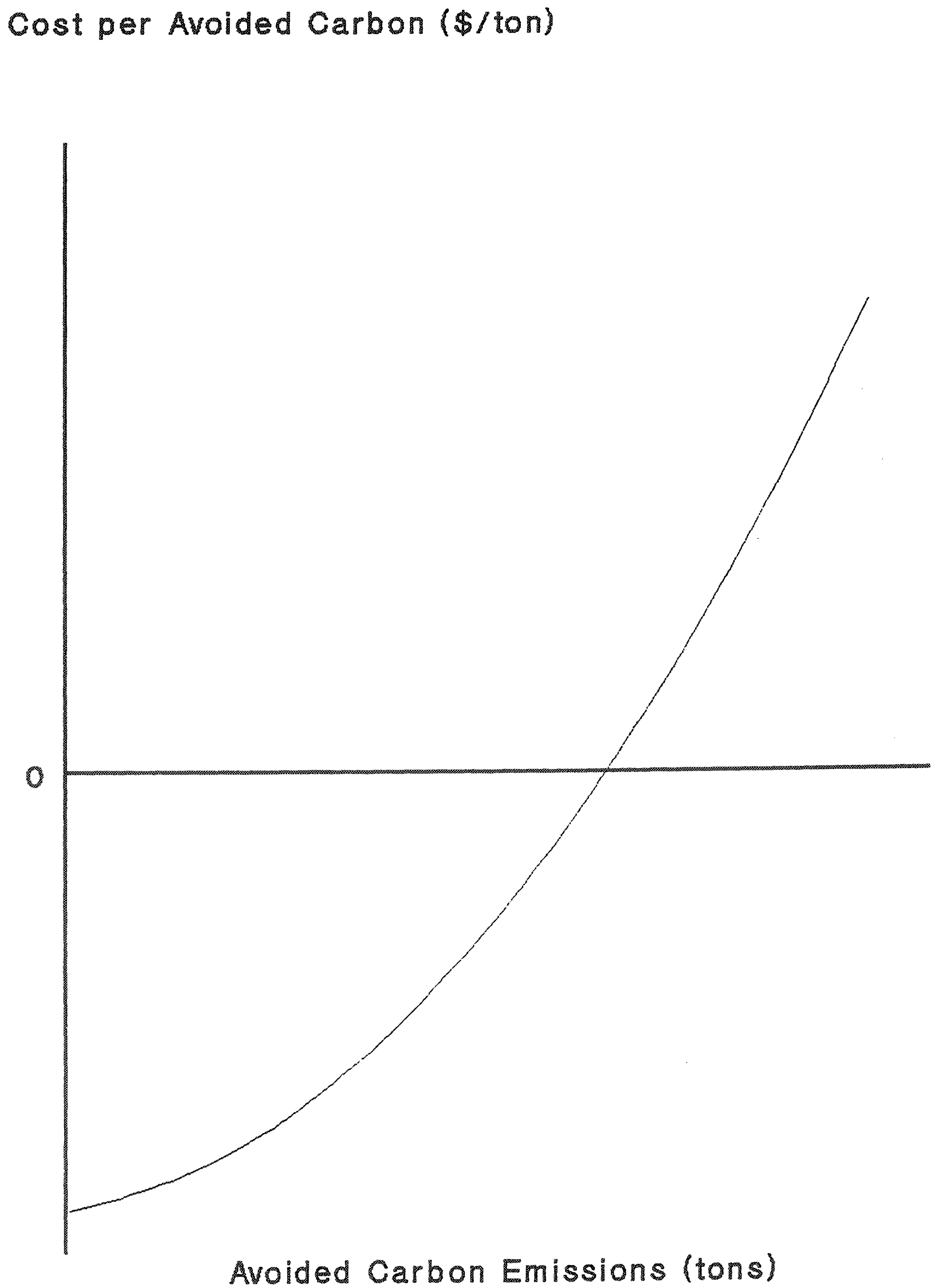
(1) Annual energy services cost expressed in 1988 dollars.

(2) Based on savings estimates from the policy proposals shown in Table 8.

(3) Includes the levelized cost of additional conservation measures relative to the EIA base case, but excludes any tax impacts from the gasoline tax or economic impacts from the initiative to increase the efficiency of electricity supply.

Sources: EIA, 1989 (Ref. 48) and Geller, 1989 (Ref. 43).

Figure 5 -- Cost Curve for Carbon Emissions Avoidance



maximize the amount of carbon avoidance achieved with a net economic benefit.

A variety of structural and behavioral barriers inhibit the adoption of cost-effective energy efficiency measures. In order to overcome these barriers, a mix of policies including economic incentives, efficiency regulations, R&D initiatives, and educational programs can be adopted. Past experience with automobile and appliance efficiency standards, for example, demonstrates that some conservation policies have been highly successful. But policies must be carefully designed and implemented in order to have the desired impacts (33). Given the potentially catastrophic impacts of global warming, it is all the more important that the United States and other nations adopt comprehensive strategies for accelerating the implementation of cost-effective energy efficiency measures.

Economic models examining the cost of reducing CO2 emissions have failed to include a negative cost portion (1, 2, 52). Those engaged in modeling national and international energy systems should incorporate end-use efficiency improvements directly into their models. Ignoring the reductions in energy use, energy service costs, and pollutant emissions that result from end-use efficiency improvements misses a large target of opportunity. Also, ignoring end-use efficiency improperly characterizes the total systems used for obtaining energy services. Models that fail to account for end-use efficiency and potential efficiency improvements should not be used to estimate the net economic impact of reducing greenhouse gas emissions.

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E891		$ 4.00	
E871		$ 6.00	
SUBTOTAL			
CA residents add 8.25% sales tax			
Add $2.00 for handling			
Delivery for rush orders			
Postage for international orders			
TOTAL			

Purchase order # ________ ☐ Check enclosed (payable in U.S. dollars to ACEEE)

Charge to my credit card: ☐ VISA ☐ MasterCard Account # ________

Expiration date ________ Signature ________

Name (please print) ________

Organization ________

________ Phone ________

Address ________

City ________ State ________ Zip ________

Send orders to:
American Council for an
Energy-Efficient Economy (ACEEE)
2140 Shattuck Avenue, Suite 202
Berkeley, CA 94704

Or phone order to: (510) 549-9914
FAX: (510) 549-9984