MEETING AMERICA'S KYOTO PROTOCOL TARGET: POLICIES AND IMPACTS

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EXECUTIVE SUMMARY

In December 1997, 160 nations negotiated and reached agreement on the Kyoto Protocol to the Framework Convention on Climate Change. The Kyoto Protocol establishes binding greenhouse gas (GHG) emissions reduction targets for industrialized nations during the first "budget period"(2008-2012). For the United States, the target is 7 percent below 1990 emissions. But the United States emitted 1,803 million metric tons (MMT) of carbon or carbon equivalent in 1998, nearly 10 percent more than U.S. GHG emissions in 1990. With the passing of time, is it still possible for the United States to meet its Kyoto Protocol target (or substantially meet its target) through domestic actions? What set of policies could be adopted to reach or approach America's Protocol target? What economic costs and benefits would these policies have? And what other impacts?

Description of Policies

In order to address these questions, we consider a broad set of national policies that would increase energy efficiency, accelerate the adoption of renewable energy technologies, and shift to less carbon-intensive fossil fuels (i.e., displace some coal use with natural gas). In total, we examine the following ten policies.

A. New Appliance Efficiency Standards and Product Labeling

The U.S. Department of Energy (DOE) has the authority to set and upgrade appliance and equipment efficiency standards where technically and economically feasible. We assume DOE sets new standards on lighting ballasts, water heaters, clothes washers, and central air conditioners and heat pumps, transformers, refrigerators and freezers, furnaces and boilers, commercial packaged air conditioning equipment, gas ranges, and reflector lamps during the next five years. As part of this policy, we also propose that the federal government expand ENERGY STAR® labeling programs to a wider range of products including various home electronics products, microwave ovens, and packaged commercial refrigeration equipment.

B. Greater Adoption of Building Energy Codes and Market Incentives for Efficient New Construction

The Energy Policy Act of 1992 (EPAct) requires all states to adopt a commercial building code that meets or exceeds the ASHRAE 90.1-1989 model standard and requires all states to consider upgrading their residential code to meet or exceed the Model Energy Code. We assume that DOE enforces the commercial building code requirement in EPAct and that states comply. We also assume that relevant states upgrade their residential energy code to either the 1995 or 1998 Model Energy Code, either voluntarily or through the adoption of a new federal requirement. Furthermore, we propose that the model energy codes are significantly improved during the next decade and that all states adopt mandatory codes that go beyond current "good practice" by 2010. To complement building energy codes, we propose offering financial incentives to stimulate the construction of some highly efficient new homes and commercial buildings.

C. Stimulating Building Retrofits

Buildings in existence today will account for approximately two-thirds of the energy used in the buildings sector in 2020. To promote energy savings in existing buildings, we propose setting energy performance targets for different types of buildings and providing a variety of inducements and services to encourage (and in some cases require) building owners to upgrade their buildings to meet these targets. For residential buildings, a possible target level is the 1993 Model Energy Code, which defines good practice for new homes. For commercial buildings, a possible target level is the eligibility threshold for the ENERGY STAR® Commercial Buildings Program. In order to induce building owners to meet these performance levels, we propose a combination of technical assistance and financing to help owners identify and implement the most cost-effective efficiency measures.

D. Public Benefit Trust Fund as Part of Electric Utility Restructuring

Electric utilities historically have funded programs to encourage more efficient energy use, 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 these "public benefit expenditures." In order to ensure that energy efficiency programs and other public benefits activities continue, we propose creating a national public benefits trust fund, similar in concept to the public benefits fund included in the Clinton Administration's federal utility restructuring proposal. The federal trust fund would provide matching funds to states for eligible public benefits expenditures. The size of the public benefits trust fund we recommend is based on a non-bypassable wires charge of two-tenths of a cent per kWh, identical to proposals included in Senator Jeffords' (S. 1369) and Rep. Pallone's (H.R. 2569) restructuring bills.

E. Renewable Portfolio Standard as Part of Electric Utility Restructuring

Utilities and other power generators can be required to supply or purchase a specified amount of capacity or percentage of total electricity generation from renewable sources through what is known as a Renewable Portfolio Standard (RPS). We propose requiring 10 percent non-hydro renewables by 2010 and 20 percent non-hydro renewables by 2020, along the lines of the requirements in Senator Jeffords bill (S. 1369). Utilities and other power generators would be allowed to achieve the RPS through installation of renewables on their own and/or purchase of tradable renewable credits. But rather than allowing the amount of renewable generation to vary with the amount of electricity demand, we assume fixed amounts of renewables are required nationwide. These amounts are calculated by applying the percentage requirements given above to the levels of electricity demand in our Base Case (see explanation of Base and Policy Cases below).

F. Standards, Market Incentives, and Voluntary Programs to Increase the Efficiency of Passenger and Freight Vehicles

The average fuel economy of new passenger vehicles (cars and light trucks) has declined from nearly 26 miles per gallon (mpg) in 1988 to less than 24 mpg in 1999 due to increasing vehicle size and power, the rising market share of light trucks, and the lack of tougher Corporate Average Fuel Economy (CAFE) standards. We propose strengthening the CAFE standards for cars and light trucks and instituting complementary market incentive and promotion programs. Specifically, we propose increasing the CAFE standards for cars and light trucks combined to 42 mpg by 2010 and 58 mpg by 2020. Furthermore, we propose expanding the federal "gas guzzler" tax and converting it to a revenue-neutral fee and rebate system. This would stimulate demand for cleaner and more efficient vehicles in all classes. Also, we recommend adopting tax incentives and other initiatives at both the federal and state levels to help create markets for innovative, highly efficient hybrid and fuel cell vehicles.

We also propose policies to improve the efficiency of new medium- and heavy-duty trucks. These policies include expanded research and development, vehicle labeling and promotion, financial incentives to stimulate the introduction of new technologies, and efficiency standards if necessary.

G. Greenhouse Gas Standards for Motor Fuels

We propose adopting full fuel-cycle GHG standards for motor fuels, similar in concept to the renewable portfolio standard for electricity generation. The standards would be specified as a cap on the average GHG emissions factor of all motor fuels, thereby reducing both petroleum use and net carbon emissions from the transport sector. Fuel suppliers would have the flexibility to meet the standard on their own or by buying tradable credits from other producers of renewable or low-GHG fuel. In particular, we propose a GHG emissions standard for gasoline, starting at a 5 percent reduction in the emissions factor in 2010 and increasing 1 percent per year to a 15 percent reduction by 2020. The GHG standards could be complemented by expanded R&D programs, market creation programs, and financial incentives to stimulate the production of low-carbon fuels such as cellulosic ethanol and biomass- or solar-based hydrogen.

H. Reducing Barriers to Combined Heat and Power

Combined heat and power (CHP) systems greatly increase energy efficiency by simultaneously producing electricity and useful thermal output in industries or buildings. However, a variety of barriers including hostile utility policies, onerous environmental permitting requirements, lack of recognition of CHP's full benefits in environmental and utility regulations, and unfavorable tax treatment are limiting the growth of CHP in the United States. In order to overcome these barriers, we propose: (1) providing expedited permitting for CHP systems; (2) recognizing the full benefits, including avoided power plant emissions and greater utility grid reliability, in environmental and utility sector assessments and policies; (3) removing utility-driven barriers through FERC action, national restructuring legislation, and state action; and (4) establishing a standard depreciation period of seven years for all new CHP systems.

I. Voluntary Agreements and Incentives to Reduce Industrial Energy Use

In order to stimulate energy efficiency improvements by industries, we propose establishing voluntary agreements between the federal government and individual companies or entire industrial sectors. Companies or sectors would pledge to reduce their overall energy and carbon emissions intensities (energy and carbon per unit of output) by a significant amount, say at least 10-20 percent over 10 years. The government would encourage participation and support implementation by providing technical and financial assistance to participating companies, offering to postpone consideration of more drastic regulatory or tax measures if a large portion of industries participate, and by expanding federal R&D and demonstration programs. Voluntary agreements of this type have resulted in substantial energy and carbon emissions reductions in some European nations such as Germany, the Netherlands and Denmark.

J. Tighter Emissions Standards on Coal-Fired Power Plants

Older, highly polluting coal-fired power plants are "grandfathered" under the Clean Air Act, meaning that a majority of the 300,000 MW of coal-fired generating capacity in the United States does not meet the same emissions standards as plants built after the enactment of the Clean Air Act in 1970. Utilities have an incentive to operate these dirty power plants due to their low operating cost. We propose requiring these older coal-fired power plants to meet the same emissions standards as new plants. Some plants would be modernized and cleaned up but many would be shut down and replaced with much cleaner resources, either renewable sources or natural gas-fired combined cycle power plants.

Analysis and Results

We analyze energy use, carbon emissions, other pollutant emissions, and economic costs for both a Base Case and integrated Policy Case during 2000-2020. We use DOE's National Energy Modeling System, known as NEMS, to conduct this analysis, along with our own assessments of some of the policies and key parameters. Our Base Case is derived from the Reference Case Forecast in the Annual Energy Outlook 1999 prepared by the Energy Information Administration. It is meant to represent energy use and carbon emissions given current policies and trends. The ten policies are considered together in what we designate as the Policy Case.

Table ES-1 shows the overall results. In the Base Case, total primary energy consumption reaches about 112 quads in 2010 and 121 quads in 2020, a 1.1 percent per year growth rate on average. The ten policies reduce primary energy consumption 18 percent by 2010 and 33 percent by 2020, relative to energy use in the Base Case in those years, through increased efficiency and greater adoption of CHP. Renewable energy use (both hydro and non-hydro) accounts for about 12 percent of primary energy supply in 2010 and 19 percent of total energy supply in 2020 in the Policy Case. In contrast, renewables contribute only 7.5 percent of total energy supply in 2020 in the Base Case, about the same percentage as in 1997.

Table ES-1: Overall Results for the Base and Policy Cases

	1997	2010 Base Case	2010 Policy Case	2020 Base Case	2020 Policy Case
Energy					
End Use (Q)	70.4	84.7	74.8	92.6	73.4
Primary Energy Use (Q)	93.2	111.9	92.0	121.1	80.5
Non-Hydro Renewable (Q)	3.6	5.0	7.7	5.7	11.6
Hydro Renewable (Q)	3.1	3.2	3.2	3.4	3.4
Intensity per Unit GDP (Q/trillion $)	12.9	11.3	9.3	10.4	6.9
Carbon					
Emissions (MMT)	1,453	1,779	1,277	1,968	894
Intensity per unit energy (MMT/Q)	15.7	15.9	13.9	16.3	11.1
Intensity per unit GDP (MMT/trillion $)	204	180	129	168	77
Air Pollutants [1]					
Sulfur dioxide (MMT)	18.2	12.3	5.4	12.4	2.9
Nitrogen oxide (MMT)	17.8	11.7	9.9	11.7	8.4
Particulate matter (MMT)	1.4	1.3	1.1	1.4	1.0
Economic Impacts [2]					
Net Benefits (billion 96$)	-	-	203	-	510

[1] Air pollutant emissions are from burning fossil fuels and biomass in the industrial, buildings, transport (on-road only), and electric sectors.

[2] Costs and benefits are cumulative, using a 5 percent discount

In the Base Case, carbon emissions reach 1,779 million metric tons carbon equivalent (MMT) by 2010 and 1,968 MMT by 2020. Base Case emissions are 33 percent greater than the 1990 level by 2010 and 47 percent greater by 2020. In the Policy Case, carbon emissions decline so that they are 12 percent less than 1997 emissions and about 4.5 percent less than 1990 emissions by 2010. Carbon emissions in 2010 in the Policy Case are about 500 MMT (28 percent) less than in the Base Case. While this is not quite enough to reach America's Kyoto Protocol target of 7 percent below 1990 emissions during 2008-2012 (assuming the Base Case Forecast is accurate), it is very close. It should be possible to achieve the Kyoto target (i.e., a further 30 MMT reduction) through some combination of: (1) further domestic reductions from additional policy initiatives; (2) deeper reductions in emissions of other GHGs; (3) purchase of emissions reductions from other Annex 1 countries; and (4) reductions in developing countries from Clean Development Mechanism projects.

The set of ten policies continues to provide carbon emissions reductions after 2010 while the economy is expanding. Compared to the Base Case, carbon emissions are cut 1,074 MMT (55 percent) in 2020 in the Policy Case. Emissions in 2020 in the Policy Case also are about 34 percent less than energy sector emissions in 1990. This level of carbon emissions reduction is consistent with a climate stabilization scenario whereby all industrialized nations cut their absolute carbon emissions by over 50 percent by 2050 and over 90 percent by 2100.

Figure ES-1: Carbon Intensity (GDP Basis): Base and Policy Cases

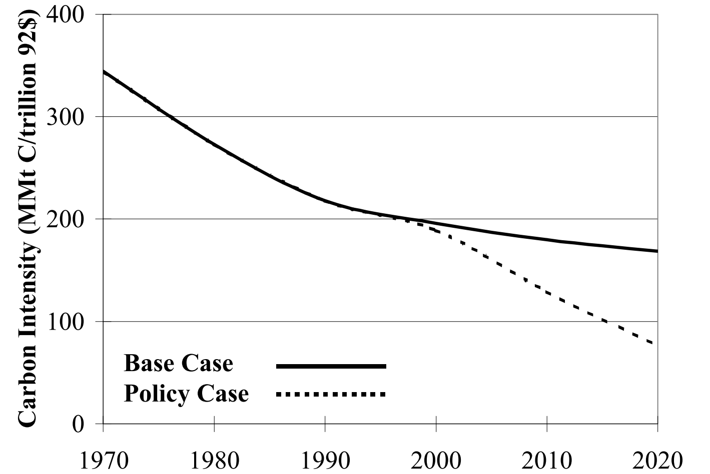


Figure ES-1 shows the history of the carbon intensity of the U.S. economy (carbon emissions per unit of GDP) from 1970 to the present along with the carbon intensity projections in the Base and Policy Cases. Carbon intensity declined by about 40 percent over the past three decades. In the Base Case, it is projected to decline at a slower rate—about 17 percent from 1997 to 2020 due to continued modest reductions in energy intensity. In the Policy Case, the projected decline is much more dramatic, by 60 percent from 1997 to 2020, owing to both energy intensity reduction and decarbonization of energy supplies. But the downward slope is much closer to historical trends in the Policy Case than in the Base Case.

Table ES-2 presents the carbon emissions reductions from each of the ten policies. In this breakdown, carbon emissions reductions arising from policies that reduce electricity use are credited to the buildings and industrial sectors since this is where the policies are aimed. Also, the public benefits trust fund policy is divided between the buildings and industrial sectors since it affects electricity consumption in both sectors. With this perspective, the buildings-related policies are responsible for about 22 percent of the overall reductions, largely through impacts on electricity generation and emissions. The industrial policies are responsible for about 25 percent of the total reductions, the transportation policies about 33 percent, and the electric supply policies about 20 percent. Figure ES-2 displays these results graphically.

The set of ten policies also significantly reduces air pollutants. Implementing the policies would reduce SO_2 emissions the most—62 percent by 2010 and 84 percent by 2020. Emissions of particulates would be cut 20 percent by 2010 and 35 percent by 2020 and NOx emissions would drop 17 percent by 2010 and 30 percent by 2020. Clearly, taking action to reduce carbon emissions as proposed in the Policy Case would provide public health and local/regional environmental benefits.

Table ES-3 summarizes the direct economic costs and benefits in the Policy Case. The policies would induce incremental investments in high-efficiency motors, advanced industrial processes, more efficient lighting and appliances, more fuel-efficient cars and trucks, renewable energy technologies, alternative fuels, cleaner and more efficient power plants, and so on. We estimate a total investment of $213 billion through 2010 and $627 billion through 2020, expressed in 1996 dollars using a 5 percent real discount rate. But final consumers would save over $400 billion through 2010 and over $1.1 trillion through 2020 in energy bill and operating savings. These savings more than offset the investments costs, with net savings of about $200 billion through 2010 and over $500 billion through 2020. Furthermore, these estimates are

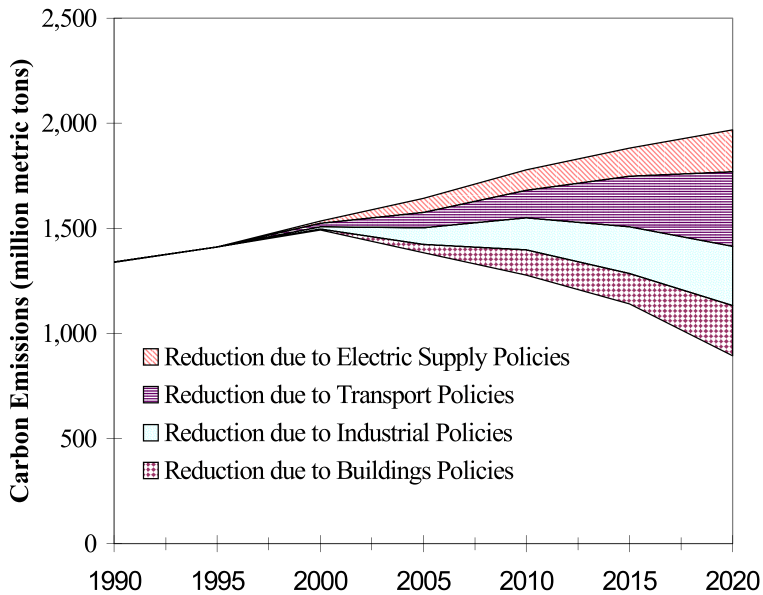
Table ES-2: Carbon Emission Reductions for Each Policy (MMT)

	1990	2010	2020
TOTAL BASE CASE EMISSIONS	**1,338**	**1,779**	**1,968**
Reductions in the Buildings Sector			
appliance standards & labeling	0	23	41
building codes	0	11	19
building retrofits	0	14	36
public benefits	0	70	142
Total Sectorial Reductions	*0*	*119*	*238*
Reductions in the Industrial Sector			
CHP	0	49	121
voluntary agreements	0	71	95
public benefits	0	33	65
Total Sectorial Reductions	*0*	*153*	*281*
Reductions in the Transportation Sector			
greenhouse gas standard for fuel	0	22	124
vehicle efficiency improvement	0	109	231
Total Sectorial Reductions	*0*	*130*	*355*
Reductions in the Electric Sector			
renewable portfolio standard	0	55	158
emission standards on coal power plants	0	43	40
Total Sectorial Reductions	*0*	*98*	*199*
TOTAL POLICY CASE EMISSIONS	**1,338**	**1,277**	**894**

conservative because they do not account for the fuel or operating savings that persist after 2020 even though some measures are installed towards the end of the time period considered, and they do not include the indirect economic benefits from lower air pollution.

Implementing the ten policies creates incomes and jobs for those companies who produce, market, and service the energy efficiency and renewable energy. The efficiency measures then lower the energy bills of the businesses and households that utilize the more efficient equipment. Re-spending of these energy bill savings creates additional jobs and incomes since expenditures are shifted to areas of the economy (such as food, housing, and entertainment) that are more labor-intensive than the energy supply sectors. While we believe the overall effect would be a net increase in jobs in the economy in the Policy Case, we did not explicitly analyze these macroeconomic impacts in this study

Figure ES-2: Carbon Emissions Reductions in the Policy Case



Conclusion

This study shows that the United States can achieve its emissions target under the Kyoto Protocol—7 percent below 1990 levels for the first "budget period" of the Protocol—entirely or largely through domestic actions, even though the first budget period starts in about eight years. However, U.S. GHG emissions are now 10 percent greater than they were in 1990. Achieving America's Kyoto target requires strong, new national policies. Further delay could jeopardize America's ability to meet the Kyoto target.

New policies are needed to stimulate greater energy efficiencies in all sectors of the economy as well as to accelerate the adoption of renewable energy sources and shift away from carbon-intensive fossil fuels. Some of the policies can be implemented without new legislation, such as adoption of more stringent appliance efficiency standards, additional product labeling, tougher fuel economy standards on cars and light trucks, reducing barriers to CHP, and voluntary agreements and related policies to reduce industrial energy use. Other policies require new legislation but have been adopted already by some states or municipalities.

Table ES-3: Cumulative Investment Costs and Fuel/O&M Savings in the Policy Case (Billion, 1996$)

	Through 2010	Through 2020
Investment Costs	213	627
Fuel and O&M Savings	416	1137
Net Savings	203	510

The set of policies proposed here would yield other benefits besides lower GHG emissions and economic benefits for households and businesses. Oil imports would be reduced, thereby improving America's trade balance and reducing its vulnerability to supply constraints and oil price shocks. U.S. industries that produce efficient and clean technologies to meet climate policy goals would be poised to capture a large share of the rapidly growing world markets for these technologies. And cutting fossil fuel use would reduce air pollutants, thereby improving public health and reducing damage to crops, forests, buildings, and water resources.

In summary, the policies proposed here can be justified even if global warming and GHG emissions were not of concern. The primary obstacles are lack of political will and in some cases industry opposition, not technical or economic viability.

I. INTRODUCTION

Human activities, particularly the burning of fossil fuels, are causing a build-up of carbon dioxide and other greenhouse gases (GHGs) in the atmosphere. The rise in GHGs in turn is increasing the average surface temperature of the earth. The average temperature has risen about 0.6°C since the late 1800s, with the increase due to GHG emissions offset in part by emissions of sulphate aerosols and changes in solar activity. If business-as-usual energy use patterns continue, it is estimated that the average temperature will further rise 1.9°C to 2.9°C between 1990 and 2100 (Wigley 1999). The potential impacts of such a large and rapid rise in temperature—sea level rise and coastal flooding, more extreme weather events, changes in regional climates, adverse impacts on human health and ecosystems, etc.—are wide-ranging and of great concern. For example, the economic losses worldwide due to extreme weather events averaged about $30 billion per year during 1990-98, many times more than losses during pervious decades (Mohr and Silverthorne 1999).

Faced with this challenge, 172 nations (including the United States) negotiated and reached agreement on the Framework Convention on Climate Change (FCCC) in 1992. The FCCC calls for stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. But U.S. and worldwide GHG emissions have continued to rise during the 1990s, leading 160 nations to adopt the Kyoto Protocol to the Convention in December 1997. The Kyoto Protocol establishes binding GHG emissions reduction targets for industrialized nations during the first budget period (2008-2012), thereby representing an initial step towards the goal of the FCCC. For the United States, the target is 7 percent below 1990 emissions. In order to facilitate implementation, the Protocol allows emissions trading between countries with binding targets, trading among the six gases covered, credit for emissions reduction projects in developing countries, and credit for net increases in carbon sinks (forests and other biomass-based resources).

According to the U.S. Department of Energy (DOE), the United States emitted 1,803 million metric tons (MMT) of carbon or carbon equivalent in 1998, nearly 10 percent more than U.S. GHG emissions in 1990 (EIA 1999). About 83 percent of total GHG emissions in 1998 were due to carbon dioxide (commonly referred to in terms of tons of carbon) and over 98.5 percent of the carbon was from burning fossil fuels (EIA 1999). Carbon emissions rose only about 5 MMT in 1998, despite strong economic growth. In fact, carbon emissions per unit of GDP fell about 2.4 percent in 1997 and 3.5 percent in 1998. These recent developments are encouraging from the perspective of halting growth in GHG emissions and achieving absolute emissions cuts. But emissions still must be cut significantly in order to achieve America's Protocol target and the target period begins in about eight years. Moreover, as much deeper cuts will be needed in subsequent years to ensure climate stabilization, it is important that technological, institutional, and policy momentum be established in the near term for a smooth and steady transition to a low carbon future.

A number of studies have examined the question of what actions the United States could take to achieve its Protocol target. In Section III, we will review another recent study. Our overall purpose is to update and complement ACEEE's and the Tellus Institute's previous examinations of this topic. In particular, we address the following questions:

- With the passing of time, is it still possible for the United States to meet its Protocol target (or substantially meet its target) through domestic actions?
- What set of policies could be adopted to reach or approach America's Protocol target?
- What economic costs and benefits would these policies have?
- What would be their broader environmental impacts?

The analysis in this report is limited to carbon emissions from the energy sector. While most of the focus in the climate change debate is on energy-related carbon emissions, much is being done (or can be done) to reduce emissions of methane, nitrous oxide, and the other gases covered by the Kyoto Protocol. With stepped-up efforts, it should be possible to achieve substantial reductions in emissions of these gases in a 10-20 year time frame (de la Chesnaye, Harvery, and Laitner 1999).

II. Description of Policies

This study examines a broad set of national policies that would increase energy efficiency, accelerate the adoption of renewable energy technologies, and shift to less carbon-intensive fossil fuels (i.e., displace some coal use with natural gas). These policies are advocated by a wide range of groups promoting a more sustainable energy future (SEC 1999). The policies address major areas of energy use in the buildings, transport, industrial, and electrical sectors. Some of the policies have been implemented already by certain states or municipalities (ICLEI 1998; Kushler 1999). But the policy set is not exhaustive; some potentially useful and complementary policies are not included (e.g., carbon emissions taxes, policies for reducing growth in passenger vehicle use, and expanded research and development [R&D] on energy efficiency and renewable energy technologies).

In total, we examine the following ten policies:

1. New Appliance Efficiency Standards and Product Labeling
2. Greater Adoption of Building Energy Codes and Market Incentives for Efficient New Construction
3. Stimulating Building Retrofits
4. Public Benefit Trust Fund as Part of Electric Utility Restructuring
5. Renewable Portfolio Standard as Part of Electric Utility Restructuring
6. Standards, Market Incentives, and Voluntary Programs to Increase the Efficiency of Passenger and Freight Vehicles
7. Greenhouse Gas Standards for Motor Fuels
8. Reducing Barriers to Combined Heat and Power

9. Voluntary Agreements and Incentives to Reduce Industrial Energy Use
10. Tighter Emissions Standards on Coal-Fired Power Plants

Below we describe each of these policies and the key assumptions made concerning the technological impacts, costs, and effects of the individual policies. As explained further in the methodology discussion in Section III, we use the Energy Information Administration's 1999 Reference Case Forecast as our "Base Case" (EIA 1998). Our policies and assumptions build on those included in this Forecast (i.e., we attempt to avoid taking credit for emissions reductions, costs, or savings already included in the EIA 1999 Reference Case Forecast).

A. New Appliance Efficiency Standards and Product Labeling

For this policy, it is assumed that DOE uses its existing authority to upgrade appliance and equipment efficiency standards where technically and economically feasible. DOE is many years behind schedule in reviewing and upgrading appliance efficiency standards but has established a goal of completing four high priority rulemakings—fluorescent lighting ballasts,[1] water heaters, clothes washers, and central air conditioners and heat pumps—during 2000. In addition to these products, we assume DOE sets new standards on transformers, refrigerators and freezers, furnaces and boilers, commercial packaged air conditioning equipment, gas ranges, and reflector lamps over the next five years. We assume these standards are at the highest levels justified under the current law. We further assume that the standards are issued and take effect without further delay, except in the case of clothes washers where we allow a longer phase-in period given the stringency of the assumed standard.

Adopting stringent new appliance standards will lead to widespread adoption of key energy efficiency technologies such as electronic ballasts, horizontal-axis clothes washers (or equivalent performance), and central air conditioners and heat pumps with a minimum seasonal energy efficiency ratio (SEER) rating of 13.0. (Geller et al. 1998). In the case of water heaters, we assume that new standards are based on top-rated conventional products (i.e., they do not require advanced technologies such as condensing gas water heaters or heat pump electric water heaters). Of course, if DOE sets less stringent standards, the energy and carbon savings will be reduced.

As part of this policy, we also propose that the federal government expand ENERGY STAR® labeling programs to a wider range of products including various home electronics products (cable boxes and telephone equipment), microwave ovens, and packaged commercial refrigeration equipment. The U.S. Environmental Protection Agency (EPA) recently extended ENERGY STAR® labeling to TVs, VCRs, and audio equipment. Labeling high-efficiency products in this manner along with promoting qualifying products should have a significant impact on manufacturers and lead to some degree of voluntary efficiency improvement, based on the experience with ENERGY STAR® labeling for personal computers and other types products. It has

[1] We did not modify our analysis to reflect a compromise on new ballast standards agreed to by energy efficiency advocates and appliance manufacturers in October 1999.

been estimated that ENERGY STAR® labeling initiated during 1993-97 led to primary energy savings of approximately 0.22 quads per year as of 1998 (Webber, Brown, and Koomey 1999).

Our analysis is based on the estimated average energy savings and sales projections for each type of product, including products where either new standards or ENERGY STAR® labeling are assumed. We also estimate the incremental cost for complying with the assumed standards on a product-by-product basis (Geller et al. 1998). In total, we estimate the new appliance standards and product labeling efforts will save 100 terawatt-hours (TWh) of electricity and 0.12 quads of natural gas (end-use only) by 2010. By 2020, the savings grow to 195 TWh and 0.25 quads of natural gas as the appliance stock continues to turn over. The cumulative investment in efficiency measures needed to realize these savings is $13.4 billion through 2010 and about $40 billion through 2020 (1996 dollars).

B. Greater Adoption of Building Energy Codes and Market Incentives for Efficient New Construction

Building energy codes require all new residential, commercial, and industrial buildings to be built to a minimum level of energy efficiency that is cost-effective and technically feasible. "Good practice" residential energy codes, defined as the 1992 (or a more recent) version of the Model Energy Code (now known as the International Energy Conservation Code), have been adopted by 32 states (BCAP 1999). "Good practice" commercial energy codes, defined as the ASHRAE 90.1-1989 model standard, have been adopted by 29 states (BCAP 1999). Some major states such as Arizona, Illinois, Michigan, New Jersey, and Texas have not adopted these "good practice" energy codes. However, the Energy Policy Act of 1992 (EPAct) requires all states to adopt a commercial building code that meets or exceeds ASHRAE 90.1-1989 and requires all states to consider upgrading their residential code to meet or exceed the 1992 Model Energy Code.

For this policy, it is assumed that DOE enforces the commercial building code requirement in EPAct and that states comply. We also assume that relevant states upgrade their residential energy code to either the 1995 or 1998 Model Energy Code, either voluntarily or through the adoption of a new federal requirement. Furthermore, we assume that the model energy codes are significantly improved during the next decade and that all states adopt mandatory codes that go beyond current "good practice" by 2010.

To complement expanded adoption and strengthening of building energy codes, we recommend the adoption of financial incentives to stimulate the construction of new buildings that are much more efficient than "good practice" as defined by the model codes. Specifically, we recommend adoption of tax credits for highly efficient new housing along the lines proposed by the Administration and included in legislation introduced by Rep. Matsui in 1999 (H.R. 2830). This proposal would provide tax incentives for new homes that are at least 30 percent more efficient than the Model Energy Code, with the amount of incentive increasing with the level of energy savings. Similar incentives should be provided to highly efficient new commercial buildings that beat the ASHRAE 90.1-1989 standard by 30 percent or more.

To quantify the impacts of these policies, we assume a 20 percent energy savings in heating and cooling in residences affected by the Phase One residential code requirement, and that half of new homes built during 2001-2010 are affected. We also assume a 20 percent energy savings in heating, cooling, and lighting in commercial buildings affected by the Phase One commercial code requirement, and that half of new commercial floor space built during 2001-2010 is affected. These are conservative assumptions, as experience has shown that building codes can reduce space conditioning energy use in new buildings by 25 percent or more (Geller and Nadel 1994; Klevgard, Taylor, and Lucas 1994). We further assume that all new residential and commercial buildings constructed during 2011-2020 are affected by the Phase Two requirement, which leads to an additional 20 percent energy saving. We make no changes in heating and cooling fuel share choices relative to current trends.

The result of these assumptions is 26 TWh of end-use electricity savings and 0.10 quads of direct natural gas savings in 2010 and an additional 0.19 quads in direct savings of other fuels. By 2020, the electricity savings reach 75 TWh and the direct gas savings grow to 0.30 quads. The total investment in energy efficiency equals about $10 billion during 2000-2010 and $26 billion during 2000-2020 (1996 dollars). We assume that the investment in efficiency measures provides twice as much fuel and electricity savings over the life of the measures on a net present value basis (i.e., an average benefit-cost ratio of 2.0).

C. Stimulating Building Retrofits

Buildings in existence today will account for approximately two-thirds of the energy used in the buildings sector in 2020. In order to reduce building sector-related carbon emissions, it is essential to reduce energy use in existing buildings. Fortunately, there are abundant opportunities for cost-effective energy savings through retrofits of existing homes and commercial buildings. For example, an evaluation of the national weatherization assistance program found that retrofits of low-income housing carried out during 1990-96 typically reduced natural gas consumption for space heating by 34 percent (Berry 1997). Also, retrofits of 15 office buildings as part of EPA's ENERGY STAR® Showcase Buildings partnership reduced energy consumption by 30 percent on average (Hicks and Clough 1998). The technologies that can be used to upgrade energy efficiency include adding insulation to walls and attics, replacing older windows with energy-efficient windows, sealing leaky heating and cooling air ducts, sealing air leaks in the building envelope, upgrading heating and cooling systems, replacing inefficient lighting, and installing control systems. In addition to saving energy, the measures can also improve air quality and comfort in the home and productivity in the workplace (duPont and Morrill 1989; Romm 1999).

To promote retrofit energy savings, we recommend a multi-faceted set of policies consisting of setting energy performance targets for different types of buildings and providing a variety of inducements and services to encourage (and in some cases require) building owners to upgrade their buildings to meet these targets. For residential buildings, a possible target level is the 1993 Model Energy Code, which defines good practice for new homes. For commercial buildings, a possible target level is the eligibility threshold for the ENERGY STAR® Commercial Buildings Program. These thresholds are set separately for different types of buildings and represent the level of performance currently met by the 25 percent most energy-efficient buildings nationwide.

In order to induce building owners to meet these performance levels, we propose a combination of technical assistance and financing to help owners identify and implement the most cost-effective efficiency measures. Attractive financing should be made widely available for building retrofits and efficiency improvements at the time-of-sale (so-called energy-efficient mortgage programs). Also, municipalities should be encouraged to adopt retrofit ordinances that require buildings to be upgraded to these performance levels prior to sale. Retrofit ordinances along these lines have been adopted in San Francisco, Minneapolis, Burlington, and a few other cities (Suozzo, Wang, and Thorne 1997). Bits and pieces of these programs are already in place, such as successful financing programs in Connecticut, Idaho, Nebraska, and Oregon (Suozzo, Wang, and Thorne 1997). But existing programs and services need to be greatly expanded in order to influence the majority of the building stock by 2020. A portion of these activities can be financed through state-implemented public benefit programs (see **Public Benefit Trust Fund as Part of Electric Utility Restructuring,** below); additional support will need to come from the private sector and governments at all levels.

Our analysis assumes that 50 percent of the existing building stock is retrofit over a 20-year period (2000-2020), with retrofit activity slower in the first decade than the second. We estimate that achieving the target levels discussed above will result in average energy savings of 30 percent in the residential sector and 27 percent in the commercial sector. Furthermore, we credit this policy with only half of these energy savings, with the remainder induced by other policies such as the Public Benefits Trust Fund. Based on a review of a variety of reports on the costs and benefits of retrofit programs, we estimate an average cost of $700 per home and $1.30 per commercial building square foot to achieve the savings credited to this program. These cost and savings estimates are based on data from the ENERGY STAR® Homes and Commercial Buildings Programs and other data sources (Hicks and Clough 1998; Suozzo, Wang, and Thorne 1997). At projected energy prices in 2020, this works out to an average simple payback period of five years in the residential sector and four years in the commercial sector.

In total, we estimate that this building retrofit policy will save 0.31 quads of natural gas and petroleum-based fuels in 2010 and 0.80 quads in 2020. Of these savings, approximately 60 percent are in the residential sector and 40 percent in the commercial sector. This policy will also save 45 TWh of electricity in 2010 and 121 TWh in 2020. Of these savings, approximately 26 percent are in the residential sector and 74 percent are in the commercial sector. The cumulative investment needed to achieve these savings totals $90 billion over the 20-year period. But by 2020, consumer energy bill savings will total approximately $17 billion annually.

D. Public Benefit Trust Fund as Part of Electric Utility Restructuring

Electric utilities historically have funded programs to encourage more efficient energy use, 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 these "public benefit expenditures" over the past five years. In order to ensure that public benefits activities continue following restructuring, several states have established public benefits funds through a small charge on all kilowatt-hours (kWhs) flowing through the transmission and distribution grid. As of July 1999, 15 states have adopted utility public benefits funds (Kushler 1999).

This policy initiative would create a national public benefits trust fund, similar in concept to the public benefits fund included in the Clinton Administration's federal utility restructuring proposal. The federal trust fund would provide matching funds to states for eligible public benefits expenditures. This policy would encourage states and utilities to continue or in some cases expand energy efficiency and other public benefits activities. The size of the public benefits trust fund we recommend is based on a non-bypassable wires charge of two-tenths of a cent per kWh, identical to proposals included in Senator Jeffords' (S. 1369) and Rep. Pallone's (H.R. 2569) restructuring bills. This is more than twice the size of the public benefits trust fund in the Clinton Administration's restructuring bill, but even this larger fund would cost the typical residential consumer only about $1 per month.

Once a public benefits fund is adopted, utilities, state agencies, or some other state-designated "fund manager" would carry out energy efficiency programs. In a more competitive, "restructured" utility market, these programs typically focus on assisting consumers unlikely to receive energy efficiency services by the private sector (i.e., low-income households or small businesses), expanding the private energy services industry, and encouraging market transformation (Eto, Goldman, and Nadel 1998). The programs lead to efficiency improvements in appliances, lighting, HVAC systems, motor systems, etc.—areas where there is still enormous cost-effective energy efficiency potential.[2]

Our analysis estimates the incremental investment in and savings from energy efficiency measures as a result of the federal public benefits trust fund. We do not include savings from public benefit programs already underway or likely to occur in the absence of a federal fund. In particular, we assume that states gradually expand their eligible programs, using 90 percent of the maximum funds available by 2005 and thereafter. Based on historical trends, we assume that energy efficiency programs represent 59 percent of the public benefits expenditures and that energy savings typically cost $0.03/kWh on a levelized basis (Nadel 1999). We also assume that 20 percent of all participants are "free riders" (i.e., consumers who would invest in efficiency measures in the absence of state/utility programs).

These assumptions result in incremental end-use electricity savings of 131 TWh in 2005, 343 TWh in 2010, and 756 TWh in 2020. For comparison, national electricity use (based on utility sales) reached 3,220 TWh in 1998 and is projected to grow to 4,345 TWh by 2020 in the EIA Reference Case Forecast (EIA 1998). Most of these savings are likely to be in the residential and commercial sectors since they are the main focus of state/utility efficiency programs using public benefits funds. The total investment in efficiency measures stimulated by the federal public benefits fund (i.e., excluding "free riders" and efficiency improvements occurring in the absence of this policy) is $104 billion during 2000-2010 and $319 billion during 2000-2020.

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[2] For example, nearly 80 percent of commercial and industrial fluorescent lighting still consists of inefficient magnetic ballasts and T12 lamps (Calwell, Dowers, and Johnson 1998). Likewise, about 90 percent of the motors used in manufacturing facilities are less efficient "standard motors" while adjustable speed drives are used in only 15-20 percent of feasible applications (OIT 1998).

E. Renewable Portfolio Standard as Part of Electric Utility Restructuring

Utilities and other power generators can be required to supply or purchase a specified amount of capacity or percentage of total electricity from renewable sources through what is known as a Renewable Portfolio Standard (RPS). Renewable energy sources generally consist of wind, solar, geothermal, and biomass-based power, but not hydro power which is considered a traditional power source for this purpose. Municipal solid waste and landfill gas are also included as renewable sources in some proposals, although the former can involve emissions of toxic compounds and is not fully renewable. As of mid-1999, eight states (Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, Texas, and Wisconsin) had adopted some type of RPS for their utilities (Kushler 1999).

The Clinton Administration has proposed a national RPS, specifically a requirement of 7.5 percent non-hydro renewables by 2010, as part of their national utility restructuring bill. In this and other RPS proposals, utilities and other power generators would be allowed to achieve the goal through installation of renewables on their own and/or purchase of tradable renewable credits. The tradable credit scheme is designed to minimize the overall cost of compliance. Some members of Congress have introduced even tougher RPS proposals, notably Senator Jeffords (S. 1369), whose bill requires 10 percent renewables by 2010 and 20 percent renewables by 2020. Our policy initiative is based on Jefford's RPS proposal and applies to all electricity generators (so-called independent power producers as well as traditional utilities). For comparison, non-hydro renewables represent about 2.3 percent of U.S. electricity supply today and are projected to grow to only 3.2 percent by 2020 in the EIA Reference Case Forecast (EIA 1998).

We make one significant modification to Jefford's basic proposal, however. Rather than allow the amount of renewable generation to vary with the amount of electricity demand (i.e., reducing renewable generation when energy efficiency policies lower electricity demand), we assume Jefford's percentage requirements are applied to the Base Case level of electricity demand and supply. We then assume this amount of renewables is provided in our "Policy Case" as well (i.e., we do not reduce the amount of renewable electricity supplied due to end-use efficiency improvements). This means we are proposing that the RPS be specified in terms of a fixed amount of renewables-based generation each year. In particular, we propose a total of 349 TWh of non-hydro renewable electricity by 2010 and 876 TWh by 2020, compared to 73 TWh in 1997 (see Table 1).

Table 1: Renewable Energy Mix for Achieving the RPS Targets

	Capital Cost (1996$/kW)		Generation (TWh)		
	2000	2010-2020	2000	2010	2020
Wind	932	745	52	197	623
Solar	4,228	2,789	1	4	10
Biomass	2,486	1,391	11	105	137
Geothermal	1,759	1,759	25	43	108
Total			89	349	876

With the assumptions explained above, the actual percentage of electricity originating from non-hydro renewables is 12 percent by

2010 and 40 percent by 2020 in our Policy Case. The assumed mix of renewables to meet these targets across the different regions of the United States is given in Table 1, along with the assumed capital costs of each technology. It is noteworthy that in this scenario, all of the "technology learning" (i.e., cost reductions with increased scale of production) occurs between 2000 and 2010.

In order to provide the levels of biomass-based power shown in Table 1, about 1 quad of biomass is needed by 2010 and about 1.3 quads by 2020. We assume this biomass is provided at $2.60 and 3.50 per million British thermal unit (Btu), respectively, from agricultural residues, forest, mill and urban wood wastes, and woody crops (Walsh et al. 1997).

F. Standards, Market Incentives, and Voluntary Programs to Increase the Efficiency of Passenger and Freight Vehicles

The average fuel economy of new passenger vehicles (cars and light trucks) has declined from a high of 25.9 miles per gallon (mpg) in 1988 to 23.8 mpg in 1999 due to increasing vehicle size and power, the rising market share of light trucks, and the lack of tougher Corporate Average Fuel Economy (CAFE) standards (Heavenrich and Hellman 1999). The standard for cars is the same as it was in 1985 and the standard for light trucks has increased just 0.2 mpg since 1987.

This policy initiative would strengthen the CAFE standards for cars and light trucks and institute complementary market incentive and promotion programs in order to significantly increase the efficiency of new vehicles over the next 20 years. Specifically, we propose increasing the CAFE standards for cars and light trucks combined to 42 mpg by 2010 and 58 mpg by 2020. Furthermore, we propose expanding the federal "gas guzzler" tax and converting it to a revenue-neutral fee and rebate system. This would stimulate demand for cleaner and more efficient vehicles in all classes. Also, we recommend adopting tax incentives and other initiatives at both the federal and state levels to help create markets for innovative, highly efficient hybrid and fuel cell vehicles.

Within this package, the tougher CAFE standards are most essential and act as the determining factor for inducing efficiency improvements. The initial CAFE standards were largely responsible for the near doubling in the average fuel economy of cars and more than 50 percent increase in light truck fuel economy from 1975 to 1987. The standards were met largely through cost-effective technologies (e.g., weight reduction, engine efficiency improvement, etc.) and without negative side effects (Greene 1999). The new CAFE standards and other complementary policies recommended here could result in 4.3 quads of energy savings by 2010 and 8.8 quads by 2020, relative to modest improvements in new vehicle fuel efficiency in the absence of the policies (Geller et al. 1998).

Tougher CAFE standards can be met through technological improvements, both refinements to conventional vehicle designs in the near term and advanced vehicle technologies (lightweight materials, hybrid drivetrains, and fuel cells) over time (DeCicco and Mark 1998). Two mass-produced electric hybrid vehicles with 50-75 percent greater fuel efficiency compared to typical new cars in their size class will be introduced in the United States in 2000. Based on vehicle technology assessment, we estimate that the 2010 fuel efficiency target can be met with an average incremental vehicle cost of $830 and the 2020 target at an average incremental cost of $1,755 (DeCicco and Mark 1998). The total investment in light-duty vehicle efficiency measures is $74 billion during 2000-2010 and $267 billion during 2000-2020 (1996 dollars).

We also propose policies to improve the efficiency of new medium- and heavy-duty trucks. These measures include expanded R&D, vehicle labeling and promotion, financial incentives to stimulate the introduction of new technologies, and efficiency standards if necessary. For heavy-duty trucks, we estimate that a 28 percent improvement in efficiency is technologically and economically feasible by 2010, relative to a 1990 baseline (DeCicco and Mark 1998). By 2020, a 52 percent efficiency improvement should be feasible relative to the 1990 baseline. These efficiency gains could result from improving the diesel engines used in trucks (both in terms of their energy and emissions performance) as well as through other measures (Sachs et al. 1992). Overall, we estimate that steadily improving truck efficiency as indicated above would save 0.6 quads by 2010 and 1.4 quads by 2020. The total investment in heavy-duty vehicle efficiency measures is $27 billion during 2000-2010 and $54 billion during 2000-2020.

G. Greenhouse Gas Standards for Motor Fuels

New policies should be adopted to stimulate a shift from petroleum-based to low-carbon and renewable transportation fuels. We recommend the adoption of full fuel-cycle GHG standards for motor fuels, similar in concept to the renewable portfolio standard for electricity generation. Such standards would reduce both petroleum use and net carbon emissions from the transport sector. The standard could be specified as a cap on the average GHG emissions factor of all motor fuels, which could be made progressively more stringent over time to allow for gradual response. Fuel suppliers would have the flexibility to meet the standard on their own or by buying tradable credits from other producers of renewable or low-GHG fuel.

In particular, we recommend adoption of a GHG emissions standard for gasoline, starting at a 5 percent reduction in the emissions factor in 2010 and increasing 1 percent per year to a 15 percent reduction by 2020. The GHG standards should be complemented by expanded R&D programs, market creation programs, and financial incentives (such as revamping the current ethanol tax incentive to specify it on a full fuel-cycle GHG basis) to stimulate the production of low-carbon fuels such as cellulosic ethanol and biomass- or solar-based hydrogen.

We estimate that the low-carbon fuel standards would result in 0.76 quads of renewable fuel production by 2010 and 2.80 quads by 2020, with most of this being incremental to the amount of renewable fuel assumed in the EIA Reference Case Forecast. As in the case of the RPS for electricity, we do not reduce the amount of renewable fuels in our Policy Case because of end-use efficiency improvements. Consequently, the amount of renewable fuels is fixed and actually higher in percentage terms in the Policy Case than the recommended standards since the vehicle efficiency policy reduces total fuel demand.

Regarding fuel type and cost, we assume that most of the incremental fuel is provided by cellulosic ethanol (as opposed to natural gas, corn-based ethanol, or other fuels). Cellulosic ethanol can be produced from waste materials (e.g., agricultural or forest wastes) or dedicated energy crops, and ethanol can be co-produced along with electricity (Lynd 1997). Cellulosic ethanol offers the potential for both lower costs than corn-based ethanol and near-zero or negative GHG emissions (Lynd 1997).[3] Cellulosic ethanol production technology is rapidly advancing, with both private and public support contributing to improvements in different aspects of the physical and biological processes. Cellulosic ethanol plants are being constructed or designed in a number of states including Louisiana, California, and New York. Ethanol can be blended into gasoline as well as used in vehicles designed to operate on "neat ethanol."

We estimate that the delivered cost of cellulosic ethanol reaches $1.75 per gallon of gasoline equivalent by 2010, based on Lynd (1997). This assumes that the roughly 220 million dry tons of biomass required for both ethanol production and renewable power generation would be provided at $2.60 per million Btu from agricultural residues, forest and mill wastes, urban wood wastes, and short rotation woody crops (Walsh et al. 1997; 1999). We assume no reduction in the cost of ethanol production between 2010 and 2020, despite promising potential for technological improvement (Lynd 1997). However, we assume that 9 percent of this biofuel is used to co-produce ethanol and electricity by 2010 and 40 percent goes to co-production by 2020. The total investment in renewable fuels is $69 billion during 2000-2010 and $342 billion during 2000-2020 (1996 dollars).

H. Reducing Barriers to Combined Heat and Power

The roughly 52,000 megawatts (MW) of combined heat and power (CHP, also known as cogeneration) capacity installed in the United States as of 1997 provided about 9 percent of total electricity production (Elliott and Spurr 1999). For comparison, a number of European countries including Germany, the Netherlands, and the Czech Republic obtain 15 percent or more of their electricity from CHP facilities. There is enormous potential to expand the use of CHP in the United States due to the large pool of suitable sites and because CHP technologies are rapidly improving. However, a variety of barriers including hostile utility policies, onerous environmental permitting requirements, lack of recognition of CHP's full benefits in environmental and utility regulations, and unfavorable tax treatment are limiting the growth of CHP in the United States (Elliott and Spurr 1999).

This policy includes actions to overcome all of these barriers by: (1) providing expedited permitting for CHP systems; (2) recognizing the full benefits, including avoided power plant emissions and greater utility grid reliability, in environmental and utility sector assessments and policies; (3) removing utility-driven barriers through FERC action, national restructuring legislation, and state action; and (4) establishing a standard depreciation period of seven years for all new CHP systems.

We estimate that taking these actions would unleash a tremendous amount of CHP implementation by the private sector, resulting in an additional 50,000 MW of installed capacity

[3] Negative GHG emissions can result if ethanol and electricity are co-produced and the avoided GHG emissions from power plants is greater than emissions from production and/or processing of the biomass.

by 2010 and 144,000 MW by 2020 (Geller et al. 1998).[4] This is consistent with the goal of doubling CHP capacity in the United States by 2010, established by DOE and EPA in December 1998. Most of this capacity would be natural gas-fired, with an average overall efficiency of around 70 percent assumed (typically around 25 percent electrical output, 45 percent useful thermal output although the power-to-heat ratio can vary). We estimate that the incremental CHP capacity in the Policy Case will generate 270 TWh of electricity in 2010 and 778 TWh by 2020. On-site fuel use will increase by about 1.1 quads in 2010 and 3.1 quads in 2020 but energy consumption in conventional power plants will fall by about 2.6 quads in 2010 and 7.1 quads in 2020. This results in reduced coal- and gas-fired generation of 266 TWh in 2010 and 746 TWh in 2020. We further assume that the fuels employed on-site would shift from the current mix used in conventional boilers to natural gas for the CHP turbines. Thus, in 2010, 0.46 quads of coal, 0.15 quads of oil, and 1.59 quads of natural gas used as boiler fuels in the Reference Case Forecast would be replaced by 2.2 quads of natural gas. In 2020, 1.34 quads of coal, 0.45 quads of oil, and 4.59 quads of natural gas would be replaced by 6.4 quads of natural gas.

Regarding costs, we estimate that incremental CHP capacity costs $631 per kW on average (1996 dollars). Larger systems (greater than 50 MW) will have installed costs below this value but smaller systems can cost $1,000 per kW or more (Elliott and Spurr 1999). Owners of CHP systems (businesses and industries) will realize net energy cost savings that pay back the first cost in 4-5 years on average (Geller et al. 1998).

I. Voluntary Agreements and Incentives to Reduce Industrial Energy Use

The industrial sector consumed about 36 quads of primary energy in 1997, 39 percent of total U.S. energy consumption. Manufacturing represents about two-thirds of industrial energy use, with six sectors dominating (petroleum refining, chemicals, primary metals, paper and pulp, food and kindred products, and stone, clay, and glass products). There is substantial potential for cost-effective efficiency improvement in both energy-intensive and non-energy-intensive industries (Elliott 1994). For example, an in-depth analysis of 49 specific energy efficiency technologies for the iron and steel industry found a total cost-effective energy savings potential of 18 percent (Worell, Martin, and Price 1999).

Our proposal for policies to stimulate widespread energy efficiency improvements in the industrial sector center around establishing voluntary agreements with individual companies or entire sectors. Voluntary agreements between government and industry have resulted in substantial energy intensity reductions in some European nations such as Germany, the Netherlands, and Denmark (Bertoldi 1999; Nuijen 1998). Voluntary agreements between government and industry have been used on a limited basis to achieve energy or environmental gains in the United States. Under our proposal, companies or entire sectors would pledge to reduce their overall energy and carbon emissions intensities (energy and carbon per unit of output) by a significant amount, say at least 10-20 percent over 10 years. The government would encourage participation and support implementation by (1) providing technical and financial

[4] Capacity is expressed in terms of the electric power generation potential.

assistance to participating companies that request assistance, (2) offering to postpone consideration of more drastic regulatory or tax measures if a large portion of industries participate, and (3) expanding federal R&D and demonstration programs.

A number of major companies are demonstrating that it is possible to significantly reduce energy and carbon intensity while enhancing productivity and profitability. For example, Johnson and Johnson set a goal in 1995 of reducing energy costs 10 percent by 2000 through adoption of "best practices" in its 96 U.S. facilities. As of April 1999, they were 95 percent of the way towards this goal, with the vast majority of projects providing a payback of three years or less (Kauffman 1999). In 1998, British Petroleum announced it would voluntarily reduce its carbon emissions to 10 percent below 1990 levels by 2010, representing an almost 40 percent reduction from projected emissions levels in 2010 given "business-as-usual" emissions growth (Romm 1999). And in September 1999, DuPont announced it would reduce its GHG emissions worldwide by 65 percent relative to 1990 levels while holding total energy use flat and increasing renewable energy resources to 10 percent of total energy inputs by 2010. DuPont is on track for achieving earlier commitments to reduce energy intensity 15 percent and total GHG emissions 50 percent by 2000, relative to 1990 levels (Romm 1999). If J&J, BP, and DuPont can make and deliver on these voluntary commitments, so can other companies.

In order to estimate the impacts of this policy, we rely on a recent, detailed analysis of voluntary agreements carried out by a team from national laboratories. Based on this analysis, we estimate that widespread adoption of voluntary agreements and supporting activities could reduce primary energy use in the industrial sector by about 4.2 quads (11 percent) in 2010 and 6.9 quads (16 percent in 2020), relative to levels forecast in the EIA Reference Case Forecast. About 40 percent of this savings comes from electricity (measured on a primary energy basis), with smaller portions coming from petroleum products, natural gas, and coal. These savings do not include any changes in energy use due to the adoption of CHP, which is analyzed separately. In order to realize these energy savings, a cumulative investment in efficiency measures of about $24 billion through 2010 and $82 billion through 2020 (1996 dollars) is needed.

J. Tighter Emissions Standards on Coal-Fired Power Plants

Older, highly polluting coal-fired power plants are "grandfathered" under the Clean Air Act. This means that a majority of the 300,000 MW of coal-fired generating capacity in the United States does not need to meet the same emissions standards for NOx, SO_2, and particulates as plants built after the enactment of the Clean Air Act in 1970. These older, dirty power plants emit 3-5 times as much pollution per unit of power generated as compared to newer, coal-fired power plants and 15-50 times as much NOx and particulates as compared to a combined cycle natural gas power plant (Cavanagh 1999).[5] When the Clean Air Act was adopted, it was expected that these dirty power plants would eventually be retired. However, utilities are continuing to operate these plants beyond their "design life" due to their low capital and operating cost. In fact, electricity generation from older coal-fired power plants increased nearly 16 percent during 1992-

[5] A natural gas combined cycle power plant emits no SO_2.

98 due in part to deregulation of wholesale power markets, which is enabling utilities to sell low-cost, "dirty" kWhs outside their region (Coequyt and Stanfield 1999).

This policy would require older coal-fired power plants to meet the same emissions standards as new plants. Some plants would be modernized and cleaned up but many would be shut down and replaced with much cleaner resources, either renewable sources or natural gas-fired combined cycle power plants. Renewable power production is stimulated on a large scale through the RPS policy. We do not assume further adoption of renewable power sources beyond that required by the RPS. Instead we assume that 25 percent of coal-fired generation remaining after the efficiency and renewables polices (383 TWh) by 2010 and 50 percent (242 TWh) by 2020 is displaced by generation from state-of-the-art natural gas combined cycle power plants. Relative to the Reference Case scenario, this represents an 18 percent reduction in coal-fired generation in 2010.[6] Because of growing amounts of renewable power production and CHP as well as end-use efficiency improvements, this policy has less impact in 2020 than in 2010 (i.e., other policies drive down use of older coal-fired power plants in the absence of tighter emissions standards). This policy reduces carbon emissions from the power sector in two ways: (1) new combined cycle power plants are much more efficient than older coal-fired plants; and (2) natural gas contains less carbon per unit of energy than coal. In effect we are proposing greatly lowering the caps on total utility sector SO_2 emissions that are now part of the Clean Air Act.

This shift from coal-fired generation to natural gas-fired generation is assumed to result in a backing down of coal generation between 2000 and 2010, and a phased retirement of coal units between 2010 and 2020, with corresponding additional new gas-fired power plants. We assume that the overall capacity factor of coal units in the 2010 to 2020 period is no less than the level to which it declines by 2010 (42 percent). Under this assumption, the cumulative coal capacity retired between 2010 and 2020 is 244 gigawatts (GW), replaced by gas-fired generation (combined cycle units) operating at a slightly higher capacity factor. The cumulative gas-fired capacity added is 213 GW. To estimate the cost of these additions, we assume gas-fired combined cycle power plants cost $450 per kW.

III. Integrated Analysis and Results

A. Methodology and Key Assumptions

The analysis of the national policies and measures was undertaken using several models. The principal model used was the (DOE/EIA) National Energy Modeling System, known as NEMS (EIA 1995). Likewise, many assumptions (including energy prices and various technology cost assumptions) were taken from the NEMS model, specifically as it was applied to produce the *Annual Energy Outlook 1999* (EIA 1998). Most notably, our Base Case is derived from and very similar to the Reference Case Forecast in the *Annual Energy Outlook 1999*.

[6] Other policies, including the RPS, removing barriers to CHP, and policies that stimulate end-use efficiency improvements, also lead to reductions in coal-fired power generation. If these other policies were not included, then this policy alone would have a much greater impact on coal-fired power generation and thus carbon emissions.

NEMS is a computer model that projects future U.S. energy consumption and supply based on energy technology and fuel choices for each sector and end-use, which in turn are derived from fuel prices, technology costs and characteristics, equipment turnover rates, and financial and behavioral parameters. In this analysis, NEMS was used for modeling the Base Case and Policy Case impacts on electricity supply and emissions. The impacts on fossil use and emissions in buildings, industry, and transportation were calculated using spreadsheet models due to limitations in the version of the NEMS model we utilized.

The electricity supply module of NEMS includes detailed data for all existing power plants in each of the thirteen National Electric Reliability Council (NERC) regions of the United States and in neighboring Canadian regions. It simulates dispatch of these plants and new plants needed to meet electricity demand in each region, based on the costs and technical characteristics of the electricity supply options and their fuels. It takes account of regional power exchanges and the sulfur-dioxide cap and trade system of the 1990 Clean Air Act Amendments. It also assumes some cost reductions for new power plants as the number of units placed in operation increases (i.e., learning and scale economies). Consequently, policies such as the renewable portfolio standard can cause technology learning and thus reduce long-run costs.

Policies that reduce projected end-use electricity requirements would affect the amount, type, size, and timing of new electric power supplies, as well as the amount and mix of generation dispatched each year, within each NERC region. Demand reductions thus result in avoided costs from reduced plant construction and operation and avoided emissions from reduced generation. Similarly, policies that constrain emissions from power supply (such as tighter emissions standards on older coal-fired power plants) or require certain resources as part of the generation mix (such as a renewable portfolio standard) would affect electricity costs and emissions.

NEMS is used to obtain the impacts of the policies that induce efficiency improvements in the use of electricity in buildings and industry, and the policies that induce fuel shifts in the electric generation mix. The cost and emissions impacts of the electricity demand policies were obtained by reducing the electricity demand in each sector for each year as the policies and their impacts phase in. These sectorial demands are then disaggregated by NEMS within each region. The model finds the least-cost capacity expansion and dispatch to meet those regional demands. These results are then compared with the Base Case NEMS runs in order to obtain the net annual changes in costs and emissions.

The avoided costs and emissions from any given demand reduction, by policy, end-use, or sector, will be the marginal changes in capacity expansion and generation owing to that reduction. The analysis thus depends on the sequence with which these reductions are modeled, as each reduction changes the margin that the next reduction affects. Rather than adopt an arbitrary sequence, we modeled the aggregate impact of all the demand-side energy efficiency policies together to obtain the total avoided costs and emissions. This yields an average emissions and cost savings across all kWh saved. The averages are then applied equally to the kWh savings from each sector/policy—that is, the total impacts are allocated *pro rata*.

The electricity supply policies were also modeled using NEMS. The RPS was modeled indirectly by increasing the average price of electricity until the renewable energy requirements in 2010 and 2020 were met. The 2010 goal of about 350 TWh of renewables consisted of a mix of 56 percent wind, 30 percent biomass, 13 percent geothermal, and 1 percent solar. Tighter emissions standards for older coal-fired power plants were simulated by assuming that 25 percent of remaining coal generation after all other policies are implemented is displaced by 2010 and 50 percent is displaced by 2020.

All fuel costs are taken from the *Annual Energy Outlook 1999* (EIA 1998). Electricity costs are modeled in NEMS, taking account of the impacts of the demand reductions and shifts in generation mix caused by the policies. However, fossil fuel prices were assumed to remain the same in the Base and Policy Cases. Economic growth is also assumed to be the same in the Base and Policy Cases—2.0 percent per year on average during 2000-2020 (EIA 1998). A 5 percent real discount rate is assumed in the analysis of costs and benefits.

Regarding the cost of biomass for cellulosic ethanol and power production, we assume that the roughly 2 quads of biomass required by 2010 (about 220 million dry tons) could be supplied at an average cost of about $2.60 per million Btu. By 2020, we assume about 4.3 quads would be supplied at an average cost of about $3.50 per million Btu (Walsh et al. 1997; 1999).

We assume that the 1 quad of cellulose-derived ethanol is blended with gasoline by 2010 and is produced from waste and bioenergy feedstocks at a cost that declines to $1.75 per gallon gasoline equivalent by that year. Expenditures for bioenergy R&D and demonstration are assumed to be $150 million per year from 2001 through 2005. By 2020, 3 quads of ethanol are produced at the same assumed cost ($1.75 cents per gallon of gasoline equivalent) as in 2010. Finally, we assume that for every quad reduction in oil consumption in transportation or other sectors, there is an additional 0.2 quads of energy savings in oil refining

B. Energy Impacts

Table 2 provides the overall energy use, carbon emissions, air pollutant, and economic impacts for 2010 and 2020. In the Base Case, total primary energy consumption reaches 111.9 quads by 2010 and 121.1 quads by 2020, a 1.1 percent per year growth rate on average. Energy growth in our Base Case is slightly higher than the Reference Case Forecast in the *Annual Energy Outlook 1999* but carbon emissions growth is nearly iden-tical. Small differences between our Base Case and the EIA Reference Case reflect the fact that we used an earlier, simplified version of the NEMS model and we made off-line pro-jections between 2010 and 2020 based on the EIA's assumptions.

Table 2: Overall Results for the Base and Policy Cases

	1997	2010 Base Case	2010 Policy Case	2020 Base Case	2020 Policy Case
Energy					
End Use (Q)	70.4	84.7	74.8	92.6	73.4
Primary Energy Use (Q)	93.2	111.9	92.0	121.1	80.5
Non-Hydro Renewable (Q)	3.6	5.0	7.7	5.7	11.6
Hydro Renewable (Q)	3.1	3.2	3.2	3.4	3.4
Intensity per Unit GDP (Q/trillion $)	12.9	11.3	9.3	10.4	6.9
Carbon					
Emissions (MMT)	1,453	1,779	1,277	1,968	894
Intensity per unit energy (MMT/Q)	15.7	15.9	13.9	16.3	11.1
Intensity per unit GDP (MMT/trillion $)	204	180	129	168	77
Air Pollutants [1]					
Sulfur dioxide (MMT)	18.2	12.3	5.4	12.4	2.9
Nitrogen oxide (MMT)	17.8	11.7	9.9	11.7	8.4
Particulate matter (MMT)	1.4	1.3	1.1	1.4	1.0
Economic Impacts [2]					
Net Benefits (billion 96$)	-	-	203	-	510

[1] Air pollutant emissions are from burning fossil fuels and biomass in the industrial, buildings, transport (on-road only), and electric sectors.

[2] Costs and benefits are cumulative, using a 5 percent discount

The ten policies reduce primary energy consumption 18 percent by 2010 and 33 percent by 2020 relative to energy use in the Base Case in those years, through increased efficiency and greater adoption of CHP. Primary energy use remains close to current levels during the next decade but falls significantly during 2010-2020. Relative to the level in 1997, non-hydro renewable energy consumption roughly doubles to 7.7 quads in 2010 and more than triples to 11.6 quads by 2020 in the Policy Case. All renewables (hydro and non-hydro) account for about 12 percent of total primary energy supplies in 2010 and 19 percent of total primary energy in 2020 in the Policy Case. In contrast, renewables contribute only 7.5 percent of total energy supply in 2020 in the Base Case, about the same percentage as in 1997.

Appendix A provides the detailed breakdown of energy use by fuel type and sector in each scenario. Oil consumption increases by about one-third by 2020 in the Base Case, with oil imports increasing by about 80 percent over that period. Thus, the oil import fraction is projected to rise from a little over 50 percent today to about three-quarters of total U.S. oil use by 2020. The substantial economic and social costs of high levels of oil imports, and vulnerability to supply constraints and price shocks have been well-documented (Greene, Jones, and Leiby 1995; Greene and Leiby 1993). The policies evaluated here would significantly reduce overall oil imports. By 2010, annual oil use would be reduced by about 18 percent, while annual imports would decrease by about 25 percent, assuming that domestic production remains unchanged. By 2020, annual oil use would be reduced by about 38 percent and imports by about 50 percent, relative to the Base Case.

C. Emission Impacts

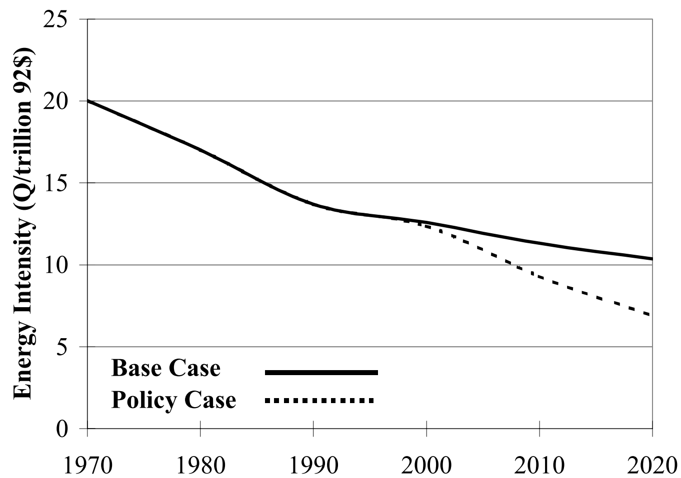
In the Base Case, carbon emissions reach 1,779 million metric tons carbon equivalent (MMT) by 2010 and 1,968 MMT by 2020, a 1.3 percent annual average growth rate during 1997-2020. Base Case emissions are 33 percent greater than the 1990 level by 2010 and 47 percent greater by 2020. In the Policy Case, carbon emissions decline so that they are 12 percent less than 1997 emissions and about 4.5 percent less than 1990 emissions by 2010. Carbon emissions in 2010 in the Policy Case are about 500 MMT (28 percent) less than in the Base Case. While this is not quite enough to reach America's Kyoto Protocol target of 7 percent below 1990 emissions during 2008-2012 (assuming the Base Case Forecast is accurate), it is very close. It should be possible to achieve the Kyoto target (i.e., a further 30 MMT annual reduction) through some combination of: (1) further domestic reductions from additional policy initiatives; (2) deeper reductions in emissions of other GHGs; (3) purchase of emissions reductions from other Annex 1 countries; and (4) reductions in developing countries from Clean Development Mechanism projects.

The set of ten policies continues to provide carbon emissions reductions after 2010 while the economy is expanding. For some of the polices, such as stimulating vehicle efficiency improvements, removing barriers to CHP, and renewable fuels standards, the impact of the policies accelerates after 2010. This is due to the time required to commercialize new technologies, increase their market share, and deploy them in a significant fraction of the eligible market. Compared to the Base Case, carbon emissions are cut 1,074 MMT (55 percent) in 2020 in the Policy Case. Emissions in 2020 in the Policy Case also are about 34 percent less than energy sector emissions in 1990. This level of carbon emissions reduction is consistent with a climate stabilization scenario whereby industrialized nations cut their absolute carbon emissions by over 50 percent by 2050 and over 90 percent by 2100 (PCAST 1999).

Our conclusion that the set of ten policies gets us close but not quite to America's Kyoto Protocol target by 2010 is dependent on the Base Case Forecast being accurate. If, in the absence of these new policies, carbon emissions do not increase as fast as projected in the Base Case Forecast, than it will be easier to achieve the Kyoto target and the set of policies may be adequate. Indeed, there is reason to believe that EIA may be overestimating growth in energy use and carbon emissions in the next 20 years. As noted earlier, the energy and carbon intensity of the U.S. economy fell substantially (over 3 percent per year) during 1997 and 1998. This means that energy use and carbon emissions grew more slowly than anticipated. While further analysis is needed to determine if these recent developments are part of a longer-term trend, it is possible that the explosive growth of information and communication technologies is starting to influence overall energy use and carbon emissions (Romm, Rosenfeld, and Herrmann 1999). Furthermore, EIA has overstated energy demand growth and missed structural or technological changes in the economy in past forecasts and studies. For example, in 1990 EIA projected a rate of energy demand growth during the 1990s that was nearly twice as large as what has actually occurred, even though economic growth has been slightly higher and oil prices much lower than what were assumed in this forecast (EIA 1990).

Figures 1 and 2 show the history of the energy intensity of the U.S. economy (primary energy use per GDP) and the carbon intensity (carbon emissions per quad of primary energy) of the economy from 1970 to the present, as well as in the Base Case and Policy Case projections. The historic decrease in energy intensity is dramatic, at about 1.7 percent per year during 1970-1998. Energy intensity decreased 2.6 percent per year on average during 1973-86 but the decline fell to 1 percent per year during 1986-98.[7]

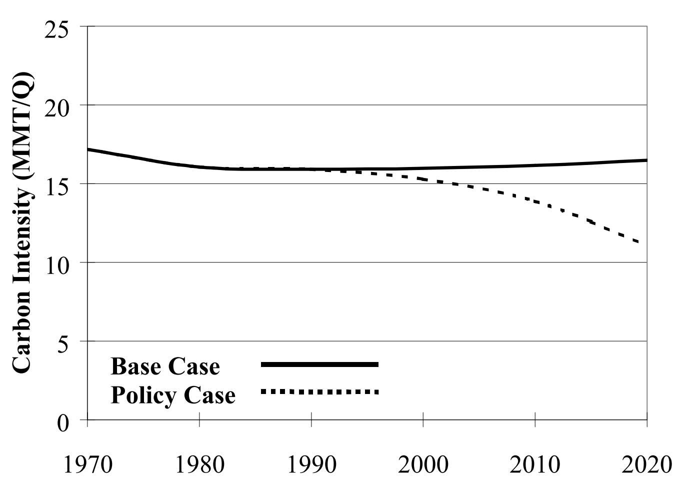
Figure 1: Energy Intensity (GDP Basis): Base and Policy Cases



The Base Case Forecast envisions a continued decline in energy intensity at about 1.3 percent per year, so that energy intensity would be about 80 percent of the current level by 2020. In the Policy Case, the energy intensity of the economy drops about 2.6 percent per year on average through 2020, twice the rate in the Base Case but approximately equal to the rate of energy intensity reduction that occurred during 1973-86.

As shown in Figure 2, the carbon intensity of primary energy consumption declined modestly (0.3 percent per year on average) during 1970-97. The reduction was caused by expansion in nuclear, bioenergy, and hydro power, although growth in coal use offset much of the de-carbonization due to nuclear and re-newable energy expansion during this period. The carbon intensity of U.S. energy supply actually has been declining over the past two centuries, falling at an average rate of about 0.9 percent per year during 1900-90 (Grubler, Nakicenovic, and Victor 1999). The Base Case Forecast, however, projects a slight increase in carbon intensity (0.2 percent per year on average)

Figure 2: Carbon Intensity (Energy Basis): Base and Policy Cases

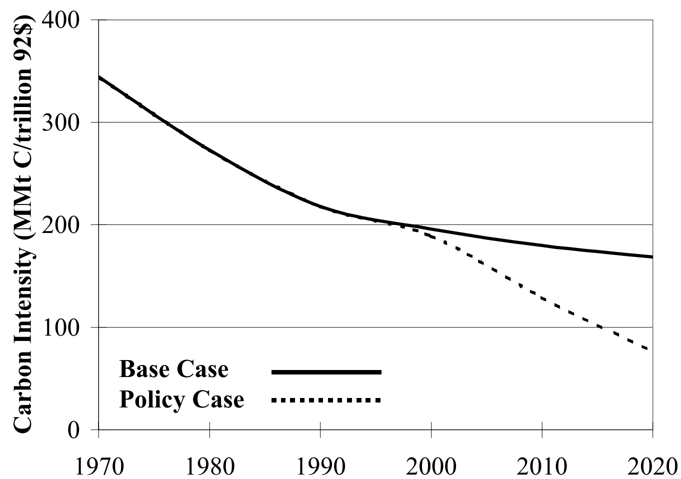


[7] As noted previously, energy intensity dropped substantially during 1997 and 1998—3.3 percent per year on average.

through 2020. The Policy Case, on the other hand, is more consistent with long-term trends and shows a 1.5 percent per year average drop in carbon intensity due to growth in renewable energy supplies and shifts from coal to natural gas within the electric sector.

Figure 3 combines the im-pacts of changing energy intensity and carbon intensity of energy use to arrive at the carbon intensity of the economy. Carbon intensity has declined by about 40 percent over the past three decades. In the Base Case, it is projected to decline at a slower rate—about 17 percent from 1997 to 2020 due to continued modest reductions in energy intensity. In the Policy Case, the projected decline is much more dramatic, by 60 percent from 1997 to 2020, owing to both energy intensity reduction and decar-bonization of energy supplies.

Figure 3: Carbon Intensity (GDP Basis): Base and Policy Cases



The results of this analysis can be compared with the findings of *America's Global Warming Solutions,* a study that used a similar approach (Bernow et al. 1999). The most salient comparison is of the carbon reductions realized by 2010. In this study, we find a decrease of 502 MMT or 28 percent of the Base Case projection of 2010 emissions. The policies analyzed in *America's Global Warming Solutions* resulted in a 654 MMT reduction or 36 percent of the baseline projection by 2010. There are several reasons for this difference. The most important is that the present study evaluated a well-defined set of policies that were not as extensive as the set analyzed in *America's Global Warming Solutions*. Thus, a larger set of policies than those considered in the present study (for example, including energy or carbon taxes or policies aimed at reducing growth in personal vehicle use) could yield even greater emissions reductions.

Another difference between the two studies is that the present study takes the *Annual Energy Outlook 1999* baseline projections of energy use, energy prices, carbon emissions, etc. as its point of departure, whereas *America's Global Warming Solutions* used the *Annual Energy Outlook 1998* projections for its baseline. Moreover, while the authors of *America's Global Warming Solutions* began policy impacts in 1998 and evaluated the impacts through 2010, in the present study we begin impacts in 2000 and continue the analysis through 2020. Given these considerations, it can be said that the results of present study are consistent with the findings of *America's Global Warming Solutions*.

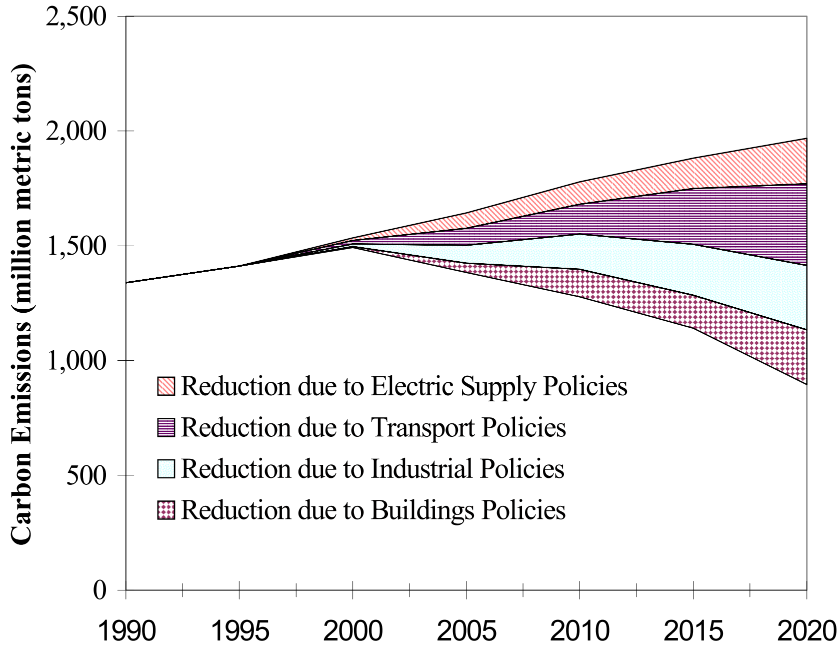
Returning to this study, Table 3 presents the carbon emissions reductions from each of the ten policies organized by sector. In this breakdown, carbon emissions reductions arising from policies that reduce electricity use are credited to the buildings or industrial sector. Also, the public benefits trust fund policy is divided between the buildings and industrial sectors since it affects electricity consumption throughout the economy. With this perspective, the buildings-related policies are responsible for about 22 percent of the overall reductions, largely through impacts on electricity generation and emissions. The industrial policies are responsible for about 25 percent of the total reductions, the transportation policies about 33 percent, and the electric supply policies about 20 percent. Figure 4 displays these results graphically. Also, Appendix B shows the carbon emissions reductions according to the sector where they occur, i.e., end-use electricity savings providing carbon emissions in the electric sector.

Table 3: Carbon Emission Reductions for Each Policy (MMT)

	1990	2010	2020
TOTAL BASE CASE EMISSIONS	**1,338**	**1,779**	**1,968**
Reductions in the Buildings Sector			
appliance standards & labeling	0	23	41
building codes	0	11	19
building retrofits	0	14	36
public benefits	0	70	142
Total Sectorial Reductions	*0*	*119*	*238*
Reductions in the Industrial Sector			
CHP	0	49	121
voluntary agreements	0	71	95
public benefits	0	33	65
Total Sectorial Reductions	*0*	*153*	*281*
Reductions in the Transportation Sector			
greenhouse gas standard for fuel	0	22	124
vehicle efficiency improvement	0	109	231
Total Sectorial Reductions	*0*	*130*	*355*
Reductions in the Electric Sector			
renewable portfolio standard	0	55	158
emission standards on coal power plants	0	43	40
Total Sectorial Reductions	*0*	*98*	*199*
TOTAL POLICY CASE EMISSIONS	**1,338**	**1,277**	**894**

Upon inspection, it may appear surprising tighter emissions standards on coal-fired power plants cause rather modest carbon reductions of 43 MMT in 2010 and 40 MMT in 2020. This is in part a result of the convention adopted in this study that carbon reductions from the supply policies are computed after the impacts of the demand policies are taken into account. The set of demand policies result in significant reductions in electricity generation and emissions. Demand reductions reduce both natural gas and coal-fired generation, with coal displacement weighted towards the less efficient plants. The RPS would tend to displace mostly natural gas generation. The effect of tighter coal plant emissions standards were computed based on a percentage reduction in coal generation; thus, with the demand policies in place it would give lower emissions reductions than without these policies in place. For comparison, we computed the impacts of the supply policies before implementing the demand policies. If the tighter emission standards are considered before any of the demand-side policies, then the carbon reductions are about 65 MMT in 2010 and 152 MMT in 2020.

Figure 4: Carbon Emissions Reductions in the Policy Case



In addition to carbon emission reductions, the set of ten policies also reduces criteria air pollutants. Air pollutants such as fine particulates (PM-10), carbon monoxide (CO), sulfur dioxide (SO_2), and ozone (formed by a mix of volatile organic compounds [VOC] and nitrogen oxides [NOx] in the presence of sunlight) cause or exacerbate health problems that include premature mortality and morbidity. Small children and the elderly are particularly at risk from these emissions (Dockery et al. 1993; Schwartz and Dockery 1992). These emissions also damage the environment, adversely affecting agriculture, forests, water resources, and buildings. Figures 5(a) through 5(c) present the impacts of the ten policies on combustion-related emissions of several criteria air pollutants. Implementing the ten policies would reduce SO_2 emissions the most—62 percent by 2010 and 84 percent by 2020. Emissions of particulates would be cut 20 percent by 2010 and 35 percent by 2020 and NOx emissions would drop 17 percent by 2010 and 30 percent by 2020. Clearly, taking action to reduce carbon emissions as proposed in the Policy Case would provide significant public health and local/regional environmental benefits.

D. Economic Impacts

Table 4 summarizes the direct economic costs and benefits in the Policy Case. The policies would induce incremental investments in high-efficiency motors; advanced industrial processes; more efficient buildings, lighting, and appliances; more fuel-efficient cars and trucks; renewable energy technologies; alternative fuels; cleaner and more efficient power plants; and so

Figure 5(a): NO_x emissions

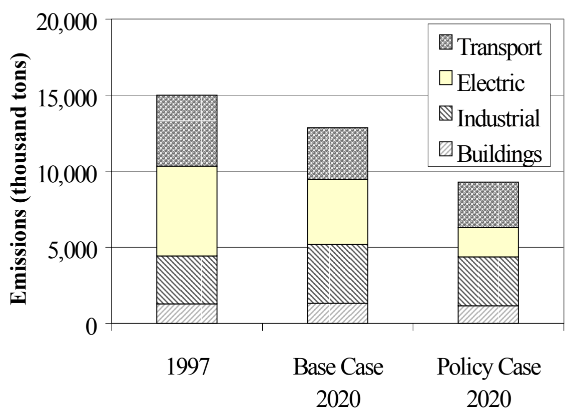


Figure 5(b): SO_2 emissions

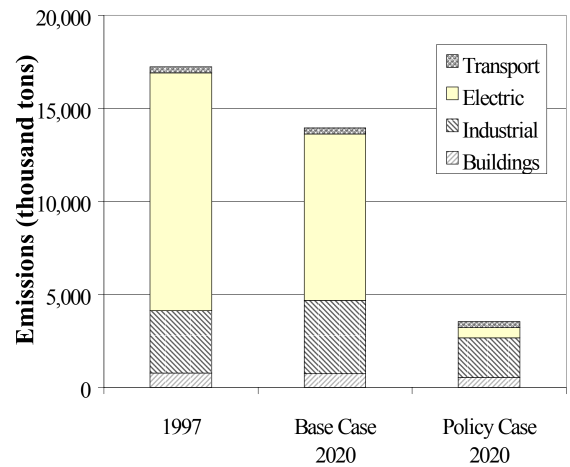
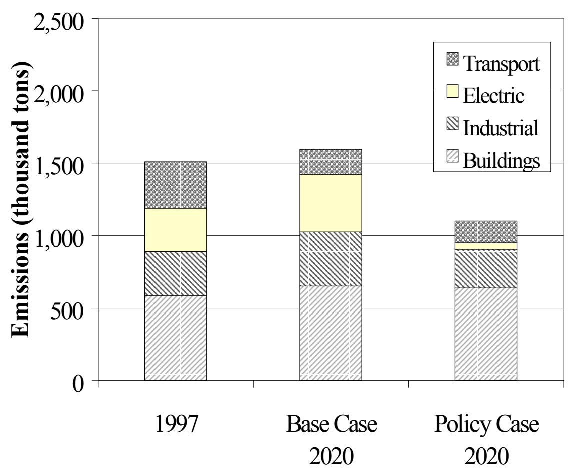


Figure 5(c): PM-10



plants; and so on. We estimate a total investment of $213 billion through 2010 and over $1.1 trillion through 2020. The energy bill and operating savings more than offset the investments costs, with net savings of about $200 billion through 2010 and over $500 billion through 2020. The net savings grow over time since energy efficiency and renewable energy measures have more time to pay back their initial cost. Furthermore, these estimates are conservative because they do not account for the fuel or operating savings that persist after 2020 even though some measures are installed towards the end of the time period considered.

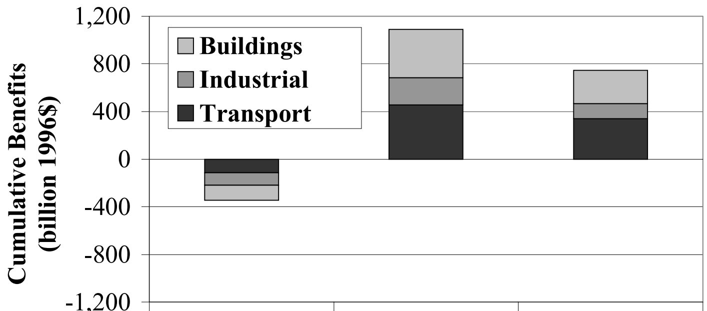
Figures 6 and 7 show further details on the cost- effectiveness of the various policies, considering all costs and savings through 2020. Figure 6 covers the seven demand-side policies (include-ing the CHP proposal) and Figure 7 covers the three supply-side policies. The de-mand-side policies in aggre-

Table 4: Cumulative Investment Costs and Fuel/O&M Savings in the Policy Case (Billion, 1996$)

	Through 2010	Through 2020
Investment Costs	213	627
Fuel and O&M Savings	416	1137
Net Savings	203	510

gate are very cost-effective, with fuel and O&M savings that are over three times the investment costs, thereby yielding net benefits of about $740 billion. On the other hand, the supply-side policies—shifting to renewable electricity and fuel sources, and requiring coal-fired power plants to meet tougher emissions standards—are not cost-effective by themselves. Investment costs exceed the fuel and O&M savings by $230 billion. Thus, combining all of the policies results in a net savings of $510 billion during the 20-year period. Appendices C and D provide further data on costs and savings.

Figure 6: Cost-Effectiveness of Demand-Side Policies by 2020 (billion 1996$)

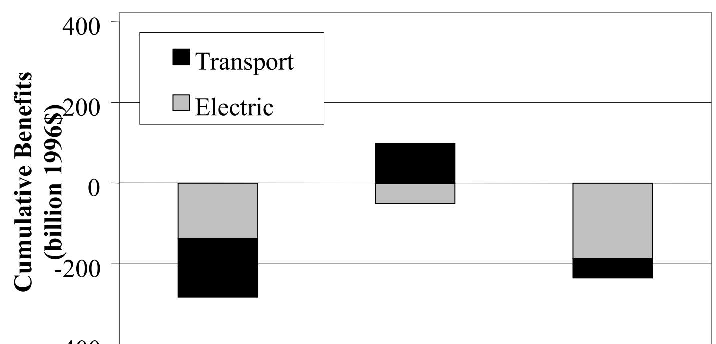


	Equipment Costs	Fuel and O&M Savings	Net Benefits
Buildings	**-128**	**406**	**278**
Industrial	**-103**	**229**	**126**
Transport	**-115**	**454**	**340**

The companies who produce, market, and service the energy efficiency and renewable energy measures implemented in the Policy Case will employ workers and add to personal income, while the energy supply industries will lose workers as demand for conventional fuels falls. The efficiency measures also lower the energy bills of the businesses, industrial firms, and households that utilize the more efficient equipment. Re-spending of these energy bill savings creates additional jobs and incomes since expenditures are shifted to areas of the economy (such as food, housing, and entertainment) that are more labor-intensive than the energy supply sectors. The combination of the direct expenditures and re-spending occurs broadly across all sectors, and much of it is local. Thus, national job increases—in construction, services, education, finance, manufacturing, agriculture, etc.—would be spread throughout the country.

While an analysis of overall macroeconomic impacts was not undertaken in this study, prior studies of this type show a net increase in jobs and personal income when energy efficiency and renewables measures are widely implemented; see Bernow et al.

Figure 7: Cost-Effectiveness of Supply-Side Policies by 2020 (billion 1996$)



	Equipment Costs	Fuel and O&M Savings	Net Benefits
Transport	**-144**	**97**	**-47**
Electric	**-137**	**-50**	**-187**

(1999); Geller, DeCicco, and Laitner (1992); Goldberg et al. (1998); and Laitner, Bernow, and DeCicco (1998). These analyses used an input-output (I-O) model that represents interactions among different sectors of the economy. The most recent national analysis, *America's Global Warming Solutions,* indicated a potential net increase of nearly 900,000 jobs by 2010 (Bernow et al. 1999). While there are uncertainties in such an analysis, and a variety of dynamic economic phenomena that are not captured, this study gives an indication of the overall macroeconomic impacts likely to result from pursing the ten policies considered here.

It also should be noted that our analysis does not take full account of the economies of scale, learning, or leadership in technology innovation that could be stimulated by the set of policies (Arthur 1994; Azar 1996). Nor does it account for the ancillary benefits, such as the human, systems, and organizational productivity improvements that could accompany the accelerated diffusion of advanced technologies and new energy resources (Porter and van Linde 1995). Such technological innovation and diffusion can have dramatic impacts on both the economic well-being and carbon intensity of society over the long run (Grubler, Nakicenovic, and Victor 1999).

IV. CONCLUSION

This study shows that the United States can achieve its emissions target under the Kyoto Protocol—7 percent below 1990 levels for the first "budget period" of the Protocol—entirely or largely through domestic actions, even though the first budget period starts in about eight years. However, U.S. GHG emissions are now 10 percent greater than they were in 1990. Thus, the U.S. will not come close to achieving its Kyoto target unless it adopts strong, new national policies. Further delay could jeopardize America's ability to meet the Kyoto target.

In order to meet America's Kyoto target, a comprehensive and aggressive set of policies must be adopted and implemented effectively. New policies are needed to stimulate greater energy efficiencies in all sectors of the economy as well as to accelerate the adoption of renewable energy sources and shift away from carbon-intensive, dirty fossil fuels. Some of the policies can be implemented without new legislation, such as adoption of more stringent appliance efficiency standards and additional product labeling, tougher fuel economy standards on cars and light trucks, reducing barriers to CHP, and voluntary agreements and related policies to reduce industrial energy use. Other policies require new legislation but have been adopted already by some states or municipalities (ICLEI 1998; Kushler 1999). These policies include strong building energy codes, public benefit programs as part of utility restructuring, and renewable portfolio standards. Adopting these policies at the national level will "level the playing field"—harmonizing policies across states, increasing the energy bill savings for consumers, and magnifying the economies of scale and "learning curve" effects from widespread energy efficiency and renewable energy deployment.

The full set of polices taken together yield direct energy bill and operating savings that exceed the costs of the technologies. While not all of the policies recommended here yield net dollar savings for households and businesses, most do. Moreover, broader economic benefits will result from stimulating innovation, improving productivity, and shifting expenditures to more labor-intensive portions of the economy than energy supply. Thus, it is still possible to meet America's Kyoto Protocol target with net economic benefits—lower costs for energy services and increased employment—rather than economic pain. The key is to be smart about how we achieve the emissions reductions and Protocol goals, emphasizing technological innovation and investment in cost-effective energy efficiency measures in the United States rather than overseas.

The set of policies proposed here would yield other benefits besides lower GHG emissions and economic benefits for households and businesses. Oil imports would be reduced, thereby improving America's trade balance and reducing its vulnerability to supply constraints and oil price shocks. U.S. industries that produce efficient and clean technologies to meet climate policy goals would be poised to capture a large share of the rapidly growing world markets for these technologies. And cutting fossil fuel use would reduce air pollutants, thereby improving public health and reducing damage to crops, forests, buildings, and water resources.

In summary, the policies proposed here can be justified even if global warming and GHG emissions were not of concern. The primary obstacles are lack of political will and in some cases industry opposition, not technical or economic viability. In particular, the Congress has been hostile to virtually all of the recommended policies. For example, Congress has prevented the Administration from upgrading the CAFE standards on vehicles, refused to include the Public Benefits Trust Fund or the Renewable Portfolio Standard in federal electric utility restructuring legislation starting to move through the Congress, objected to new tax incentives for innovative energy efficiency and renewable energy technologies, and cut funding for DOE's renewable energy programs and EPA's energy efficiency and climate protection programs. The Clinton Administration has been more supportive than the Congress but the Administration has not been willing to advocate or act on controversial policies such as tougher CAFE standards or tougher emissions standards on dirty coal-fired power plants. The auto, electric utility, oil and coal industries, for example, have opposed specific policies and blocked action.

As we move into the new millennium, policy makers should reconsider their positions. America can meet and go beyond its Kyoto Protocol target, thereby demonstrating responsibility and leadership in the worldwide effort to reduce the rate of climate change and stabilize GHG concentrations in the atmosphere, while benefiting U.S. consumers, our local environment, and the economy as a whole. But U.S. policy makers must demonstrate statesmanship—serving the public interest and standing up to the narrow interests that have prevented these policies from being enacted so far.

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APPENDIX A. ENERGY RESULTS BY FUEL AND SECTOR

Total Energy Consumption by Fuel and Sector in 1997 (Quads)

	Buildings	Industrial	Transport	Electricity	Total
Petroleum	2.1	9.3	24.1	1.4	36.9
Natural Gas	8.5	9.9	0.7	3.5	22.7
Coal	0.2	2.4	0.0	17.5	20.1
Nuclear	0.0	0.0	0.0	6.8	6.8
Renewable Energy	0.6	1.9	0.0	4.2	6.7
Primary Total	**11.5**	**23.5**	**24.8**	**33.4**	**93.2**
Indirect Electric	7.1	3.5	0.1		10.7
End-Use Total	**18.6**	**27.0**	**24.9**		**70.5**

Total Energy Consumption by Fuel and Sector in 2010 (Quads)—Base Case

	Buildings	Industrial	Transport	Electricity	Total
Petroleum	1.7	10.8	31.3	1.1	45.0
Natural Gas	9.4	11.4	1.2	5.7	27.7
Coal	0.2	2.5	0.0	22.0	24.8
Nuclear	0.0	0.0	0.0	6.4	6.4
Renewable Energy	0.6	2.3	0.1	5.1	8.1
Primary Total	**11.9**	**27.1**	**32.6**	**40.3**	**111.9**
Indirect Electric	8.8	4.1	0.2		13.1
End-Use Total	**20.8**	**31.2**	**32.8**		**84.7**

Total Energy Consumption by Fuel and Sector in 2010 (Quads)—Policy Case

	Buildings	Industrial	Transport	Electricity	Total
Petroleum	1.5	8.6	25.9	0.4	36.3
Natural Gas	8.9	12.0	1.2	4.2	26.3
Coal	0.2	1.4	0.0	10.9	12.5
Nuclear	0.0	0.0	0.0	6.0	6.0
Renewable Energy	0.6	2.3	0.9	7.0	10.8
Primary Total	**11.2**	**24.4**	**27.9**	**28.5**	**92.0**
Indirect Electric	7.1	4.1	0.2		11.3
End-Use total	**18.3**	**28.4**	**28.1**		**74.8**

APPENDIX A. ENERGY RESULTS BY FUEL AND SECTOR (CONTINUED)

Total Energy Consumption by Fuel and Sector in 2020 (Quads)—Base Case

	Buildings	Industrial	Transport	Electricity	Total
Petroleum	1.6	11.5	34.7	1.0	48.7
Natural Gas	9.9	12.5	1.4	7.9	31.7
Coal	0.2	2.6	0.0	24.6	27.4
Nuclear	0.0	0.0	0.0	4.2	4.2
Renewable Energy	0.7	2.6	0.2	5.6	9.0
Primary Total	**12.4**	**29.2**	**36.2**	**43.3**	**121.1**
Indirect Electric	10.0	4.6	0.2		14.8
End-Use Total	**22.4**	**33.7**	**36.4**		**92.6**

Total Energy Consumption by Fuel and Sector in 2020 (Quads)—Policy Case

	Buildings	Industrial	Transport	Electricity	Total
Petroleum	1.3	6.5	21.9	0.1	29.8
Natural Gas	8.7	16.1	1.3	2.6	28.7
Coal	0.2	0.6	0.0	2.7	3.4
Nuclear	0.0	0.0	0.0	3.6	3.6
Renewable Energy	0.7	2.6	3.0	8.7	14.9
Primary Total	**10.9**	**25.7**	**26.2**	**17.7**	**80.5**
Indirect Electric	6.2	4.2	0.2		10.6
End-Use Total	**17.1**	**29.8**	**26.5**		**73.4**

APPENDIX B. CARBON EMISSIONS AND EMISSIONS REDUCTIONS IN EACH SECTOR (MMT)

	1990	2010	2020
BASE CASE EMISSIONS	**1,338**	**1,779**	**1,968**
Buildings Sector			
Base Case Emissions	150	173	179
Appliance standards & labeling	0	2	4
Building codes	0	5	4
Building retrofits	0	5	12
Policy Case Emissions	150	161	159
Industrial Sector			
Base Case Emissions	279	320	342
CHP	0	-10	-30
Refinery production	0	22	51
Voluntary agreements	0	50	77
Policy Case Emissions	279	258	244
Transportation			
Base Case Emissions	432	620	687
Greenhouse gas fuel standard	0	15	54
Vehicle efficiency improvement	0	90	191
All Policy Case Emissions	432	516	442
Electricity			
Base Case Emissions	476	665	758
Renewable portfolio standard	0	55	158
Emission standards on coal plants	0	43	40
Voluntary agreements	0	21	18
CHP	0	63	210
Public benefits	0	104	207
Building policies	0	37	76
CHP from ethanol Production	0	4	59
All Policy Case Emissions	476	342	49
POLICY CASE EMISSIONS	**1,338**	**1,277**	**894**
Summary			
TOTAL Base Case Emissions	1,338	1,779	1,968
Reduction in Buildings Sector	0	11	20
Reduction in Industrial Sector	0	62	99
Reduction in Transport Sector	0	105	245
Reduction in Electric Sector	0	323	710

Note: this table shows carbon emission reductions that occur within each sector (i.e., physically emitted from stacks, tailpipes, etc. from combustion on site) for the Base and Policy Cases.

Emissions reductions resulting from end-use electricity savings owing to new appliance standards and labeling programs are counted in the electricity sector since physically that is where the emissions reductions occur.

Note also that removing barriers to CHP decreases emissions in the electric sector (by 63 MMT of carbon in 2010) by displacing central station fossil fuel generation, and increases emissions in the industrial sector (by 10 MMT in 2010) by increasing industrial gas consumption in shifting to cogeneration.

Considered in this way, about two-thirds of the total reductions occur in electric sector emissions, about 20 percent in transportation sector emissions, and about 10 percent in industrial sector emissions.

APPENDIX C. COSTS AND BENEFITS BY SECTOR—ALL SUPPLY-SIDE AND DEMAND-SIDE POLICIES (CUMULATIVE DISCOUNTED COSTS AND SAVINGS, BILLION 1996$)

	Demand-Side Policies		Supply-Side Policies		All Supply- and Demand-Side Policies	
Equipment Costs	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
Electric	0	0	47	137	47	137
Buildings	50	128	0	0	50	128
Industrial	41	103	0	0	41	103
Transport	32	115	42	144	74	259
Total	123	345	89	282	213	627
Fuel & O&M Savings						
Electric	0	0	-21	-50	-21	-50
Buildings	152	406	0	0	152	406
Industrial	89	229	0	0	89	229
Transport	169	454	26	97	196	552
Total	411	1,089	5	47	416	1,137
Net Savings						
Electric	0	0	-69	-187	-69	-187
Buildings	102	278	0	0	102	278
Industrial	48	126	0	0	48	126
Transport	137	340	-16	-47	122	293
Total	287	744	-84	-234	203	510

APPENDIX D: CUMULATIVE DISCOUNTED COSTS AND SAVINGS THROUGH 2020 (BILLION 1996$)

Policy	Costs	Benefits	Net Benefits
Appliance efficiency standards and product labeling	18	59	41
Building energy codes	12	30	19
Building retrofits	43	44	1
Public benefit trust fund	106	238	132
Renewable portfolio standard	112	-24	-136
Vehicle efficiency	115	503	388
Fuel GHG standard	144	108	-36
Combined heat & power	20	117	97
Voluntary agreements	36	98	62
Tighter emission controls on coal power plants	20	-37	-58
Total	**627**	**1,137**	**510**