APPROACHING THE KYOTO TARGETS:
FIVE KEY STRATEGIES FOR THE UNITED STATES

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PREFACE

This report was a team effort with Howard Geller as overall coordinator and editor. Steve Nadel conducted the analysis of appliance standards and related voluntary programs, public benefits trust fund, and reducing power sector emissions. Neal Elliott conducted the analysis of combined heat and power. John DeCicco and Martin Thomas conducted the analysis of vehicle efficiency improvements.

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EXECUTIVE SUMMARY

There is compelling evidence that emissions of carbon dioxide and other greenhouse gases (GHGs) are inducing climate change at an alarming rate and are therefore posing serious environmental, economic, and social risks. Faced with this challenge, nations negotiated the Framework Convention on Climate Change in 1992 at the Rio Earth Summit. As further evidence of GHG-induced climate change and its potential impacts mounted during the 1990s, a Protocol to the Framework Convention was negotiated and completed at the Third Conference of Parties in Kyoto, Japan in December 1997. The Kyoto Protocol establishes legally binding GHG emissions limits for 38 industrialized countries starting in the 2008-2012 time period. The United States agreed to a target for this initial budget period of 7 percent below its 1990 emissions levels.

The United States emitted 1,753 million metric tons (MMT) of carbon or carbon equivalent in 1996, 8.3 percent more than the 1,618 MMT emitted in 1990. These values include the six gases covered by the Kyoto protocol. Considering only carbon dioxide (which is responsible for about 85 percent of the total for these six gases), emissions increased by nearly 120 MMT (9 percent) between 1990 and 1996. Preliminary data show that emissions of carbon dioxide rose an additional 22 MMT (1.5 percent) in 1997.

This situation is not expected to get much better given current policies and trends. The Energy Information Administration (EIA) projects that carbon emissions alone will reach 1,577 MMT in 2000, 1,803 MMT in 2010, and 1,956 MMT in 2020 (see Figure ES-1). Compared to the 1,346 MMT emitted in 1990, EIA is projecting an increase of 17 percent by 2000, 34 percent by 2010, and 45 percent by 2020. Thus, the United States will have to take vigorous and effective action in order to meet its Kyoto target.

This report presents and analyzes five major energy efficiency policy initiatives that could greatly help the United States achieve its Kyoto target. These policies would stimulate widespread energy efficiency improvements in all key sectors of the economy—buildings, transport, industry and electricity supply. By doing so, the initiatives yield energy bill savings that exceed the cost of the measures on a net present value basis. Thus, the initiatives reduce GHG emissions at an economic benefit rather than cost to the nation.

Our proposals build on ongoing efforts and the new climate technology initiatives recently proposed by the Clinton Administration. In some areas, we combine elements of the Administration's proposal with additional policies that are needed to overcome the full range of barriers inhibiting greater energy efficiency in the marketplace. In other areas, we recommend a combination of market incentives, regulatory reforms, and efficiency standards in order to transform energy use patterns and maximize economic and environmental benefits.

Methodology

For each strategy, we analyze potential energy savings, carbon emissions reductions, costs, and energy bill savings for investments made during 2000-2020. Our analysis uses the Reference Case Forecast in the EIA's *Annual Energy Outlook 1998* as a baseline projection. This is the most recent official energy supply and demand forecast by the U.S. Department of Energy (DOE). It assumes continuation of existing energy efficiency policies and programs, but no additional policies and programs. In our analysis, we tried to exclude any efficiency improvements explicitly or implicitly included in this forecast.

Key assumptions used in our analysis, including energy price projections, economic growth, growth in the housing, appliance, vehicle and power plant stocks, and emissions coefficients per unit of energy supplied, also are derived from the *Annual Energy Outlook 1998*. Our analysis of the cost effectiveness of various energy efficiency measures utilizes a 6 percent real discount rate. This value is roughly equivalent to the cost of capital averaged over time and is similar to the discount rate used by DOE to analyze policies such as prospective appliance efficiency standards.

Policy Proposals

Appliance and Equipment Efficiency Standards and Related Voluntary Programs

Federal legislation has established minimum efficiency standards on a wide range of residential appliances, lighting products, motors, and other mass-produced products. Minimum efficiency standards remove the least efficient products from the market, thereby increasing the scale and reducing the cost for more efficient products. The appliance standards legislation directs DOE to periodically review and strengthen the minimum efficiency standards where technically and economically feasible.

Our strategy consists of: (1) rapidly completing ongoing efficiency standards rulemakings that have been labeled as "high priority" (i.e., clothes washers, ballasts, residential central air conditioners, residential water heaters, and distribution transformers); (2) issuing new standards on other currently regulated products for which rulemakings are behind schedule (i.e., commercial heating and cooling equipment, furnaces and boilers, dishwashers, and reflector lamps); and (3) continuing with the next round of standards for products that were the subject of past rulemakings (i.e., refrigerators and room air conditioners).

Complementing efficiency standards, we also recommend that DOE, EPA, and utilities continue to develop and implement voluntary programs to promote products that are significantly more efficient than the minimum requirements, as well as high-efficiency equipment not covered by the standards. Our analysis includes energy savings from low-cost improvements to home electronics and packaged commercial refrigeration equipment, two areas where we believe voluntary programs could have a significant impact, in addition to energy savings from new minimum efficiency standards on a wide range of products.

Public Benefit Trust Fund as Part of Electric Utility Industry Restructuring

Electric utilities historically have funded a variety of activities that benefit the public but are not directly tied to electricity production and supply. These activities include programs to encourage customers to use energy more efficiently, assist low-income families with home weatherization and energy bill payment, promote the development of renewable energy sources, and undertake research and development. However, increasing competition and restructuring have led to a decline in utility "public benefit expenditures" over the past five years.

In order to ensure that public benefit activities continue to take place following restructuring, several states have established public benefit trust funds through a small charge on all electricity providers who use the transmission and distribution grid (whether traditional utilities, independent power producers, or others). As of June 1998, nine states have adopted utility public benefit funds.

Our strategy is to create a national public benefits trust fund modeled on the proposal made by Chairman Richard Cowart of the Vermont Public Service Board and included in the Clinton Administration's utility restructuring proposal released in March 1998. Specifically, the Administration has proposed a $3 billion per year public benefits trust fund that would provide matching funds to states for eligible public benefits expenditures. This proposal would encourage states and utilities to continue or in some cases expand energy efficiency and other public benefits activities.

Our analysis estimates the incremental investment in and savings from energy efficiency measures as a result of the federal public benefits fund. We do not include savings from utility energy efficiency programs already underway or likely to occur in the absence of a federal fund. We estimate that energy efficiency improvements resulting from the federal fund would cut national electricity use about 7 percent by 2010 and 11 percent by 2020.

Vehicle Fuel Economy Improvement

The average fuel economy of new light vehicles (cars and light trucks) has remained nearly constant for more than a decade and is not expected to increase in the future given current policies and trends. This is in spite of a wide range of technologies that are already available for increasing fuel economy as well as the emergence of advanced, ultra-efficient designs with hybrid-electric or fuel cell drivetrains that can substantially reduce energy use and pollutant emissions (e.g., the Toyota Prius, a five-passenger hybrid-electric sedan now manufactured in Japan that is expected to be available in the United States by 2000).

Our vehicle fuel economy strategy combines mutually reinforcing policies for improving the energy and emissions performance of cars and light trucks. Elements of this strategy include: (1) tougher CAFE standards on cars and light trucks in order to achieve a new-fleet average fuel economy of about 42 mpg by 2010 and 59 mpg by 2020; (2) a revenue-neutral fee and rebate (feebate) system to motivate sales of cleaner and more efficient vehicles in all classes; (3) tax incentives plus voluntary fleet purchasing commitments to stimulate the introduction and sales of highly efficient vehicles; and (4) continued R&D on next-generation vehicle technologies.

This strategy will stimulate widespread adoption of incremental energy efficiency improvements (i.e., engine improvements and weight reduction) as well as "leapfrog" technologies when they become available. Within this package, stronger CAFE standards act as the determining factor for inducing fleet-wide efficiency improvements.

Combined Heat and Power

Combined heat and power (CHP) systems convert as much as 90 percent of fuel input into useful energy, compared to 30-35 percent for a conventional power plant. Recent advances in combustion turbines and reciprocating engines are reducing CHP system costs, enabling much smaller CHP systems, and increasing potential electricity output per unit of fuel input. In spite of these advances, implementation of CHP systems is slowing in the United States due to barriers such as burdensome environmental permitting, environmental regulations that do not recognize overall CHP impacts, utility policies that discourage CHP installation, and unfavorable tax treatment.

Our strategy addresses all of the major barriers to CHP deployment. It includes: (1) providing expedited permitting for CHP systems; (2) implementing output-based air pollution regulations; (3) removing utility-driven barriers through national restructuring legislation, FERC authority, and actions by individual states; and (4) establishing a standard depreciation period of seven years for all new CHP systems.

We estimate that taking these actions would result in a doubling in installed CHP capacity by 2010, adding 50 GW_e to the 49 GW_e of capacity projected in the Reference Case. Furthermore, we estimate that the installed capacity could reach 192 GW_e by 2020 as technologies for CHP continue to improve and barriers are removed. The incremental CHP capacity would displace about 5 percent of projected conventional power generation in 2010 and 13 percent of projected conventional generation in 2020 in the Reference Case.

Reducing Power Sector Carbon Emissions

Apart from greater end-use efficiency and expanded use of CHP, power sector carbon emissions can be reduced by: (1) improving the efficiency of electric generating plants and using less fuel per kWh produced; and (2) switching to less carbon-intensive fuels (e.g., towards renewable energy and natural gas, and away from coal and oil). The average efficiency of fossil fuel power plants will rise as older power plants are retired and new combined cycle and other higher efficiency power plants are added. The Reference Case forecast projects that the average efficiency of all fossil fuel power plants will increase from 32 percent (an average heat rate of 10,600 Btu/kWh) in 1996 to about 36 percent (average heat rate of 9,600 Btu/kWh) in 2010 and 38 percent (average heat rate of 9,100 Btu/kWh) in 2020.

Further efficiency improvements could be made given that the most efficient combined cycle plants now being sold commercially have efficiencies on the order of 52 percent (heat rate of 6,600 Btu/kWh). However, barriers such as different environmental standards for old and new power plants, pressures to minimize capital expenditures, and political obstacles to large-scale fuel switching are limiting the turnover and replacement of the power plant stock.

Our strategy calls for a heat rate "cap and trade" system for fossil fuel power plants with the cap progressively reduced over time. The trading system would provide credits to generators that are below the prevailing heat rate cap. The credits could be sold to less efficient generators, allowing the market to determine the most economically efficient way to meet the caps. Specifically, we suggest caps of 8,600 Btu/kWh in 2010 and 7,700 Btu/kWh in 2020, 10 percent below levels projected for those years in the Reference Case forecast. Power sector carbon emissions would decline as a result of improving power plant efficiency as well as stimulating some fuel switching from coal to natural gas.

Unlike the other energy efficiency strategies, this initiative is likely to have a net positive cost as it would not result in energy bill savings. However, this cost is likely to be relatively modest and offset many times over by the net economic benefits from the other strategies.

Overall Results

Table ES-1 summarizes the potential impacts of the five energy efficiency strategies. Taken together, the five initiatives could lower carbon emissions in 2010 by about 310 MMT. This level of reduction is equivalent to about 21 percent of total U.S. carbon emissions as of 1997 and 17 percent of the 1803 MMT of carbon emissions projected in 2010 in the Reference Case Forecast (see Figure ES-1). This level of reduction is also about 61 percent of the estimated carbon reduction needed to meet the U.S. target in the Kyoto Protocol.[1]

Among the strategies, vehicle fuel economy improvements provide about 35 percent of the total carbon reductions, followed by the federal public benefits fund at 22 percent of the total,

[1] The Kyoto goal is to cut U.S. GHG emissions to 7 percent below their 1990 levels. In order to achieve this goal, we assume that carbon emissions must be reduced to 3 percent below their 1990 level with the remainder of reductions achieved through increasing carbon sinks, disproportionate reductions in other greenhouse gases, and international trading.

power supply improvements at 21 percent, CHP promotion at 14 percent, and appliance standards and related voluntary programs at 8 percent.

The carbon emissions reductions could increase substantially by 2020 as efficiency improvements continue to be made and more appliances, buildings, vehicles, and power plants are replaced. Specifically, we estimate that the five initiatives could lower carbon emissions in 2020 by around 603 MMT, 31 percent of projected emissions of 1,956 MMT that year in the EIA's Reference Case Forecast. By 2020, the five energy efficiency initiatives alone could return U.S. carbon emissions to nearly their level in 1990.

ES-1: Carbon Emissions Projections

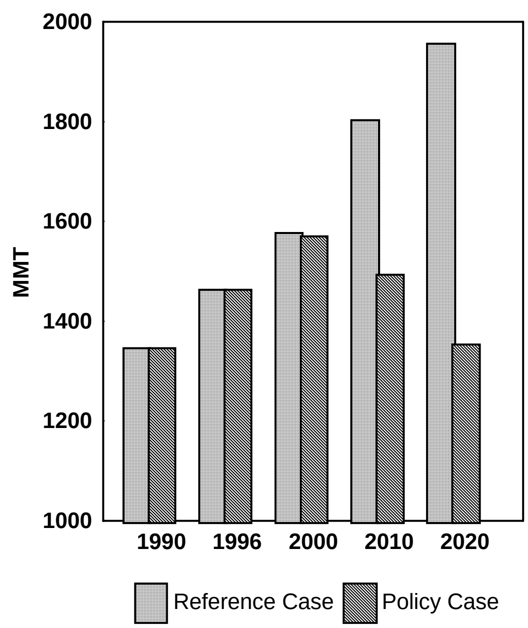


Table ES-1 also summarizes the estimated economic impacts of the five energy efficiency initiatives. Investments in efficiency measures through 2010 are estimated to cost $181 billion, but the net present value of energy cost savings over the lifetime of these measures is estimated to equal $344 billion (all values in 1996 dollars). Thus, energy bill savings exceed the costs of the measures by nearly a factor of two, resulting in a net economic benefit of around $163 billion.

The positive economic results in our study, and others like it, contradict the results of a number of "top-down" economic modeling studies that indicate reducing GHG emissions and/or achieving the Kyoto target will harm the U.S. economy. These studies contain unfavorable assumptions that lead to economic losses, such as no recycling of carbon tax revenue, no consideration of technological response, no-cost savings from energy efficiency improvements, no economic benefits from pollution abatement, and no international trading.

Our analysis shows that if we are intelligent about the policies and measures used to reduce GHG emissions, we can achieve substantial reductions with a net economic gain, not a penalty. Furthermore, our analysis is conservative in that it does not consider non-energy benefits (e.g., reduced damages from air pollution abatement or reduced vulnerability to oil price shocks from lower oil imports), the downward pressure on energy prices resulting from lowering energy demand, or potential capital cost reductions as markets for the energy efficiency measures grow.

In summary, the five initiatives presented in this report should play a central role in the U.S. strategy for achieving our Kyoto target and for making further GHG emissions reductions over the longer term. For a few of our recommended initiatives, partial efforts are underway or proposed. This is the case for appliance efficiency standards and related voluntary programs, the federal public benefits trust fund, and the combined heat and power initiative. However, further actions are needed to fully implement these initiatives and achieve the maximum emissions and economic benefit. In the case of the vehicle fuel economy and power supply efficiency initiatives, little or no effort is being made at the present time to implement the policies we recommend. Action on vehicle fuel economy in particular is long overdue and is essential for achieving our GHG emissions reductions goals.

Table ES-1: Overall Carbon Emissions Reduction and Economic Impacts.

	Avoided Carbon Emissions (MMT)		Net Present Value of Costs and Savings for Measures Installed during 1999-2010 (billion $)		
Strategy	2010	2020	Cost	Savings[1]	Net Benefit
Appliance Standards	25	44	13	28	15
Public Benefit Fund	69	111	86	124	38
Vehicle Efficiency Package	108	222	50	119	69
CHP Initiative	43	111	22	73	51
Power Plant Initiative	65	115	~10	—	-10
TOTAL	310	603	181	344	163

[1] The net present value of energy savings over the lifetime of energy efficiency measures installed during 1999-2010.

INTRODUCTION

There is compelling evidence that emissions of carbon dioxide and other greenhouse gases (GHGs) are inducing climate change at an alarming rate and are therefore posing serious environmental, economic, and social risks. As President Clinton recently stated:

> The World's leading climate scientists have concluded, unequivocally, that if we don't reduce the emissions of greenhouse gases into the atmosphere all across the Earth, then the temperature of the Earth will heat up, seas will rise and increasingly severe floods and droughts will occur, disrupting life in low coastal areas, disrupting agricultural production and causing other difficulties for the generations of the 21st century (Clinton 1998).

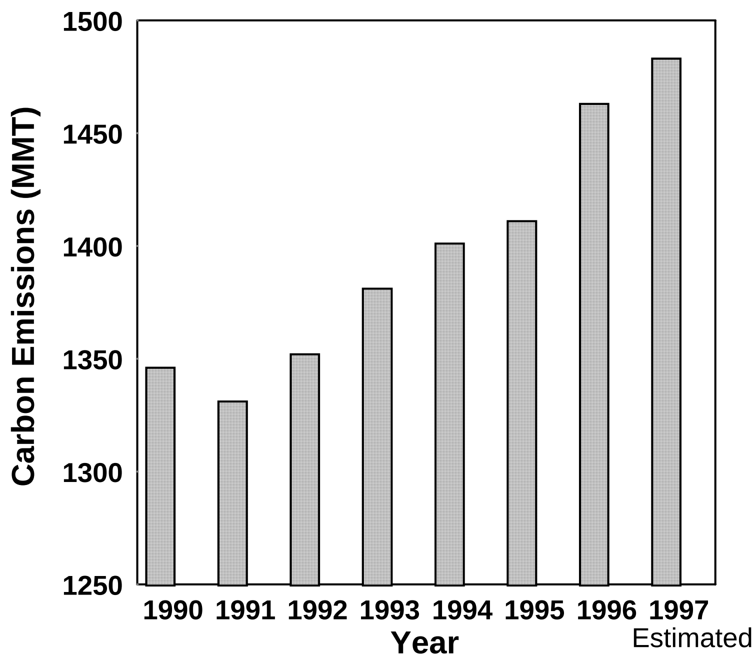
Faced with this challenge, nations negotiated the Framework Convention on Climate Change in 1992 at the Rio Earth Summit. The convention, signed by President Bush, entered into force in March 1994 after ratification by 164 nations. The Convention includes a commitment by the United States and other industrialized countries to seek to reduce emissions of carbon dioxide and other GHGs to 1990 levels by 2000.

As further evidence of GHG-induced climate change and its potential impacts mounted during the 1990s, a Protocol to the Framework Convention was negotiated and completed at the Third Conference of Parties in Kyoto, Japan in December 1997. The Kyoto Protocol establishes legally binding GHG emissions limits for 38 industrialized countries starting in the 2008-2012 budget period. The United States agreed to a target for this initial budget period of 7 percent below the 1990 emissions levels. The Protocol also allows emissions trading between countries with binding limits, trading among the six gases covered under the Protocol, credit for emissions reduction projects carried out in developing countries, and credit for increasing carbon stocks ("sinks"). Thus, the United States could, in practice, meet its target without actually reducing its own emissions to 7 percent below their 1990 levels.

According to the U.S. Department of Energy (DOE), the United States emitted 1,753 million metric tons (MMT) of carbon or carbon equivalent in 1996, 8.3 percent more than the 1,618 MMT emitted in 1990 (EIA 1997a). These values include the six gases covered by the Kyoto protocol. Considering only carbon dioxide (which is responsible for about 85 percent of the total for these six gases), emissions increased by nearly 120 MMT (9 percent) between 1990 and 1996 (see Figure 1). And preliminary data show that emissions of carbon dioxide rose an additional 22 MMT (1.5 percent) in 1997 (Geller and Thorne 1998). Given the rise in emissions in the past eight years and current trends, the United States will have to take substantial action in order to meet its 2008-2012 target.

Voluntary initiatives undertaken since the Framework Convention was adopted are helping to restrain growth in GHG emissions. The Clinton Administration estimates that current efforts

Figure 1: U.S. Carbon Emissions for Fossil Energy Consumption, 1990-1997.



Sources: EIA 1997a; 1997 estimate by ACEEE based on preliminary consumption data published by the Energy Administration.

will reduce carbon emissions by about 32 MMT and emissions of all six gases by about 73 MMT of carbon equivalent in 2000 (DOS 1997). But this is clearly not enough to meet either the Rio treaty target or the goal of the Kyoto Protocol. In fact the Energy Information Administration recently forecast that given current policies and trends, carbon emissions alone will reach 1,577 MMT in 2000, 1,803 MMT in 2010, and 1,956 MMT in 2020 (EIA 1997b). Compared to the 1,346 MMT emitted in 1990, DOE is projecting an increase of 17 percent by 2000, 34 percent by 2010, and 45 percent by 2020. The growth in emissions in the 1990s is attributed to robust economic growth, low energy prices, and limited funding of ongoing emissions mitigation efforts (EIA 1997a).

There is considerable controversy concerning the economic impacts of significantly reducing U.S. GHG emissions. "Top-down" economic modeling with worst-case assumptions indicates that stabilizing carbon emissions at the 1990 level could reduce GDP by 0-2.4 percent (Repetto and Austin 1997). The unfavorable assumptions that lead to loss of economic output in these studies include no recycling of carbon tax revenue, no consideration of technological responses, no-cost savings from energy efficiency improvements, no economic benefits from pollution abatement, and no international trading or joint implementation. Using more favorable assumptions would lead to more positive results. For example, Janet Yellen, Chair of the Council of Economic Advisers within the Clinton Administration, has testified that meeting the Kyoto target would have a very small negative impact on GDP (0.1 percent GDP loss in 2010) if the United States takes advantage of the flexibilities in the treaty (Yellen 1998).

But even the Yellen testimony ignores the economic benefits that could result from reducing GHG emissions; e.g., from reducing consumers' energy bills, stimulating capital investment, and avoiding damages from climate change and air pollution more broadly. Economic modeling as well as "bottom-up" engineering studies that consider efficient economic and technological responses and that account for the positive and negative economic impacts associated with cutting GHG emissions conclude that substantial reductions are possible with a net economic gain (Energy Innovations 1997; Interlaboratory Working Group 1997; Laitner 1997; Repetto and Austin 1997).

In this context, the Clinton Administration has proposed expanding U.S. efforts to reduce GHG emissions in an economically sound manner. In particular, the President has proposed a Climate Change Technology Initiative that includes $2.7 billion in additional R&D and deployment activities as well new tax incentives that are estimated to cost the Treasury $3.6 billion over five years (The White House 1998). The R&D and deployment activities are focused on increasing the availability and adoption of cost-effective energy efficiency and renewable energy measures. The tax incentives are focused on stimulating commercialization and sales of advanced energy efficiency and renewable energy technologies. The Administration also has proposed policies that would support implementation of energy efficiency and renewable energy technologies to some degree as part of its electric utility restructuring proposal. While these proposals are a step in the right direction, much more needs to be done to meet the Kyoto target and go beyond it in order to slow global warming over the long run.

The energy efficiency initiatives presented and analyzed in this report would help the United States achieve its Kyoto target with net economic benefits rather than costs. Our proposals build on ongoing efforts and the new initiatives recently proposed by the Clinton Administration. In some areas, we combine elements of the Administration's proposal with additional policies that are needed to overcome the full range of barriers inhibiting greater energy efficiency in the marketplace. In other areas, we recommend a combination of market incentives, regulatory reforms, and efficiency standards in order to transform energy use patterns and maximize the economic and environmental benefits.

Below we present five strategies that together could take us over 60 percent of the way towards meeting our Kyoto target (with respect to carbon emissions reductions). These policies would stimulate widespread energy efficiency improvements in all key sectors of the economy—buildings, transport, industry, and electricity supply. However, these policies do not exhaust the opportunities for emissions reductions through cost-effective efficiency improvements. Nor do they address the emissions reductions that are possible through greater use of renewable energy sources.

Methodology

For each strategy, we analyze potential energy savings, carbon emissions reductions, costs and energy bill savings for investments made during 2000-2020. Our analysis uses the Reference Case Forecast in the *Annual Energy Outlook 1998* as a baseline projection (EIA 1997a). This is the most recent official energy supply and demand forecast by the U.S. Department of Energy. It assumes continuation of existing energy efficiency policies and programs, but no additional policies and programs. Our analyses try to exclude any efficiency improvements explicitly or implicitly included in this forecast.

Key assumptions used in our analysis also are derived from the *Annual Energy Outlook 1998*, including energy price projections, economic growth, growth in housing, appliance, vehicle and power plant stocks, and emissions coefficients per unit of energy supplied. Our analyses of the cost-effectiveness of various energy efficiency measures utilize a 6 percent real discount rate. This value is roughly equivalent to the cost of capital averaged over time and is similar to the discount rate used by the U.S. Department of Energy to analyze policies such as prospective appliance efficiency standards. Appendix A provides the assumptions regarding energy prices and utility heat rates and carbon emissions coefficients. Other important assumptions used for analyzing each strategy are provided in the sections below.

APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS AND RELATED VOLUNTARY PROGRAMS

Opportunity

Residential and commercial buildings currently account for 36.5 percent of national energy use (including losses in electricity generation and supply). EIA's Reference Case Forecast projects that total energy use in buildings will increase about 0.8 percent per year during 1996-2010 while electricity use in buildings will increase 1.5 percent per year on average (EIA 1997a). Carbon emissions due to energy use in buildings are expected to climb to 612.5 MMT by 2010, 19 percent greater than emissions in 1996 and 33 percent greater than emissions in 1990. Two-thirds of these emissions are associated with electricity generation.

Most of the energy used in the residential and commercial sectors is consumed by heating and cooling equipment and appliances of various types. In the residential sector, furnaces, boilers, air conditioners, heat pumps, refrigerators, water heaters, clothes washers and dryers, ranges and dishwashers together account for approximately 85 percent of energy consumption. In the commercial sector, heating, cooling, lighting, water heating, refrigeration, and office equipment account for approximately 65 percent of energy use (EIA 1997a). And in the industrial sector, lighting equipment and electric motors account for more than 75 percent of electricity consumption (EIA 1997d).

With most of this equipment, substantial cost-effective energy savings are possible by purchasing high-efficiency equipment rather than standard-efficiency equipment whenever new equipment is needed. Some examples of the energy savings that are possible from equipment that is readily available on the market, and the cost-effectiveness of these savings, are summarized in Table 1. For most of these products, high-efficiency products are produced and sold, with market shares ranging from a few percent (for tumble-action clothes washers, very high-efficiency central air conditioners, and dry-type distribution transformers) to 10-20 percent (for high-efficiency water heaters and commercial, unitary air conditioners) to 50 percent (for electronic ballasts).

Barriers

While high-efficiency equipment is generally available on the market, there are many barriers that constrain purchase and use of this equipment. Among these barriers are:

- *Uninformed decision-makers*. Often the decision-maker is too busy to research the cost-effectiveness of a decision, or information on high-efficiency products is not readily available. In the commercial and industrial sectors, purchasing decisions are often made by a purchasing department or maintenance staff who have little knowledge about the energy efficiency of the equipment they purchase.

- *Third-party decision-makers*. Many times the decision-maker (e.g., a developer or a landlord) is responsible for purchasing equipment, but someone else (e.g., a tenant) is responsible for paying the energy bills. In these instances, the purchaser tends to buy the least expensive equipment because they do not benefit from improved equipment efficiency.

Table 1. Costs and Savings of High-Efficiency Appliances and Equipment.

Product	Incremental Cost for High Efficiency	Annual Energy Savings	Return on Investment	Discounted Lifecycle Cost Savings
Tumble-action clothes washers	$175	40% (705 kWh, 22 therms)	43% electric 19% gas	$575 electric $160 gas
SEER 14 central air conditioners	$250 for 3 ton unit	29% (368 kWh)	11%	$34
EF .93 electric water heaters	$17	8% (325 kWh)	>100%	$235
EF .62 gas water heaters	$44	13% (29 therms)	39%	$125
T8 fluorescent lamps & electronic ballasts	$4/3-lamp fixture	17% (65 kWh/3-lamp fixture	>100%	$42
EER 11 commercial unitary a/c	$1000 for 10 ton unit	17% (2750 kWh)	20%	$960
TP-1 dry-type distribution transformers	$898 for 150 kVA unit	2% (3467 kWh)	28%	$1570

Source: Nadel and Suozzo 1998.
Notes: Costs and savings are relative to standard-efficiency equipment now widely being sold. Costs are for high-volume mass-produced units; for the most part estimates from DOE efficiency standards rulemakings are used. Savings based on national average consumption patterns. Clothes washer analysis includes water and sewer bill savings. Energy savings valued at residential and commercial retail prices in 2000 per EIA (1997a). Lifecycle cost savings calculated using a 6 percent real discount rate.

- *Financial procedures that overemphasize initial costs and de-emphasize operating costs*. In the residential sector, consumers often view the product with the lowest first cost as the "best buy," ignoring operating costs. In the commercial and industrial sectors, companies generally closely scrutinize capital costs, which tends to favor purchase of inexpensive equipment. Operating costs are generally not scrutinized as closely (Comnes and Barnes 1987). Furthermore, when operating costs are reduced, the savings typically show up in a corporate level account, and are rarely passed on to the department that made the decision and the investment. This diversion of benefits discourages energy-saving investments.

- *Limited stocking of efficient products*. Equipment distributors generally have limited storage space and therefore only stock equipment that is in high demand. This creates a "Catch-22" situation: users purchase inefficient equipment so distributors only stock inefficient equipment. Purchasing efficient equipment thus may require a special order, which takes more time. When most equipment fails, it must be replaced immediately. Thus, if efficient equipment is not in stock, even customers who want efficient equipment are often stuck purchasing standard equipment (Stout and Gilmore 1989).

Strategy

To address these barriers, a number of policies and strategies are being pursued presently. More can be done, however, resulting in substantial additional energy and carbon savings.

The “flagship” of efforts to improve appliance and equipment efficiency are minimum efficiency standards. Minimum efficiency standards remove the least efficient products from the market, leaving consumers to choose from a wide array of improved efficiency products with all of the usual options and features. Since more efficient products are the norm, they are produced in great quantity, which reduces costs. Minimum efficiency standards were first adopted in 1978 by California and subsequently adopted by other states, leading to passage of federal appliance efficiency standards in 1987, fluorescent ballast standards in 1988, and standards on a variety of commercial and industrial products in 1992. These standards, collectively, are estimated to reduce electricity use by 88 TWh (2.7 percent) in 2000 and 245 TWh (6 percent) in 2015 (Geller and Goldstein 1998). The impacts of standards already adopted are accounted for in EIA’s 1998 energy consumption forecast; however, the forecast does not assume adoption of any new or revised standards.

Complementing efficiency standards are several other policies including education and rebate programs and building code requirements. Education programs include the Federal Trade Commission’s *Energy Guide* labels and U.S. Environmental Protection Agency (EPA) and DOE’s *Energy Star* program. Rebate programs have been offered by many utilities to encourage purchases of high-efficiency appliances, heating, cooling and lighting equipment, and electric motors. However, none of these other options have the energy-saving impact of minimum efficiency standards because they do not affect all purchase decisions. Education programs generally only reach a small fraction of decision-makers, and even the most successful utility rebate programs offered to date have served only 20-60 percent of eligible customers (Nadel, Pye, and Jordan 1994). Building codes generally apply only to new and substantially renovated buildings, leaving the large number of existing buildings unaffected. Voluntary programs can achieve very high penetration rates only when efficiency improvements are low-cost, easy for manufacturers and consumers to make, and heavily promoted.

Each of the laws establishing minimum efficiency standards directed DOE to periodically review and strengthen the minimum efficiency standards where feasible but these rulemakings have moved slowly. Of the more than 30 rulemakings that should have taken place to date, only eight have actually been completed.

In order to increase appliance and equipment energy savings, we recommend that:

(1) DOE speedily complete ongoing efficiency standards rulemakings that have been labeled as "high priority" (i.e., clothes washers, ballasts, residential central air conditioners, residential water heaters, and distribution transformers).

(2) DOE follow-up with additional rulemakings on currently regulated products for which revised standards are behind schedule (e.g., commercial heating and cooling equipment, furnaces, dishwashers, and reflector lamps) and then continue with the next round of revisions for products that were the subject of past rulemakings (i.e., refrigerators and room air conditioners).

(3) EPA, DOE, and utilities continue to develop and implement voluntary programs to promote equipment that significantly exceeds minimum efficiency requirements, as well as high-efficiency equipment not presently covered by standards. Such programs can lay the groundwork for new standards or, where improvements are low cost, possibly obviate the need for minimum efficiency standards. Examples of the latter might include products which draw substantial energy even when nominally "off" (e.g., telephone answering machines, cordless phones, cable TV boxes and audio equipment) and many types of packaged commercial refrigeration equipment (e.g., vending machines and beverage merchandisers). In the event voluntary programs are not effective on these products, DOE and Congress should consider implementing minimum efficiency standards.

Analysis

In order to analyze the costs and benefits of these policies, we conducted two analyses. First, we analyzed in detail the costs and energy and economic benefits of future equipment efficiency standards. Second, we reviewed other studies on potential energy savings from low-cost improvements to home electronics and packaged commercial refrigeration equipment in order to estimate the potential benefits of voluntary programs to promote energy savings in these products.

For the analysis of future equipment efficiency standards, the basic approach was to compare the current standard with a projected new standard in order to estimate average energy savings per unit sold. We then multiplied these savings by annual product sales for each year the new standard is in effect. In general, standard levels were chosen that in our judgement have a very good chance of being implemented, as evidenced by models on the market today. The key assumptions used and details of the analysis are shown in Appendix B. Regarding the priority rulemakings now underway, we assume DOE requires tumble-action (also known as horizontal-axis) clothes washers effective in 2006, electronic ballasts effective in 2003, central air conditioners and heat pumps with a minimum SEER of 13.0 effective in 2005, and water heaters at levels achieved by the most efficient conventional technology products in 2003.

For the analysis of small appliances and packaged refrigeration equipment, we reviewed studies by Thorne and Suozzo (1998) and ADL (1996) to estimate total savings available from low-cost improvements (defined as just a few dollars in the former case, and a two-year payback or less in the latter case), and then assumed that 50-75 percent of these savings (varying by type of equipment) could be achieved from voluntary programs by 2010. The early response to a new labeling program for TVS and VCRs indicates that high participation and savings are possible. This analysis is also summarized in Appendix B.

The cost of administering these policy initiatives is relatively low. DOE spends about $6 million per year analyzing, setting, and enforcing appliance efficiency standards, for example. Since these administrative costs are less than 1 percent of the capital costs of efficiency measures in our analysis, we exclude them from consideration.

Overall, our analysis found that new efficiency standards and related voluntary programs could result in the following:

- Primary energy savings of about 1.15 Quads in 2010 and 2.14 Quads in 2020.
- Avoided carbon emissions of approximately 25 MMT in 2010 and 44 MMT in 2020.
- By 2010, over $20 billion per year in consumer energy bill savings, or about $175 per household.
- Over the 1999-2010 period, the standards would lead consumers to invest some $13.4 billion in efficient appliances but would result in savings over the life of this equipment more than two times the cost, resulting in net savings to consumers of about $15 billion (on a net present value basis).

These and other results are summarized in Table 2.

Table 2. Summary of Savings from Appliance and Equipment Efficiency Standards and Related Voluntary Programs.

Product	Energy Savings (Quads)		Consumer Energy Bill Savings in 2010 (million 1996$)	NPV of Investment Through 2010 (million 1996$)	NPV of Energy Savings for Sales Through 2010 (million 1996$)	Reduction in Carbon Emissions (MMT)	
	2010	2020				2010	2020
Clothes washers	0.13	0.37	1974	3,106	4,561	2.5	7.4
Fluorescent ballasts	0.12	0.21	2,141	1,114	4,027	2.7	4.7
Central air conditioners & heat pumps	0.18	0.38	3,671	3,892	5,850	4.2	8.4
Residential water heaters	0.17	0.25	2,742	1,304	5,325	3.5	4.8
Distribution transformers	0.05	0.11	683	846	1,878	1.1	2.4
Other appliance and equipment standards	0.21	0.45	3,322	3,173	6,694	4.2	9.0
Energy Star home electronics	0.24	0.28	4,721	Not analyzed	Not analyzed	5.0	5.6
Energy Star packaged refrigeration equipment	0.06	0.09	1008	Not analyzed	Not analyzed	1.3	1.9
TOTAL	1.15	2.14	20,262	13,435	28,335	24.7	44.3

PUBLIC BENEFIT TRUST FUND AS PART OF ELECTRIC UTILITY INDUSTRY RESTRUCTURING

Opportunity

Electricity generation accounts for over 36 percent of national energy use (excluding cogeneration). EIA's Reference Case Forecast projects that grid-connected electricity generation will increase from 34.2 Quads in 1996 to 40.2 Quads in 2010, an average growth rate of about 1.2 percent per year (EIA 1997a). Carbon emissions due to electric generation are expected to climb to 663 MMT by 2010, 28 percent greater than emissions in 1996 and 39 percent greater than emissions in 1990. Nearly 90 percent of the carbon emissions from the electric sector are due to coal-fired power plants. While the use of natural gas for power generation is increasing, coal-fired power plants are still expected to account for 83 percent of sectoral carbon emissions in 2010.

Electric utilities have historically incorporated expenditures for a variety of activities that benefit the public and are not directly tied to electricity production and supply in their rates. Examples include expenditures to do the following:

- assist and encourage customers to use energy more efficiently;
- assist low-income families with weatherization and fuel assistance;
- promote the development of pre-commercial renewable energy sources; and
- undertake research and development activities that could have long-term benefits but lack short-term commercial returns.

In 1995, the latest year for which full data are available, electric utility expenditures on public purpose programs totaled $6 to 7.5 billion. In 1995, utility energy efficiency programs saved 55 billion kWh (1.8 percent of national electricity use) while renewable energy systems generated 63 billion kWh (not including hydroelectric power). Utility low-income programs served approximately two million low-income households[2] (Scheer, Brinch, and Eto 1998).

While utility DSM programs have captured many efficiency opportunities over the past decade, opportunities for cost-effective electricity savings remain large. For example, approximately 80 percent of fluorescent lighting in commercial and industrial buildings still utilizes inefficient T12 lamps and magnetic ballasts (Calwell, Dowers, and Johnson 1998). Citing another example, a 1997 analysis for the Mid-Atlantic states of New York, New Jersey

[2] Low-income households served based on ACEEE estimate of $200 average expenditure per household.

and Pennsylvania found that cost-effective efficiency measures can reduce electricity use in the region 33 percent by 2010 (Nadel et al. 1997). With a cumulative investment of $27 billion in efficiency measures during 1997-2010, consumers could realize electricity bill savings of $79 billion during the same period, according to this study.

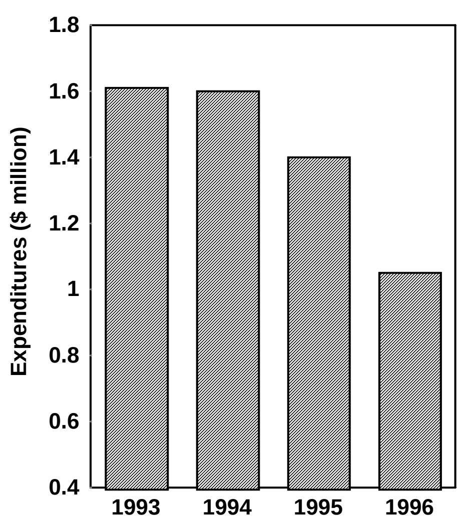
Barriers

Restructuring, by design, is intended to spur price competition between electricity suppliers, with the result that all nonessential costs, including public benefit expenditures, are likely to be slashed. There is already ample evidence that public benefit expenditures have declined significantly since the publication of California's landmark restructuring proposal in April 1994. For example, total utility spending on demand-side management (DSM) was $1.9 billion in 1996, down from a peak of $2.7 billion in 1993 (EIA 1997f). Utility direct spending on energy efficiency programs peaked in 1993 at $1.61 billion per year, declining to $1.05 billion in 1996 (see Figure 2). Incremental energy savings from utility energy efficiency programs (additional savings relative to savings achieved in the prior year) have plunged even further, from nearly 10 billion kWh in 1993 to 4.3 billion kWh in 1996 (see Figure 3). And according to a recent study by the General Accounting Office (GAO 1996), electric utility R&D expenditures declined from approximately $710 million in 1993 to $476 million in 1996, a drop of 33 percent. From all informal reports, these declines continued during 1997 and 1998.

Strategy

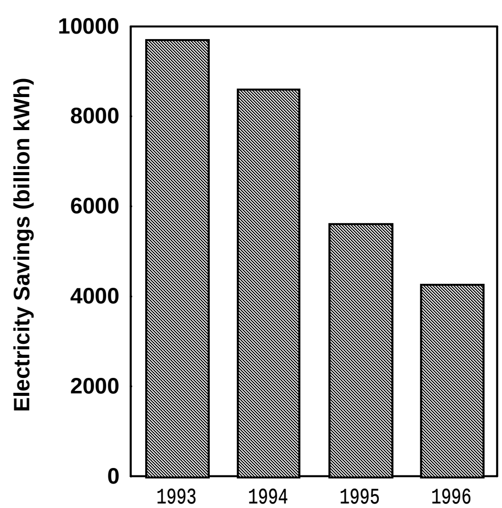
In order to ensure that important public benefit activities continue to take place following restructuring, several states have established public benefit funds. Funds are raised from a small

Figure 2: Electric Utility Energy Efficiency Expenditures



Source: EIA 1993-1997.

Figure 3: Incremental Utility Energy Efficiency Savings



Source: EIA 1993-1997.

charge on electricity distribution service, with charges ranging from 0.3 to 4.0 *tenths* of a cent per kWh. (Note: a tenth of a cent is often referred to as one *mil.*) All electricity providers who use the T&D grid (whether traditional utilities, independent power producers, or others) are assessed the charge and contribute to the fund, thereby "leveling the playing field" among providers. As of June 1998, nine states had adopted public benefit funds—California, Connecticut, Illinois, Massachusetts, Montana, New Hampshire, New York, Pennsylvania and Rhode Island.[3] Funds raised are allocated by state officials to a variety of public benefit activities. Of the funds already established, nearly all cover programs for low-income households, energy efficiency, and renewable energy, and some explicitly list R&D and unique state-specific activities (Energetics 1998).[4]

At the national level, Chairman Richard Cowart of the Vermont Public Service Board has proposed that a National Systems Benefits Trust be created to match, on a dollar for dollar basis, state expenditures on specified public benefit activities (Cowart 1997). Two legislative proposals—S. 686 authored by Senator Jeffords (R-VT) and H.R. 1359 authored by Congressman DeFazio (D-OR)—incorporate the Cowart proposal. The proposal has since been endorsed by 30 other state public utility commissioners and numerous consumer, environmental and industry groups. It is also included in the Clinton Administration's restructuring proposal released in March 1998. Specifically, the Administration has proposed a $3 billion per year public benefit fund (PBF) to provide matching funds to states.

Under all of these proposals, states would make decisions on how to spend funds, choosing among four areas—services for low-income households, energy efficiency, renewable energy sources not receiving credit through a renewable portfolio standard, and public interest R&D (i.e., R&D activities with significant public benefits that are not likely to be funded through the private market).[5] Funds would be collected by transmission system operators under FERC-approved transmission tariffs, and paid over to an independent administrator designated by FERC. Program governance (e.g., developing detailed implementation policies) would be the responsibility of a Joint Federal-State Board made up of FERC commissioners and state

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[3] In addition, Arizona, Maine, and Maryland have decided to fund certain public benefit activities through the rates of distribution utilities. Several other states are close to finalizing public benefit funds including New Jersey, Oregon, Vermont and Wisconsin.

[4] In states without Renewable Portfolio Standards, a variety of renewable energy activities are funded through the Public Benefit Fund. In states with Renewable Portfolio Standards, expenditures from Public Benefit funds are generally limited to development and demonstration of pre-commercial renewable energy sources. State-specific public benefit activities include environmental protection programs in New York and clean coal technology development in Illinois.

[5] In addition, Jeffords includes "universal" and "affordable" service, meaning reasonably priced services for rural residents.

regulators nominated by the National Association of Regulatory Utility Commissioners (NARUC) and appointed by the Secretary of Energy. Funds would be collected, per kWh, as power leaves the generating station and enters the transmission grid. This arrangement is based closely on the Universal Service Fund established under the Telecommunications Act of 1996, administered by the National Exchange Carriers Association (an independent administrator appointed by the FCC) and governed by a joint federal (FCC)/state utility commission representatives board (Scheer, Brinch, and Eto 1998). Our strategy is based on the Clinton Administration's PBF proposal.

Analysis

To estimate the likely impacts of the proposal on consumers, U.S. energy use, and emissions from electric generating plants, we developed a computer spreadsheet model. Our analysis includes only the energy efficiency portion of the PBF — which we estimate to be 59 percent of the total PBF. Expenditures and benefits of renewable energy, R&D, and non-efficiency low-income programs are not included in our analysis. Our analysis begins by examining the full impacts of the PBF, including both federal and state programs. We then estimate the portion of costs and benefits that can be specifically attributed to a federal PBF, and the portion likely to occur in the absence of further federal action. We only count the former since EIA's Reference Case Forecast implicitly assumes continuation of ongoing utility DSM and energy efficiency efforts. Other key assumptions in the analysis are as follows:

- A one-mil PBF is adopted by Congress in 1999 and begins operation January 1, 2000. The PBF accumulates a small surplus in the early years, before most states have an opportunity to act, but the surplus is soon used up and by 2006 available federal PBF funds are rationed as state requests modestly exceed the federal PBF funding available. Although the PBF in the Administration's restructuring proposal would sunset after 15 years, we assume the policy remains in effect indefinitely.

- Fifty-nine percent of PBF funds are used for energy efficiency (including low-income energy efficiency) with the remainder used for other public benefit activities. This share is based on the split between efficiency, non-efficiency low-income programs, and utility R&D in 1995, but assume that R&D expenditures increase 25 percent due to increased attention to renewables R&D.

- Energy efficiency measures implemented as part of the PBF program have an average levelized cost of $0.03 per kWh saved. On average, PBF funds are used to pay one-third of measure costs, with the remaining two-thirds of funding coming from customers, energy service companies, and other efficiency service providers. These values are based in part on the broad array of past utility demand-side management (DSM) programs and in part on a subset of programs that have emphasized the market transformation approach to program design. Increasingly, states and utilities are emphasizing the market transformation approach

(Nadel and Latham 1998). Our analysis takes into account the cost for administering utility energy efficiency programs as well as "free riders" (i.e., program participants who would still adopt the efficiency measures without utility incentives).

- Efficiency measures on average have a life of 13 years but savings degrade at the rate of 3 percent annually, starting in the second year. Thus, savings in the tenth year are approximately 75 percent of first year savings. Once measures wear out, we assume that 75 percent will be replaced at owner expense because owners are satisfied with the savings and performance and wish to continue them.

- In the absence of federal action, we assume state PBFs totaling $1.9 billion annually will be adopted ($1.06 billion already adopted plus $0.8 billion from states that are now considering PBFs — details are provided in the Appendix C). This $1.9 billion represents 28 percent of the total federal/state pool available, leaving 72 percent of the pool that can be directly credited to a federal PBF.

- Energy savings will reduce carbon, sulphur dioxide and nitrogen oxide emissions in proportion to emissions from all fossil fuel plants (weighted average of coal, gas and oil). Emissions rates show a gradual decline over time as power plant efficiency improves and natural gas accounts for a growing share of the generation mix (see Appendix A). Transmission and distribution losses of 6-7 percent are included in the calculation of avoided emissions.

Assumptions used in the analysis and year by year results are provided in Appendix C. The results are summarized in Table 3. Overall, federal plus state public benefit funds will have a substantial positive impact on consumer energy bills, national energy use, and pollutant emissions. Impacts include:

- By 2010, energy efficiency expenditures attributable to public benefit activities will reduce annual U.S. electricity consumption by 411 billion kWh. Of these savings, 296 billion kWh (7.1 percent of projected electricity consumption in 2010 in the Reference Case) are attributable to a federal PBF. By 2020, we estimate that public benefit activities will reduce national electricity use by 714 TWh, while the federal PBF alone will reduce electricity use by 514 billion kWh (11.1 percent of consumption in the Reference Case).

- The energy savings attributable to a federal PBF will reduce U.S. carbon emissions by 69 MMT in 2010 and 111 MMT by 2020. Substantial reductions in emissions of sulfur dioxide (0.96 million tons in 2010), nitrogen oxides (0.61 million tons in 2010), and other air pollutants will also occur.

- Over the 1999-2010 period, we estimate that the federal PBF will result in incremental investments of $86 billion in energy efficiency measures along with energy bill savings of about $124 billion over the lifetime of these measures (on a net present value basis in 1996$). Thus, the federal PBF would result in net savings of around $38 billion.

Table 3. Estimated Impacts of the Federal Public Benefits Fund (Energy Efficiency Portion Only).

Impact	2000	2005	2010	2015	2020
Incremental Efficiency Investment due to Federal PBF (billions$)	0.6	14.6	13.5	21.1	20.5
Incremental Electricity Savings due to Federal PBF (TWh/yr)	3	172	296	454	514
Value of Incremental Energy Savings for Consumers (billion$)	0.2	11.1	18.5	26.9	29.7
Avoided Carbon Emissions (MMT)	1	42	69	101	111
Avoided SO_2 Emissions (thousand tons)	13	660	960	1,280	1,340
Avoided NOx Emissions (thousand tons)	7	390	610	870	940

These benefits are based on a national charge of one mil per kWh, matched by an equivalent state charge. The combined national/state charge will raise electric *rates* by 3 percent above otherwise projected levels in 2010. But by reducing electricity consumption by an average of 10 percent, the combined PBF will result in reductions in the average electric *bill* of approximately 7 percent (since bills are the product of rates times consumption). Thus, consumers as a whole will realize significant financial benefits while contributing towards the goal of reducing greenhouse gas emissions.

VEHICLE FUEL ECONOMY IMPROVEMENT

Opportunity

Light duty vehicles (cars and light trucks) currently account for 56 percent of transportation sector energy use. The EIA's Reference Case Forecast projects light duty vehicle energy use to grow from 14.0 Quads in 1996 to 17.8 Quads in 2010, an annual average rate of 1.7 percent (EIA 1997a). Overall transportation energy use is expected to rise 2.4 percent annually, due in part to large increases in air travel and freight transport. In 2010, according to the Reference Case Forecast, the sector will remain about 95 percent dependent on petroleum and continue to lead all other sectors in GHG emissions growth. EIA's Reference Case does not list carbon emissions from light duty vehicles, so we use an emissions factor of 25.2 MMT per quad based on full fuel-cycle emissions (19.0 MMT from end use and 6.2 MMT from upstream emissions). Carbon emissions from light vehicles essentially keep pace with energy use, growing at 1.7 percent annually from 1996 to 2010, leading to 448 MMT of carbon emissions in 2010, 27 percent greater than emissions in 1996 and 54 percent above 1990 emissions.

In spite of today's trend of increasing energy use and GHG emissions, opportunities abound for moving toward a more sustainable transportation system. Advances in technology offer hope that, with public policy guidance, the U.S. transportation system can evolve to provide its amenities at lower cost, while accumulating less environmental damage that compromises the future. Progress in automotive engineering, from improvements in conventional technology to advanced, ultra-efficient designs with hybrid-electric or fuel cell drive trains, can substantially reduce energy use and emissions. The technologies that are already available for increasing fuel economy include engine improvements such as multipoint fuel injection and variable valve control, transmission improvements such as continuously variable transmission, and load reductions such as better aerodynamics or use of lighter weight materials (DeCicco and Ross 1996).

Recent announcements by automakers demonstrate the emergence of advanced highly efficient vehicles. Toyota is now mass producing the Prius in Japan, a five-passenger hybrid-electric sedan that is expected to be available in the United States by 2000.[6] Each of the U.S. Big-3 automakers have unveiled prototype vehicles using lightweight materials and hybrid drivetrains that can achieve double or higher fuel economy compared to today's cars. For example, Ford's P2000 prototype family sedan attains 63 miles per gallon (mpg). Daimler-Benz also has indicated it plans to mass-produce fuel-cell vehicles by 2003-2005 (Nauss 1997).

Vehicle technology improvements are but one element of a comprehensive climate-sensitive transportation policy, albeit the single most important element. Although not analyzed here,

[6] The Prius appears to have a fuel economy of 50 to 55 mpg on U.S. tests (city-highway composite rating).

measures to promote travel demand reduction, low-carbon fuels, more efficient freight movement, and slower growth in air travel should also be pursued (Energy Innovations 1997).

Barriers

The barriers to vehicle fuel economy improvement include: (1) gasoline prices are at an all-time low; (2) fuel prices do not fully reflect environmental, social, and national security costs associated with oil consumption (i.e., the externalities); (3) fuel costs are a relatively small portion of the total cost of owning and operating a vehicle, and the net value to consumers of higher fuel economy is not very great; (4) consumers lack all the necessary information to optimize their fuel economy decisions, and (5) manufacturers obtain higher profits from selling inefficient sport utility vehicles than they do from selling more fuel-efficient cars (Greene 1998). The significant technological advances made during the past decade have gone to increasing power and performance, not to increasing fuel economy.

But the principal barrier to implementing the opportunities for more efficient vehicle technology is the lack of regulatory guidance, through strengthened Corporate Average Fuel Economy (CAFE) standards. The CAFE standard for cars is the same as it was in 1985, and for light trucks, it is just 0.2 mpg above the 1987 level. Compounding the problem is increasing sales of light trucks, which topped 45 percent of total passenger vehicle sales in 1997 . The result is that fleet-wide new vehicle CAFE in 1996 was 24.6 mpg, the same as in 1983 and down from a high of 25.9 mpg in 1988 (EPA 1996). While automakers may sell several hundred high-tech electric vehicles in 1998, they will also sell over two million sport utility vehicles. The experience of the last 10 years clearly shows that without increases in CAFE standards, aggregate fuel economy performance will not improve and carbon emissions will continue to rise.

Strategy

Our vehicle fuel economy strategy combines mutually reinforcing policies and programs for improving the energy and emissions performance of cars and light trucks. A goal of this package is to engage competitive forces in the automotive industry to induce continuous progress in energy and environmental performance, analogous to the market-driven progress that already occurs for other vehicle features. This strategy will stimulate the widespread adoption of incremental energy efficiency improvements (e.g., engine improvements and weight reduction) as well as "leapfrog" technologies such as hybrid drivetrains, fuel cells, and new lightweight materials. Elements of this strategy include the following:

- Strengthening CAFE standards on cars and light trucks in order to achieve new-fleet fuel economy of at least 41.7 mpg by 2010. In addition, raise CAFE standards to achieve 75 mpg by 2030, along with ongoing improvements of emissions control requirements for noxious pollutants.

- Expanding the federal "gas guzzler" tax to a revenue-neutral fee and rebate (feebate) system to motivate sales of cleaner and more efficient vehicles in all classes. Such vehicle-price incentives could be tied to both GHG and criteria emissions, with appropriate adjustments for vehicle size or equity among manufacturers. Above-average vehicles in each class would receive rebates, while below-average vehicles would be assessed fees.

- Establishing a market creation program for highly efficient vehicles, involving tax incentives such as those recently proposed by the Clinton Administration, plus coordinated, voluntary purchasing of advanced vehicles by public and private fleets and individuals.

- Encouraging state-based incentive programs for cleaner and more efficient vehicles, converting sales taxes or vehicle fees to feebates favoring greener vehicles, and promoting state and local government participation in a nationwide market creation program.

- Refocusing R&D for "next-generation" vehicle technologies, particularly lightweight designs, fuel cells, and hybrids; coordinating federal and state efforts to reduce both GHG and criteria air pollution, while continuing to enhance safety.

Within this package, the regulatory measure (stronger CAFE standards) acts as the determining factor for inducing fleet-wide efficiency improvements. We modeled an annual ramp-up of 1.5 mpg between 1999 and 2010 (for the average combined new car and light truck fleet) based on efficiency levels estimated to be achievable and cost-effective using available technologies (DeCicco and Ross 1996). After 2010, we model a 1.67 mpg per year increase to achieve 75 mpg by 2030. Vehicle price incentives and programs for market creation would support the standards on the consumer side, addressing concerns that standards alone do not generate sufficient customer interest in environmentally improved vehicles (DeCicco 1997; DeCicco, Geller, and Morrill 1993).

Analysis

The EIA Reference Case Forecast assumes the average fuel economy of new cars increases slightly (0.4 percent per year) during 1996-2020 while the average fuel economy of new light trucks dips during 1996-2010 but then recovers to reach the level in 1996 by around 2017. With these assumptions, the average fuel economy of the on-road fleet remains essentially flat during 1996-2010 and then rises about 1 mpg between 2010 and 2020 (see Table 4). Furthermore, the Reference Case Forecast assumes that light duty vehicle-miles of travel (VMT) increases 1.5 percent per year on average during 1996-2020 (EIA 1997a). With these assumptions, energy use by light duty vehicles increases from 14.0 Quads in 1996 to 19.2 Quads in 2020 in the Reference Case, 1.3 percent per year average growth.

To analyze the policy package, CAFE levels were specified as inputs to a vehicle stock model, which projects vehicle sales and replacement, energy consumption, and carbon emissions. The standards are assumed to be binding and thus subsume the vehicle efficiency effects of other policies and programs. Starting from a base level of 23.7 mpg (9.9 liters per 100 kilometers) (EPA unadjusted composite urban/highway average of car and light truck fleets), improvements were assumed to begin in 1999 and reach a new fleet average of 41.7 mpg (5.6 liters per 100 kilometers) by 2010 (see Table 4). The details of the fuel economy analysis are presented in Appendix D.

For the post-2010 period, we link efficiency improvement rates to the tripled fuel economy goal of the Partnership for a New Generation of Vehicles (DOC 1994). With a vigorous R&D effort along with tax incentives to stimulate commercialization and early sales, we believe that mass-produced advanced-technology vehicles could be introduced into passenger cars in the 2005-2010 time period. Allowing another 10 years for the technology to diffuse to all other segments suggests that average fuel economy for the new fleet could triple, reaching 75 mpg (3.1 liters per 100 kilometers) as soon as 2020. A number of analysts project that high-efficiency fuel-cell vehicles could be competitive with gasoline vehicles on a life-cycle cost basis sooner than that (DeLuchi 1992; Mark 1996; Williams et al. 1995).

Table 4: Comparison of Light-Duty Vehicle Fuel Economy, Energy Use, and Carbon Emissions in the Reference and Policy Cases.

	2000	2005	2010	2015	2020
Reference Case					
Vehicle miles traveled (10^{12})	**2.45**	**2.67**	**2.89**	**3.08**	**3.24**
New fleet mpg	**23.3**	**23.7**	**24.1**	**24.5**	**25.0**
On-road stock mpg	**20.3**	**20.2**	**20.3**	**20.7**	**21.2**
Energy use (Quads)	**15.0**	**16.5**	**17.8**	**18.6**	**19.2**
Carbon emissions (MMT)	**379**	**415**	**448**	**467**	**484**
Policy Case					
Vehicle miles traveled (10^{12})	**2.45**	**2.67**	**2.89**	**3.08**	**3.24**
New fleet mpg	**26.7**	**34.2**	**41.7**	**50.0**	**58.4**
On-road stock mpg	**20.4**	**22.5**	**26.7**	**32.3**	**38.9**
Energy use (Quads)	**15.1**	**14.8**	**13.5**	**11.9**	**10.4**
Carbon emissions (MMT)	**379**	**371**	**340**	**298**	**262**

We assume that full transformation of the market to next-generation vehicles of tripled fuel economy takes until 2030. This trajectory is compatible with an evolutionary strategy. Vehicles using various non-conventional designs, providing a distinct step forward but less than tripled efficiency, could be phased into the fleet sooner, leading to a gradual, mixed-technology transition to next-generation vehicles over three decades, from 2000 to 2030. Over a 31-year horizon (1999 to 2030) this degree of new-fleet efficiency increase would average 3.8 percent per year, in line with the improvement trajectory deemed feasible over the next 12 years using conventional technologies alone. Any increase in driving that might be induced by the vehicle efficiency improvements is assumed to be offset by intermodal and other transport system improvements, leading to reductions in light duty vehicle use.

The fuel economy trajectory that would result from the policy package is shown in Figure 4. The on-road values estimate real-world fuel economy for all cars and light trucks (new and used) in a given year. Relative to 1998, the policy package would attain a 32 percent improvement in on-road fuel economy by 2010 and a 92 percent improvement by 2020.

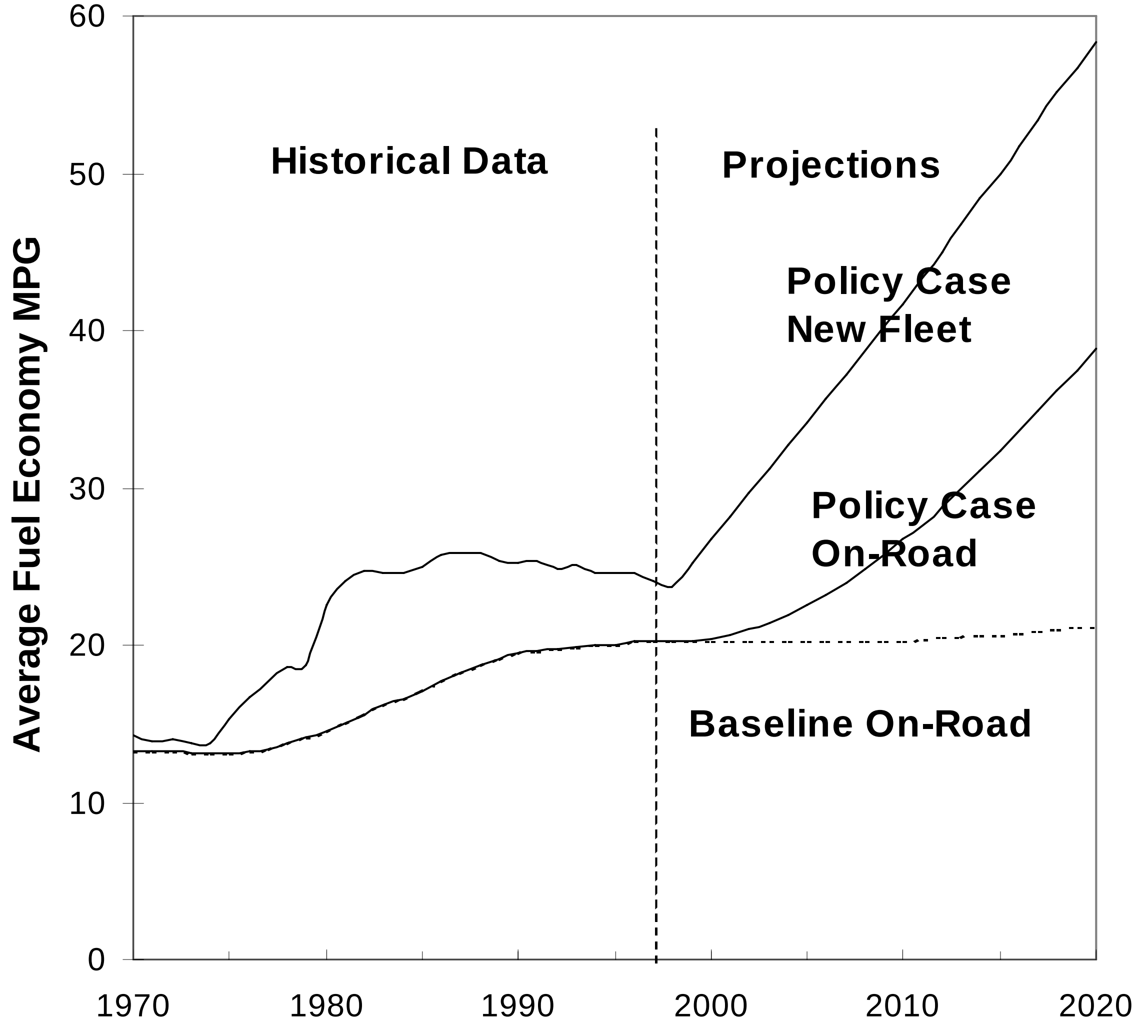
Increasing vehicle efficiency requires investments in improved technologies, implying slightly higher average costs for new vehicles. Near-term improvements will entail refinements to conventional vehicle designs, which are likely to dominate the market through 2010. Over time, advanced designs such as electric hybrids and fuel-cell powered vehicles with low-mass structures would increase in market share.

We estimate that in 2010, the retail price increment averages $767 per vehicle in order to achieve an average fuel economy of 41.7 mpg. By 2020, assuming success of the PNGV bolstered by ongoing market-pull policies, new vehicles are assumed to cost about $1,900 more on average than today's vehicles of comparable size and performance. These incremental costs are based in part on the economies of scale that will result if the fuel economy of all new vehicles is steadily improved.

The combined impacts of the fuel economy strategy leads to substantial energy and GHG emission reductions that deepen over time. Lags in stock turnover delay the start of significant energy savings until around 2005, but savings grow as newer, higher-efficiency vehicles replace older ones. Energy use by light-duty vehicles dips by 2010 to 13.5 Quads and continues to decline to 10.4 Quads by 2020 (see Table 4). Energy use is 20 percent below the baseline level of 17.8 Quads in 2010 and 46 percent below the baseline level of 19.2 Quads in 2020.

In the policy case, light vehicles emit 340 MMT of carbon per year in 2010, 108 MMT below the baseline forecast. By 2020, carbon emissions are reduced to 262 MMT, 10 percent lower than in 1990, and over 46 percent below the 2020 baseline of 484 MMT (see Table 4). It should be noted that these values assume continued reliance on petroleum as the dominant fuel source. A shift towards less carbon-intensive fuels would result in even lower carbon emissions.

Figure 4: Average Fuel Economy of Light Duty Vehicles



New fleet MPG is the composite EPA city/highway unadjusted average of the new car and new truck fleets. On-Road MPG is average of all new and used vehicles adjusted to reflect real-world driving conditions.

Technology improvements offering higher fuel economy should be pursued hand-in-hand with efforts to greatly reduce criteria emissions. Advanced technologies, particularly electric drivetrains using hybrid or fuel-cell designs, offer major reductions of VOC, CO, NOx, and PM emissions. Although not estimated here, clean air benefits of the advanced vehicle strategy outlined here will be substantial.

Fuel price savings exceed costs from the start because near-term opportunities for vehicle fuel economy improvements have very low incremental costs. All of the pre-2010 efficiency gains are through refinements of conventional vehicle technology, which in the near term largely come from the application of existing technologies re-optimized for higher fuel economy rather than for higher acceleration as has been seen in recent years. We do not monetize the additional benefits of avoided air pollution and petroleum supply externalities. Through 2010, the net present value of incremental technology investment costs amounts to $50 billion. But over the lifetime of these vehicles, the net present value of the fuel savings is $119 billion, implying a net economic gain of $69 billion for consumers.

The United States imported 3.2 billion barrels of crude oil and petroleum products in 1997, net imports equaled about 48 percent of its petroleum supplies.[7] The import fraction is projected to increase to 60 percent by 2010 in the Reference Case Forecast (EIA 1997a). If the policy package is implemented, annual oil savings from transportation would equal 810 million barrels in 2010, enough to reduce projected net petroleum imports that year by 15 percent.

[7] This import fraction accounts for both imports and exports of crude oil and petroleum products.

COMBINED HEAT AND POWER

Opportunity

Conventional electricity generation is relatively inefficient, converting only about one-third of the fuel's potential energy into useful energy. Engineers have long appreciated the tremendous efficiency opportunity of combining electricity generation with serving thermal loads in buildings and factories, which converts as much as 90 percent of the fuel input into useful energy. Combined heat and power (CHP) systems initially consisted primarily of boilers that generated steam, some of which was used to turn steam turbines that generated electricity. Due to the cost and complexity of these systems, they were mostly confined to sizes of more than 50 $MW_{e,}$[8] precluding their installation at many manufacturing facilities or in commercial buildings.

Recent advances in electricity generation technologies, in particular advanced combustion turbines and reciprocating engines, are reducing system costs, enabling much smaller CHP systems and increasing potential electricity output per unit of fuel input. Combustion turbines are now cost-effective in many applications down to 500 kW_e and reciprocating engines can be cost-effective down to 50 kW_e, with even smaller equipment on the horizon. This smaller equipment dramatically expands the number of sites where CHP can be installed. In fact, a turbine or engine can replace existing fuel burners in some existing boilers, adding electricity generation capability while reducing on-site emissions of pollutants (Interlaboratory Working Group 1997).

In the past two decades, interest in CHP has been spurred by the Public Utilities Regulatory Policies Act (PURPA). PURPA played a critical role in moving cogeneration into the marketplace by addressing many barriers that were present in the 1970s and early 1980s. These barriers included high standby charges from utilities and unwillingness to buy excess power.

The 1990s saw a change in the power market with the emergence of independent power producers (IPP) who did not need to find a use for waste heat. "Avoided costs" were falling rapidly, driven by declining fuel costs and changes in generation mix. Rather than buying power at their avoided cost, utilities were purchasing power in wholesale markets based on market conditions. Concurrently, many utilities increased standby charges to cogenerators in part to discourage cogeneration and the resulting loss of sales revenue. These developments slowed, but by no means eliminated, expansion of cogeneration capacity during the 1990s (Poirier 1997).

Reliable data on CHP systems are only available since the early 1990s. In 1995, CHP provided 42 GW_e of electricity generation capacity, accounting for about 6 percent of total U.S. generating capacity. The industrial sector accounted for over three-quarters of this generation

[8] $_e$ signifies electricity.

(EIA 1997d). In the early 1990s, about three GW_e of new CHP capacity were added annually. The number of new projects, however, has declined in recent years from 81 in 1994 to 46 in 1996 (Poirier 1997). Interest in CHP among end-users remains strong but implementation is inhibited by the barriers discussed below.

The EIA's Reference Case Forecast projects only modest growth in CHP capacity for the coming decade, with 49.3 GW_e of capacity and 299 TWh of power generation by 2010 (EIA 1997a). This projection assumes net additions of only 550 MW_e per year on average during 1995-2005 and 280 MW_e per year during 2005-2010. The EIA actually projects a slight decline in CHP capacity during 2010-2020. This is in spite of large untapped CHP potential; for example, the chemicals industry has developed only about 30 percent of its total cogeneration potential and only about 10 percent of the potential at sites with under 40 MW_e of peak electric demand (Bryson, Major, and Davidson 1998).

CHP implementation in Europe far outstrips that in the United States. For example, the fraction of electricity generation provided by CHP systems exceeds 30 percent in the Scandinavian countries. CHP is a key element in the climate change mitigation strategies of many of our industrialized trading partners, including the United Kingdom, Denmark, Sweden, the Netherlands, and Germany. In 1997, the European Commission proposed a strategy for further encouraging the development of CHP systems and removing barriers to their market penetration (Cogen Europe 1997).

Barriers

Although the technical performance and cost of CHP systems have greatly improved, significant barriers limit widespread use of CHP in the United States (Casten and Hall 1998). These barriers influence investments in capital equipment and tend to "lock-in" continued use of polluting and less-efficient infrastructure of electricity generation equipment. The main barriers to CHP include the following:

(1) *Environmental Policies*—Environmental permitting for CHP systems is complex, costly, time consuming, and uncertain. Air pollution permits are required from state environmental authorities before plant construction can begin. Current environmental regulations do not recognize the overall energy efficiency of CHP, or credit the emissions avoided from displaced electricity generation.

(2) *Utility Policies*—Many utilities currently charge discriminatory backup rates and require overly complex interconnection arrangements. Increasingly, utilities are charging (or are proposing to charge) prohibitive “exit” and/or “transition” fees to customers who build CHP facilities.

(3) *Tax Policies*—Depreciation schedules for CHP investments vary depending on system ownership. The depreciation period can be as long as 39 years for some types of owners, far longer than the depreciation period for utility-owned power plants. Also, the varying depreciation period limits the use of alternative financing or ownership arrangements.

Strategy

Experts are confident that the declining trend in new projects can be reversed, and significant new CHP capacity could be installed if these barriers are removed (Casten and Hall 1998; Davidson 1998; Kaarsberg and Elliott 1998). We propose a multifaceted strategy that involves changes in policy and regulations by both the federal government and the states. Our strategy addresses all of the major barriers to CHP deployment discussed above.

(1) *Set up expedited permitting for CHP systems*. Permitting for CHP systems that use standardized engines and turbines should be streamlined. All developers should be allowed to start building CHP systems at their own discretion, with operation dependent on complying with air pollution rules. While the EPA can recommend new procedures, it will be up to state environmental agencies to implement this policy.

(2) *Implement output-based air pollution regulations.* CHP's efficient use of energy will be recognized if permitting is based on the emissions per unit of *usable energy out* rather than *per unit of fuel consumed*. The EPA should adopt output-based standards for NOx and other criteria pollutants accounting for both the useful heat and power produced by CHP systems.

(3) *Address issues of utility access and stranded-cost recovery through a national restructuring bill, FERC jurisdiction, and actions by individual states.* Some states, such as Massachusetts, have already enacted restructuring plans that give favorable treatment to CHP by exempting owners of CHP systems from paying for stranded cost recovery. However, other states, like Pennsylvania, have rejected such measures (Bluestein 1998). Likewise, some states allow their utilities to specify overly complex interconnection procedures as well as charge high rates for backup power. The federal government should pass legislation either requiring favorable treatment at the state level or at least recommending that states adopt such policies on their own.

(4) *Establish a common classification of CHP investments so that all systems have a single depreciation schedule that reflects the economic life of the equipment.* In particular, we recommend a standard depreciation period of seven years for all new CHP systems. This is similar to the depreciation period for reciprocating engines and gas turbines that are used in mobile applications.

Analysis

Estimating the potential for increased installation of CHP is difficult because of a broad range of system types and large numbers of potential sites. If the barriers are removed, it is anticipated that much of the early capacity additions will occur at larger industrial and district energy sites that already have existing, large boiler systems. As time progresses, smaller industrial, institutional, and commercial facilities will begin to constitute a greater portion of the new capacity. New district energy systems, which consolidate the thermal demands of several facilities or buildings, will take longer to develop because of their complexity.

A number of studies have attempted to quantify the electric generation capacity potential from increased implementation of CHP. These studies have used varying data sources and approaches. One approach is based on the steam generation capacity of the existing inventory of boilers (ICF Kaiser 1997; Interlaboratory Working Group 1997) and assumptions on the form of CHP implemented and economics of operation. Another approach is based on annual steam generation data (Bernow et al. 1997; Energy Innovations 1997; Interlaboratory Working Group 1997), with assumptions about boiler operating characteristics and average ratio of electricity to steam production. Both approaches have yielded results of similar order of magnitude.

DOE and EPA convened a group of experts[9] in the fall of 1997 to compare these projections and develop a consensus regarding achievable CHP potential. The results of this meeting are presented in Table 5. ACEEE has used this estimate of achievable CHP potential as the basis for its analysis, which projects the levels of CHP implementation in the Policy Case shown in Figure 5. Table 6 also presents the key assumptions and results of this analysis. Subsequent analyses indicate that there may be significant additional potential through district heating and smaller scale CHP systems (Kaarsberg et al. 1998; Spurr 1998).

By 2010, we estimate that a total of 100 GW_e of CHP can be implemented if the barriers are removed to a large degree, thereby doubling installed capacity compared to the EIA "business-as-usual" forecast. We estimate that this additional capacity will produce 195 TWh (4.9 percent of conventional electricity generation) with a net energy savings of 1,500 TBtu (1.5 Quads) (see Appendix E). The net energy savings account for some additional energy use on-site. The additional CHP capacity climbs to 90 GW_e by 2015 and 144 GW_e by 2020, equivalent to 14.5 percent of the installed electric generating capacity in 2020 (excluding cogeneration capacity) in the EIA's Reference Case Forecast. By 2020, the additional CHP capacity will displace 562 TWh (12.6 percent) of conventional electricity generation and will result in net energy savings of about 3.9 Quads.

[9] Experts included Steve Bernow, Tellus Institute; Joel Bluestein, Energy and Environment Analysis; Peter Carroll, Solar Turbines; Keith Davidson, Onsite Energy; Neal Elliott, ACEEE; Mark Hall, Trigen; Tina Kaarsberg, Northeast Midwest Institute; Skip Laitner and Joe Bryson, EPA; Mark Spurr, International District Energy Association; and John Atcheson and David Bassett, Office of Energy Efficiency and Renewable Energy, U.S. DOE.

Overall CHP system efficiency (useful energy output divided by fuel input) varies with configuration, from 50 percent for some smaller reciprocating engine-based systems to over 80 percent for some larger turbine-based systems. System efficiency also varies with the ratio of electricity and/or mechanical power to heat energy generated (e.g., steam), with the most efficient systems having power-to-heat ratios of less than 0.5. Average overall system efficiency in our analysis is approximately 70 percent, with an average power-to-heat ratio of 0.5. This implies an electricity-only efficiency of 23 percent and a thermal-only efficiency of 47 percent.

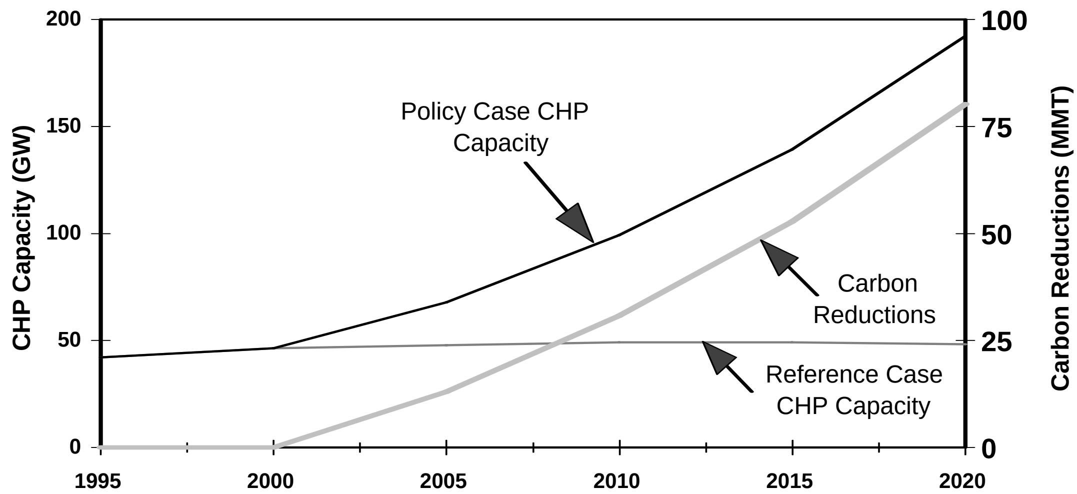
Table 5: Potential Electricity Generation Capacity and Carbon Reductions from CHP Systems in 2010.

	Carbon Reduction MMT/year	**Capacity GW (electricity)**
Current Trend (EIA 1997b)	—	**49**
Technical Potential[1]		
industrial/comm.	80	100+
district energy	27	60
total	107	160+
Achievable Potential[2]		
industrial/comm.	27 (16-37)	34
district energy	7 (7-10)	15
Total	34 (30-40)	49

[1] Technical Potential, in this instance, refers to 100 percent of technically and economically justified CHP.
[2] Achievable Potential takes into account the limitations of the supply infrastructure in implementing systems.
Source: DOE 1997.

Since less fuel is burned to generate the same amount of energy, emissions of carbon dioxide and other pollutants are reduced. These reductions are made even more dramatic because most CHP systems are fueled with natural gas and have very low emissions, while over 55 percent of our nation's electricity is currently generated in coal-burning power plants (EIA 1997b). The inherent efficiency of CHP along with the shift to less carbon-intensive and cleaner fuel allows carbon to be reduced by 18 MMT by 2005, increasing to 43 MMT by 2010. By 2020, a carbon emissions reduction of 111 MMT can be expected if the CHP capacity expands to the degree assumed (see Table 6).

Figure 5. Installed U.S. CHP Capacity and Avoided Carbon Emissions.



Source: ACEEE estimates

Table 6. Estimated Impacts from the Accelerated Adoption of Combined Heat and Power Systems.

	2000	2005	2010	2015	2020
CHP Capacity—Reference Case (GW_e)	46.4	47.9	49.3	49.3	48.3
CHP Capacity—Policy Case (GW_e)	46.4	68	99	139	192
Displaced Utility Generation (TWh)	—	78	195	351	562
Net Energy Savings (TBtu)	—	625	1,508	2,520	3,916
Net Energy Cost Savings (million $)	—	3,230	7,350	11,480	17,320
Cumulative Capital Expenditure (million $)	—	13,000	32,500	58,500	93,600
Emissions Reductions	—				
Carbon (MMT)	—	18.1	42.6	73.1	111.1
SO_2 (MMT)	—	0.32	0.81	1.46	2.33
NOx (MMT)	—	0.15	0.37	0.66	1.05

Table 6 includes our estimates of the avoided SO_2 and NOx emissions from CHP adoption.[10] While most of these reductions come from avoided utility electricity generation, some also come from reduced on-site emissions. CHP is an economic approach to reducing air pollutants because it increases thermal efficiency, which saves fuel and the resulting emissions. Traditional pollution control techniques, on the other hand, are less cost-effective and can reduce overall thermal efficiency.

Because of the diversity of system configurations, permitting issues, system sizes, and repowering versus new construction, it is difficult to generalize about the incremental cost of adding CHP capacity. Larger systems (greater than 50 MW_e) tend to have lower costs per unit of capacity, often less than $500 per installed kW_e. The incremental installed cost for smaller systems can approach $1,000 per kW_e, though in some cases the cost of permitting can approach a quarter of this cost. Based on discussions with experts (Carroll 1998; Davidson 1998; Hall

[10] This strategy may not result in overall reduction in SO_2 and NOx emissions in the aggregate since these emissions are or will be covered by emissions caps. This strategy (and others proposed in this report) will make it easier to meet the emissions caps.

1998; Parks 1998), ACEEE has elected to use an installed cost of $650 per kW_e. This may represent an overly conservative assumption since we anticipate a majority of the new capacity installed by 2010 will be large systems in industrial facilities.

The projected additional 50 GW_e of CHP capacity installed by 2010 would require a cumulative investment of $ 32.5 billion and would yield net energy cost savings of $7.3 billion per year by 2010. This implies an average simple payback of 4.4 years. The net present value of the energy cost savings over the lifetime of additional CHP capacity installed during 1999-2010 equals $73.5 billion, 3.3 times the net present value of investments made during 1999-2010. These calculations do not include potential savings from avoiding on-site pollution control equipment, or the potential economic value of avoided SO_2, NOx, and CO_2 emissions.

REDUCING POWER SECTOR CARBON EMISSIONS

Opportunity

In 1996, U.S. electric generators (excluding cogenerators) emitted 517 MMT of carbon. The EIA's Reference Case Forecast projects electric generator emissions to grow to 663 MMT by 2010 (EIA 1997a). Opportunities to reduce power sector carbon emissions (apart from greater end-use efficiency and expanded use of CHP) are two-fold: (1) to improve the efficiency of electric generating plants, by using less fuel per kWh produced; and (2) to switch to less carbon-intensive fuels (e.g., towards renewable energy and natural gas, and away from coal and oil).

The heat rate of fossil fuel power plants (Btus of fuel consumed per kWh generated) has declined from 15,100 Btu per kWh in 1949 to 10,600 Btu per kWh in 1996 (EIA 1997b). Expressed differently, the average efficiency of fossil fuel plants has increased from about 23 percent to 32 percent.[11] EIA projects that average efficiency will continue to rise as older power plants are retired and new combined-cycle and other higher-efficiency power plants are added. Specifically, EIA projects that the average efficiency will reach about 36 percent (9,600 Btu per kWh) in 2010 and 38 percent (9,100 Btu per kWh) in 2020 (including utility and non-utility power producers) (EIA 1997a). However, the most efficient combined-cycle plants now being sold commercially have efficiencies on the order of 52 percent and heat rates around 6,600 Btu per kWh (Linden 1997). Thus, on a technical potential basis, if all fossil fuel power plants were replaced with units with an average efficiency of 52 percent, power sector emissions in 2010 would decline about 30 percent, cutting carbon emissions by about 190 MMT. Furthermore, if this generation all came from natural gas plants, carbon emissions would decline by a further 32 percent (an additional 215 MMT) relative to the EIA's Reference Case Forecast for 2010.

Of course, replacing all existing fossil fuel power plants with state-of-the-art natural gas plants is prohibitively expensive, and relying overwhelmingly on natural gas raises serious questions about fuel availability and dependency on a single fuel. Still, additional heat rate improvements averaging 10 percent or so appear feasible, as would some additional shift away from carbon-intensive fuels. Coal alone accounted for 57 percent of electric utility generation in 1997 and the fraction of electricity produced by coal-fired power plants actually has risen slightly in recent years (EIA 1998).

Barriers

Barriers to carbon emissions reductions in the power sector are several-fold. First, the large sunk capital costs in carbon-intensive and relatively inefficient existing power plants limits the cost-effective carbon reduction potential. High-efficiency natural gas plants are generally

[11] Efficiencies used throughout this section are based on the higher heating value of fossil fuel, which is the convention used in the United States.

cheaper per kWh than new coal plants. But new high-efficiency gas plants can compete with only a small fraction of existing coal plants. However, as discussed below, the substitution potential becomes much greater if a moderate cost penalty is accepted. Second, coal companies, coal miners, and owners of coal-fired power plants are strongly opposed to efforts to restrict emissions from coal-fired plants. This makes it difficult to close existing power plants and shift fuels on political grounds, even where it is economically viable. Third, under existing Clean Air Act regulations, old, high-polluting plants are "grand fathered" and need to meet less stringent emissions standards than new plants, be they gas- or coal-fired. This encourages life extension of existing plants and discourages building new capacity. And fourth, competitive pressures and restructuring are leading to increases in availability and operation of existing low-cost (often coal) power plants in the short run. Some observers expect this trend will continue. For example, Paul Joskow wrote recently:

> However, competition may increase incentives to continue to maintain and operate low-cost coal-fired plants in the U.S. that have operating costs below the costs of new CCGT [combined-cycle, gas-turbine] facilities that might have been retired under the old regime, as these plants will have new unregulated markets to serve. In the U.S., my guess is that the life extension effort will be larger than the retirement effect in the medium term, absent major changes in air pollution rules governing emissions of NOx, particulates, and carbon dioxide which require major retrofit investments or increase significantly the effective cost of burning coal in existing facilities (Joskow 1998).

Strategy

Several strategies have been proposed to address these barriers and obtain power sector carbon reductions. Probably the simplest is to implement a "cap and trade" program for power sector (or multi-sector) carbon emissions, similar to the SO_2 cap and trading scheme established by the Clean Air Act Amendments of 1990. Such a scheme would limit carbon emissions to a pre-determined amount, such as at 1990 emissions levels. Under such a system, since emissions allowances are fully tradable, the market will determine the most economically efficient way to reach these levels through a combination of heat rate improvements, fuel switching, and improvements in end-use efficiency. The constraints on implementing a carbon cap and trade system are political—the utility and coal industries and their allies strongly oppose adopting carbon emissions caps.

Alternatively, standards could be imposed on average heat rate, with allowable heat rates progressively reduced over time. As with carbon emissions caps, trading could be allowed, in that generators that are below the prevailing heat rate cap could earn credits that could be sold to less efficient generators, allowing the market to determine the most economically efficient way to meet the requirements. Such a proposal has been advanced by Bayless and Casten (1997), two energy industry CEO's. The advantage of such a system is that it is fuel neutral and thus is not likely to generate as severe opposition from the coal industry. Another advantage is that it could stimulate implementation of combined heat and power systems (an important energy efficiency strategy discussed previously in this report), if credit is provided for any useful thermal energy ("waste heat") obtained from power plants or cogeneration facilities. This policy could stimulate some fuel switching in that lower heat rates are more easily achieved with natural gas.

Another complementary strategy is a renewable energy portfolio standard (RPS). Such a standard requires that a set percentage of each generator's output must come from renewable sources, but permits trading among generators so that generators with excess renewable energy allowances can sell them to generators without adequate allowances. An RPS has been adopted by a number of states and is included in a number of federal utility restructuring proposals. We do not consider the potential carbon emissions reductions from an RPS in our analysis of energy efficiency strategies.

Analysis

Estimating carbon emissions reductions from the different strategies is relatively easy. Estimating economic impacts is much harder. If a carbon cap and trade system were implemented capping power sector emissions at 1990 levels for 2010, then emissions would be no greater than 447 MMT in 2010, 186 MMT (28 percent) less than the EIA's Reference Case Forecast for 2010. A portion of this reduction could be provided through end-use efficiency improvements (e.g., stimulated by new efficiency standards and/or a PBF) and a portion through supply-side efficiency improvements and fuel switching.

If a heat rate cap of 8,600 Btu per kWh were imposed (10 percent below the EIA's Reference Case Forecast for 2010), carbon savings would modestly exceed 10 percent (e.g., 66 MMT), due largely to the direct heat rate improvement and secondarily to the fact that coal plant heat rates are on average higher than gas, so a heat rate reduction requirement would likely stimulate some fuel switching. Reducing the heat-rate cap an additional 10 percent to 7,700 Btu per kWh in 2020 would cut emissions that year by at least 115 MMT (15 percent) relative to those in the EIA Reference Case Forecast. Likewise, EIA has estimated the carbon savings from an RPS, estimating that requiring 5 percent of 2020 generation to come from non-hydro renewables would reduce carbon emissions 15 MMT in 2010 and 27 MMT in 2020, while a 10 percent requirement in 2020 would cut emissions 32 MMT in 2010 and 63 MMT in 2020 (EIA 1997a).

Economic impacts of these policies are much harder to estimate. The Clean Air Taskforce estimates that power sector carbon emissions can be reduced to 11 percent below the 1990 level (i.e., a carbon savings of 155 MMT) by retiring 30 percent of the existing stock of fossil plants (the dirtiest units) and replacing them with state-of-the-art gas-fired plants. Such a program would also substantially reduce emissions of NOx, hydrocarbons, and other pollutants. It would also help to correct the market distortion of grand fathering old plants from new source performance standards. According to their analysis, these environmental benefits could be obtained while increasing electric rates by an average of only 2-3 percent relative to a no-new-regulation scenario (Brick 1998). A key assumption in this analysis is that a typical new combined-cycle gas plant can produce electricity for only $0.0275 per kWh.

An analysis by the Interlaboratory Working Group (1997) for DOE estimates potential carbon reductions from low-cost re-dispatching, retirements, and new construction. According to this study, these actions can reduce carbon emissions in 2010 by 33-77 MMT with a net increase in power production cost of $2.2 billion—about 1 percent of project utility sector revenues in 2010.

In summary, we believe it would be reasonable to achieve at least 65 MMT of carbon emissions reductions in 2010 and 115 MMT of reductions in 2020 from supply-side efficiency improvements plus low-cost fuel switching. These reductions should be possible at relatively low net cost (on the order of $2 billion in 2010), prompted by policies such as a power plant heat rate standard or carbon emissions cap and trading system.

CONCLUSION

The five energy efficiency initiatives presented above could make a major contribution towards meeting the U.S. goal under the Kyoto Protocol. Given current trends, the Energy Information Administration projects that U.S. carbon emissions will increase to 1,803 MMT by 2010 compared to 1990 emissions of 1,346 MMT (EIA 1997a). In order to achieve our Kyoto target, carbon emissions in 2010 will need to be reduced to 1,298 MMT or less.[12] In others words, a reduction of around 505 MMT per year is required by around 2010, relative to the "business-as-usual" forecast of carbon emissions that year, for U.S. compliance with the Protocol during the first budget period.

Table 7 summarizes our estimates of the potential impacts of the five energy efficiency strategies. Taken together, the five initiatives could lower carbon emissions in 2010 by about 310 MMT, about 61 percent of the estimated carbon reduction needed to meet the Kyoto target. This level of reduction is equivalent to about 21 percent of total U.S. carbon emissions as of 1997 and 17 percent of the 1,803 MMT projected in 2010 in the EIA's Reference Case Forecast (Figure 6). Fuel economy improvements in light vehicles provide about 35 percent of the total carbon reductions, followed by the federal Public Benefits Fund at 22 percent of the total, power supply improvements at 21 percent, CHP promotion at 14 percent, and appliance standards and related voluntary programs at 8 percent.

The carbon emissions reductions could increase substantially by 2020 as efficiency improvements continue to be made and more appliances, buildings, vehicles, and power plants are replaced. Specifically, we estimate that the five initiatives could lower carbon emissions in 2020 by around 603 MMT, 31 percent of projected emissions of 1,956 MMT that year in the EIA's Reference Case Forecast (Figure 6). By 2020, the five energy efficiency initiatives alone could return U.S. carbon emissions to nearly their level of 1990.

Table 7 also summarizes the estimated economic impacts of the five energy efficiency initiatives. Investments in efficiency measures through 2010 are estimated to cost $181 billion, but the net present value of energy cost savings over the lifetime of these measures is estimated to equal $344 billion (all values in 1996 $). Thus, the energy bill savings exceed the costs of the measures by nearly a factor of two, resulting in a net economic benefit of $163 billion. The net economic benefits would increase if measures installed after 2010 were included in the analysis. Furthermore, these figures are conservative in that they do not consider non-energy benefits (e.g., reduced damages from air pollution abatement or reduced vulnerability to oil price shocks

[12] The Kyoto goal is to cut U.S. GHG emissions to 7 percent below their 1990 levels. In order to achieve this goal, we assume that carbon emissions must be reduced to 3 percent below their 1990 level with the remainder of reductions achieved through increasing carbon sinks, disproportionate reductions in other greenhouse gases, and international trading.

from lower oil imports), the downward pressure on energy prices resulting from lowering energy demand, or potential capital cost reductions as markets for the energy efficiency measures grow.

Table 7: Overall Carbon Emissions Reduction and Economic Impacts.

	Avoided Carbon Emissions (MMT)		Net Present Value of Costs and Savings for Measures Installed during 1999-2010 (billion $)		
Strategy	2010	2020	Cost	Savings[(1)]	Net Benefit
Appliance Standards	25	44	13	28	15
Public Benefit Fund	69	111	86	124	38
Vehicle Efficiency Package	108	222	50	119	69
CHP Initiative	43	111	22	73	51
Power Plant Initiative	65	115	~10	—	-10
TOTAL	310	603	181	344	163

(1) The net present value of energy savings over the lifetime of energy efficiency measures installed during 1999-2010.

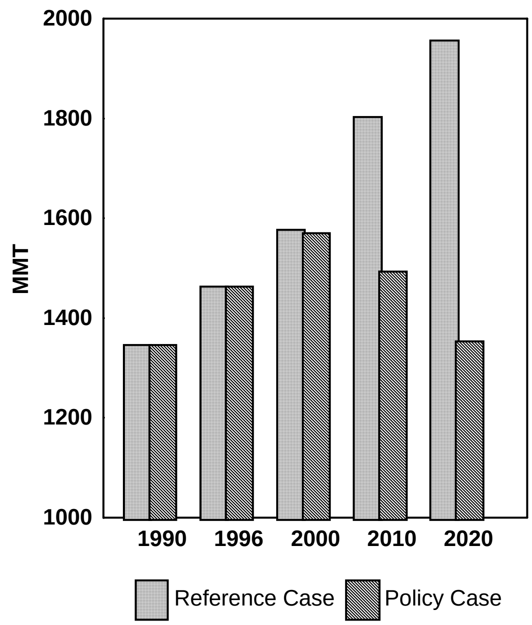
Our economic analysis is consistent with other studies of the economic impacts of reducing U.S. GHG emissions (Laitner, Bernow, and DeCicco 1998; Repetto and Austin 1997). If we are intelligent about the policies and measures used to reduce GHG emissions, we can achieve substantial reductions with a net economic gain, not an economic penalty. In fact, we estimate that our five measures could provide a net economic savings of around $50 billion per year in 2010 (energy bill savings minus the cost of measures installed that year). This is equivalent to about 8 percent of the forecasted national energy bill that year in the Reference Case Forecast and about 0.5 percent of GDP forecasted that year.[13]

It is important to note that these five energy efficiency initiatives by no means exhaust the opportunities for cost-effective energy efficiency gains. Further reductions could result from:

[13] This estimate assumes average growth in GDP of 2.2 percent per year during 1996-2010.

(1) increasing the efficiency of new buildings through greater adoption of state-of-the-art building codes, better builder training and code enforcement, and related voluntary programs; (2) reducing the energy intensity of major industrial processes through incentives for innovation and capital stock turnover; (3) initiatives to increase the energy efficiency of freight transport; and (4) initiatives to restrain growth in vehicle use and vehicle-miles of travel.

Figure 6: Carbon Emissions Projections



Furthermore, additional emissions reductions could be achieved by accelerating the introductions of renewable energy sources and encouraging a shift to less carbon-intensive fossil fuels through policy instruments such as a renewable portfolio standard in the utility sector and financial incentives to encourage bioenergy-based fuels for transport applications. Other studies show that a more comprehensive set of energy efficiency and renewable energy initiatives could return U.S. carbon emissions to their 1990 level or less by 2010 with positive economic impacts (Bernow et al. 1997; Energy Innovations 1997; Interlaboratory Working Group 1997). The results of this study confirm and add further details to these earlier studies, pointing out again that confronting global warming could be a boon to the U.S. economy if we are smart about how we pursue GHG emissions reductions.

In summary, the five initiatives presented in this report should play a central role in the U.S. strategy for achieving our Kyoto target and for making further GHG emissions reductions over the longer term. For a few of our recommended initiatives, partial efforts are underway or proposed. This is the case for appliance efficiency standards and related voluntary programs, the federal public benefits trust fund, and the combined heat and power initiative. However, further actions are needed to fully implement these initiatives and achieve the maximum emissions and economic benefit. In the case of the vehicle fuel economy and power supply efficiency initiatives, little or no effort is being made at the present time to implement the policies we recommend. Action on vehicle fuel economy in particular is long overdue and is essential for achieving our GHG emissions reductions goals.

Appendix A: Key assumptions

	1995	2000	2010	2020
Energy price (1996 $)				
Residential electricity (cents/kWh)	8.5	7.8	7.3	6.8
Commercial electricity (cents/kWh)	7.6	7.2	6.5	6.0
Industrial electricity (cents/kWh)	4.8	4.3	3.9	3.5
Residential natural gas ($/TCF)	6.25	5.93	5.58	5.60
Commercial natural gas ($/TCF)	5.22	5.02	4.79	4.91
Industrial natural gas ($/TCF)	2.43	2.81	3.01	3.26
Gasoline ($/gal)[1]	1.18	1.21	1.26	1.27
Utility fossil fuel heat rate (Btu/kWh)	10,400	10,200	9,600	9,100
Utility emissions coefficients[2]				
Carbon emissions (MMT/TWh)	0.240	0.242	0.218	0.202
SO_2 emissions (thousand tons/TWh)	5.64	4.29	3.03	2.44
NOx emissions (thousand tons/TWh)	3.50	2.36	1.94	1.71

[1]Includes federal and state taxes
[2]Average emissions rates for all fossil fuel power plants.

Source: EIA 1997a

References

ADL [Arthur D. Little, Inc.]. 1996. *Energy Savings Potential for Commercial Refrigeration Equipment.* Prepared for the U.S. Department of Energy. Cambridge, Mass.: Arthur D. Little, Inc.

Appliance. 1996. "Statistical Review." *Appliance* 53(4):43-46.

———. 1998. "1998: The Beat Goes On." *Appliance* 55(1): 46-58.

Baxter, L. 1998. "Electricity Policies for Low-Income Households." *Energy Policy* 26(3): 247-256.

Bayless, Charles, and Thomas Casten. 1997. "Leave CO_2 to the Entrepreneurs" (Op Ed column). *Washington Post*. December 31: A21.

Bernow, Stephen, William Dougherty, Max Duckworth, Sivan Kartha, Michael Lazarus, and Michael Ruth. 1997. *Policies and Measures to Reduce CO_2 Emissions in the United States: An Analysis of Options for 2005 and 2010.* Boston, Mass.: Tellus Institute.

Bluestein, Joel. (Energy and Environmental Analysis, Inc.) 1998. Personal communication to Neal Elliott.

Brick, Steve. 1998. "Memorandum re: CO_2 Emission Reductions Resulting from Environmental Comparability Policy/Competition vs. The Kyoto Protocol." Boston, Mass: Clean Air Taskforce.

Bryson, Teresa, William Major, and Keith Davidson. 1998. "Chemical and Kilowatts." *Energy* xxiii (3): 26-28.

Calwell, Chris, Danielle Dowers, and Doug Johnson. 1998. *How Far Have We Come? Remaining Opportunities for Upgrading Fluorescent Ballasts and Lamps.* SM-98-4. Boulder, Colo: E Source, Inc.

Carroll, Peter. (Solar Turbines, Inc.) 1998. Personal communication to Neal Elliott.

Casten, Thomas R., and Mark C. Hall. 1998. *Barriers to Deploying More Efficient Electrical Generation and Combined Heat and Power Plants.* White Plains, N.Y.: Trigen Energy Corp.

Clinton, William. 1998. "Radio Address of President Clinton to the Nation." January 31.

Cogen Europe. 1997. *European Cogeneration Review 1997*. Brussels, Belguim: Cogen Europe.

Comnes, Alan, and Richard Barnes. 1987. *Efficient Alternatives for Electric Drives*. ORNL/TM-10415. Oak Ridge, Tenn: Oak Ridge National Laboratory.

Cowart, Richard. 1997. "Restructuring and the Public Good: Creating a National Systems Benefits Trust." *The Electricity Journal*. April.

Davidson, Keith. (OnSite Energy, Inc.) 1998. Personal communication to Neal Elliott.

DeCicco, J.M. 1997. *Developing a Market Creation Program to Promote Efficient Cars and Light Trucks.* Washington, D.C.: American Council for an Energy-Efficient Economy.

DeCicco, J.M., H.S. Geller, and J.H. Morrill. 1993. *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles*. Washington, D.C.: American Council for an Energy-Efficient Economy.

DeCicco, J.M., and M. Ross. 1996. "Recent Advances in Automotive Technology and the Cost-Effectiveness of Fuel Economy Improvement." *Transportation Research* D-1(2): 79-96.

DeLuchi, M.A. 1992. *Hydrogen Fuel Cell Vehicles*. UCD-ITS-RR-92-14. Davis, Calif.: Institute of Transportation Studies.

DOC [U.S. Department of Commerce]. 1994. *Partnership for a New Generation of Vehicles, Program Plan*. Washington, D.C.: U.S. Department of Commerce.

———. 1995. *Current Industrial Reports: Electric Lamps—MQ36B, Summary 1994.* Washington, D.C.: U.S. Department of Commerce.

DOE [U.S. Department of Energy]. 1997. "Combined Heat and Power: The Potential to Reduce Emissions of Greenhouse Gases" (Working Paper). Washington, D.C.: Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

———. 1998. "Life Cycle Cost of Clothes Washers—January 12 Draft (spreadsheet)." Washington, D.C.: U. S. Department of Energy.

DOS [U.S. Department of State]. 1997. *Climate Action Report*. Washington, D.C.: U.S. Department of State.

EIA [Energy Information Administration.] 1994. *Electric Power Annual 1994: Vol.*2. Table A.3. Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1995. *Household Energy Consumption and Expenditures 1993.* DOE/EIA-032(93). Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1996. *Annual Energy Outlook 1997.* Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1997a. *Annual Energy Outlook 1998*. DOE/EIA-0383(98). Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1997b. *Annual Energy Review 1996*. DOE/EIA-0384(96). Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1997c. Emissions of Greenhouse Gases in the United States, 1996. DOE/EIA-0573(96). Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———.1997d. *Manufacturing Energy Consumption Survey, 1994*. Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1997e. *Monthly Energy Review, December 1997.* Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1997f. *U.S. Electric Utility Demand-Side Management, 1996*. DOE/EIA-0589(96). Washington, D.C.: Energy Information Administration, U.S. Department of Energy.

———. 1998. *Monthly Energy Review May 1998*. DOE/EIA-0035(98/01). Washington, DC: Energy Information Administration, U.S. Department of Energy.

Energetics. 1998. *Status of State Activities on Public Purpose Programs.* Washington, D.C.: U.S. Department of Energy, Office of Utility Technologies.

Energy Innovations. 1997. *Energy Innovations: A Prosperous Path to a Clean Environment.* Washington, D.C.: Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists.

EPA [U.S. Environmental Protection Agency]. 1996. *Light-Duty Automotive Technology and Fuel Economy Trends Through 1996.* Ann Arbor, Mich.: U.S. Environmental Protection Agency.

Eto, J., S. Kito, L. Shown, and R. Sonnenblick. 1995. *Where did the Money Go? The Cost and Performance of the Largest Commercial Sector DSM Programs*. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Eto, J., E. Vine, L. Shown, R. Sonnenblick, and C. Payne. 1994. *The Cost and Performance of Utility Commercial Lighting Programs*. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

GAO [General Accounting Office]. 1996. *Changes in Electricity-Related R&D Funding*. GAO/RCED-96-203. Washington, D.C.: General Accounting Office.

Geller, H.S., and D.B. Goldstein. 1998. *Equipment Efficiency Standards: Mitigating Global Climate Change at a Profit.* Washington, D.C.: American Council for an Energy-Efficient Economy and San Francisco, Calif.: Natural Resources Defense Council.

Geller, H.S., and J. Thorne. 1998. *U.S. Carbon Emissions Climb in 1997.* Washington, D.C.: American Council for an Energy-Efficient Economy.

Greene, D.L. 1998. “Why CAFE Worked.” *Energy Policy* (forthcoming).

Hall, Mark. (Trigen, Inc.) 1998. Personal communication to Neal Elliott.

ICF Kaiser. 1997. *Revised Analysis of Cogeneration Economic Potential (Draft)*. Washington, D.C.: ICF Resource.

Interlaboratory Working Group. 1997. *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond*. LBNL-40533 and ORNL-444. Berkeley, Calif.: Lawrence Berkeley National Laboratory and Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Joskow, Paul L. 1998. “Electricity Sectors in Transition.” *The Energy Journal* 19(2): 25-52.

Kaarsberg, Tina, Joel Bluestein, Joseph Romm, and Arthur Rosenfeld. 1988. “The Outlook for Small-Scale CHP in the USA.” *CADDET Energy Efficiency Newsletter* June.

Kaarsberg, Tina, and Neal Elliott. 1998. “Combined Heat and Power: Saving Energy and the Environment.” *Northeast-Midwest Economic Review* March/April: 4-10.

Laitner, Skip. 1997. *What You Measure Is What You Get: The Benefits of Technology Investment as a Climate Change Policy*. Washington, D.C.: U.S. Environmental Protection Agency, Office of Atmospheric Programs.

Laitner, Skip, Stephen Bernow, and John DeCicco. 1998. “Employment and Other Macroeconomic Benefits of an Innovation-Led Climate Strategy for the United States.” *Energy Policy* 26(5): 425-432.

LBNL [Lawrence Berkeley National Laboratory]. 1996. *Draft Report on Potential Impacts of Alternative Efficiency Levels for Residential Cooking Products*. Washington, D.C.: U.S. Department of Energy, Office of Codes and Standards.

Linden, Henry R. 1997. “Operational, Technological and Economic Drivers for Convergence of the Electric Power and Gas Industries.” *The Electricity Journal* 10(4): 14-25.

Mark, J. 1996. *Zeroing Out Pollution: The Promise of Fuel Cell Vehicles*. Cambridge, Mass.: Union of Concerned Scientists.

Nadel, S., and H. Geller. 1996. “Utility DSM, What Have We Learned? Where Are We Going?” *Energy Policy* 24(4): 289-302.

Nadel, S., S. Laitner, Marshall Goldberg, R. Neal Elliot, J. DeCicco, H. Geller, and R. Mowris. 1997. *Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Nadel, S., and L. Latham. 1998. *The Role of Market Transformation Strategies in Achieving a More Sustainable Energy Future*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Nadel, S., M. Pye, and J. Jordan. 1994. *Achieving High Participation Rates: Lessons Taught by Successful DSM Programs.* Washington, D.C.: American Council for an Energy-Efficient Economy.

Nadel, S., and M. Suozzo. 1998. *Selecting Targets for Market Transformation Programs: A National Analysis*. Washington, D.C.: American Council for an Energy-Efficient Economy.

Nauss, Donald. 1997. “Fuel Cells: Top Engine of Change.” *L.A. Times*. August 13: A1, A7.

NEMA [National Electrical Manufacturers Association]. 1997. *Comments on the LBL Draft Report on Potential Impacts of Possible Energy Efficiency Levels for Fluorescent Lamp Ballast, Ballast Docket EE-RM-97-500.* Arlington, Va.: National Electrical Manufacturers Association

ORNL [Oak Ridge National Laboratory]. 1997. *Determination Analysis of Energy Conservation Standards for Distribution Transformers.* ORNL-6847. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Parks, William (U.S. Department of Energy). 1998. Personal communication to Neal Elliott.

Poirier, Jean-Louis. 1997. “Global Power Market Forecast: The Prospects to the 21st Century.” Paper presented at the Twelfth Annual Cogeneration and Independent Power Market Conference, New Orleans, La., March 23-24.

Repetto, Robert, and Duncan Austin. 1997. *The Costs of Climate Protection: A Guide for the Perplexed*. Washington, D.C.: World Resources Institute.

Sanchez, Marla. 1997. *Miscellaneous Electricity Use in U.S. Residences.* Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Scheer, R., J. Brinch, and J. Eto. 1998. *Maintaining Support for Public Purpose Programs in Competitive Electricity Markets: An Analysis of the Proposed National Systems Benefits Trust* (Draft). Washington, D.C.: Energetics and Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Spurr, Mark. 1998. *District Energy Systems Integrated with Combined Heat and Power: Analysis of Environmental and Economic Benefits: Interim Report*. Washington, D.C.: International District Energy Association.

Stout, Timothy, and William Gilmore. 1989. "Motor Incentive Programs: Promoting Premium Efficiency Motors." Paper presented at the Electric Council of New England Demand-Side Management Conference, Boston, November.

Thorne, Jennifer, and Margaret Suozzo. 1998. *Leaking Electricity: Standby and Off-Mode Power Consumption in Consumer Electronics and Household Appliances.* Washington, D.C.: American Council for an Energy-Efficient Economy.

White House, The. 1998. *Climate Change Technology Initiative—1999 Budget Briefing Materials*. Washington, D.C.: The White House.

Williams, R.H., E.D. Larson, R.E. Katofsky, and J. Chen. 1995. “Methanol and Hydrogen from Biomass for Transportation.” *Energy for Sustainable Development* 1(5): 18-34.

Yellen, Janet. 1998. "Testimony before the House Commerce Committee on the Economics of the Kyoto Protocol." March 4.