A Small Price to Pay

US Action to Curb Global Warming Is Feasible and Affordable

Union of Concerned Scientists
and
Tellus Institute

Union of Concerned Scientists

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Contents

Executive Summary

The recent Kyoto Protocol mandates that the United States cut its emissions of heat-trapping gases to 7 percent below 1990 levels by the period 2008–2012. This report examines the feasibility and cost of potential US actions to reach this target. We conclude that:

- Claims that compliance with the Kyoto Protocol would be prohibitively expensive and would seriously harm the American economy are sharply overblown.

- The United States can make significant reductions in its greenhouse-gas emissions, with overall economic savings or at a modest cost.

- Opponents of action ignore the potentially large economic costs of climate change, as well as the fact that global warming could produce numerous social, demographic, and political dislocations that cannot be easily quantified in an economic model.

- Steps to reduce emissions of carbon dioxide, the most significant heat-trapping gas, would produce considerable health and environmental co-benefits from reductions in dangerous air pollutants.

- The United States can meet all or most of the Kyoto Protocol's mandated emissions reductions through domestic actions that will have zero or negative net costs. There are many viable options for reducing the use of high-carbon fuels, especially coal and oil. Additional savings may be available through the emissions-trading mechanisms in the Kyoto Protocol, but the United States need not rely on those provisions to achieve its commitment.

- Because most of its initial carbon-reduction steps will have low or no cost, our nation's competitive position in most industries would be largely unaffected.

To reach these conclusions, the Tellus Institute and the Union of Concerned Scientists surveyed and compared a series of studies from the past 10 years that examine the future prospects for energy-efficient and low-carbon fuel technologies. These analyses—from the US government's national energy laboratories, the National Academy of Sciences, the Office of Technology Assessment, and private and nongovernmental energy research organizations—evaluated policies and measures that would help to overcome market barriers and promote the development and adoption of these technologies. Our survey of these studies shows that great technological potential exists for the United States to significantly reduce its carbon dioxide emissions. In many cases, the resulting savings on energy bills from the use of more efficient measures would outweigh the cost of implementing those measures. Moreover, the same measures that would reduce carbon dioxide emissions would also yield other significant environmental and public health benefits.

The report also compares the findings in two of the more recent studies with the US target under the Kyoto Protocol. In this comparison, we account for changes in business-as-usual projections of energy use and carbon emissions made by the Energy Information Administration since the completion of these studies. When adjusted for these new baselines, the first of the two studies—*Policies and Measures to Reduce CO_2 in the US* (Tellus 1997, 1998)—indicates that the United States would be able to cut its emissions to 13 percent below 1990 levels in 2010, thereby surpassing its Kyoto target, while at the same time still realizing net economic savings. The results of the second study, *Scenarios of US Carbon Reductions* (DOE 1997) by five US national laboratories, would take the United States about three-quarters of the way toward achieving the Kyoto target. The shortfall could then be made up by either adding other cost-effective carbon-reduction measures or by using emissions trading and other flexibility mechanisms in the Kyoto Protocol.

The results obtained by the technology-based studies discussed in this report differ from the predictions of climate policy skeptics and of some conventional economic models. We believe, however, that the technology-based studies provide a more realistic view of the economics of climate change abatement and should be given greater credence. To provide support for this perspective, this report points out key weaknesses in those studies that claim climate change action will be economically prohibitive. For example, such "top down" studies often assume that our nation is already in "the best of all possible worlds." These studies fail to acknowledge that market barriers can be overcome with targeted policies and also fail to account for the large potential of technological innovation and diffusion. In addition, most of these studies implausibly assume that carbon reductions can only be achieved by imposing high energy taxes, without other taxes being reduced to compensate for these increases. Finally, they fail to account for the enormous costs of climate change itself, or for the ancillary benefits of measures that reduce carbon emissions.

A Small Price to Pay

Introduction

How much will it cost the United States to reduce the threat of global warming? The recent Kyoto Protocol mandates that our country cut its emissions of heat-trapping gases to 7 percent below 1990 levels. But would this require severe economic sacrifice, as some have claimed? Or are there ways to reach this target at a low cost or even with some economic benefit for the country? The answers to these questions will help determine whether the United States embraces the Protocol and begins to take meaningful steps to prevent global warming.

There is solid evidence that our nation can meet its obligations under the Kyoto Protocol with overall economic savings or at a very modest cost. Important analyses—from the US government's national energy laboratories, the National Academy of Sciences, the Office of Technology Assessment, and private and nongovernmental energy research organizations—have shown compellingly that the United States could significantly reduce its emissions of carbon dioxide, the most important heat-trapping gas, while maintaining a healthy economy. Moreover, the same measures that would reduce these emissions would also yield other significant environmental and public health benefits, most notably from lower levels of air pollution.

At the heart of the studies that show these very encouraging results are policies and measures that would overcome market barriers to energy-efficient and low-carbon fuel technologies, and that would stimulate technological innovation. In many cases, the resulting savings on energy bills would outweigh the cost of implementing the measures. Thus, while the most expensive measures required to meet the target would have positive net costs, the overall net cost of all measures required to meet the target would be negative, thereby producing savings.

Nevertheless, critics of action have been quick to label the Kyoto Protocol too expensive. They argue that any meaningful steps to reduce the threat of global warming would sharply lower Americans' living standards and force many people out of work. At a recent hearing of the US House Subcommittee on National Economic Growth, Natural Resources and Regulatory Affairs, the chair, David McIntosh (R-Indiana), claimed that complying with the Kyoto Protocol would increase the prices of consumer goods by more than 50 percent and the price of gasoline by 70 cents a gallon (McIntosh 1998). A witness before the subcommittee, Mary Novak of WEFA, Inc., predicted that "[t]he US would lose more than 2.4 million jobs." (Novak 1998)

Such alarmist economic predictions rely on faulty analysis that assumes the nation goes about reducing fossil fuel use in especially costly and short-sighted ways**.** The naysayers do not acknowledge the potential contribution of existing advanced and low-carbon technologies, nor do they recognize the potential impact of policies that could overcome market barriers impeding diffusion of these technologies. Moreover, they do not consider technological progress, nor the possibility of implementing policies that would expedite such progress. Finally, they do not take into account the enormous costs of climate change itself, nor of the ancillary environmental, health, and economic benefits of measures that reduce carbon emissions.

In this report, we examine recent studies in the United States and elsewhere, which show that energy-related carbon emissions can be reduced cost- effectively. We compare these studies' findings to the specific emission reduction targets the United States would have to meet under the Kyoto Protocol. We also show why these empirically based studies provide a useful indication of the actual costs of taking action and why they are more credible than predictions of immense economic gloom.

The Context for Climate Change Action

The Risk of Climate Change. In recent years, scientists have increased their understanding of the global climate system. They have become more confident in their projections of future climate change and have even concluded that human activities are most likely already causing changes to the global climate. Nevertheless, emissions of heat-trapping gases continue to rise, exacerbating the risk of climate change. Atmospheric concentrations of carbon dioxide (CO_2), the most significant heat-trapping gas, are now about 30 percent above preindustrial levels. Annually, the burning of fossil fuels—oil, coal, and natural gas—across the globe sends about 6 billion tons of carbon into the atmosphere, while land-use changes (mainly burning and decomposition of forest biomass) contribute another 1 billion tons. Under a business-as-usual future, in which no special efforts are made to avert climate change, annual emissions of carbon would likely increase nearly threefold, to about 20 billion tons, by the end of the next century. As a result, atmospheric concentrations of CO_2 would reach over 700 parts-per-million, or some two-and-a-half times preindustrial levels, causing the global average temperature to rise between 1.4 and 2.9 degrees Celsius, with even greater increases in some regions (Houghton 1996).

The potential consequences of such change are myriad and far-reaching. Sea levels could rise between 19 and 86 centimeters, with severe implications for coastal and island ecosystems and their human communities. More frequent, prolonged, and intense extreme weather events, as well as shifts in regional climates, could cause ecological, economic, health, social, and political disruptions. One-third of the world's forested areas would likely experience major changes in species composition, with more frequent outbreaks of pests and greater frequency and intensity of forest fires. Agricultural systems could come under severe stress, creating increased risk of hunger and famine in Africa, South and Southeast Asia, and other regions already experiencing difficulty feeding all their people. There could be wide-ranging impacts on human health, both from direct effects, such as more intense heat waves, and from indirect effects, such as more extensive geographical range of vector-borne diseases, including malaria and dengue fever (Watson et al. 1996).

The precise timing and extent of such impacts remains uncertain. It should be noted, however, that such complex nonlinear systems can have extreme outcomes that could trigger much more rapid change than the "best case" projections. This would cause additional ecological and social disruptions and further limit society's ability to adapt. It could also require efforts to mitigate climate change that are more hurried, more costly, and less effective. Consequently, early and sustained action, across many fronts, is needed to bring about the technological, institutional, and economic transitions needed to protect the global climate.

The Kyoto Protocol. The Third Conference of the Parties to the United Nations Framework Convention on Climate Change (UN FCCC) in Kyoto in December 1997 was a historic event that provides a pivotal opportunity to reverse the course towards climate disruption on which the world is currently headed. At Kyoto, signatory nations to the existing UNFCCC agreed to greenhouse-gas reduction targets that would be legally binding on industrialized nations when ratified. The Kyoto Protocol provides a comprehensive and integrated framework for greenhouse-gas mitigation responsibilities and actions; it represents an important first step toward the level of reductions needed to stabilize the earth's climate.

Whether this promise is realized depends in part on how the details of the Protocol are worked out and implemented, and how industrialized nations, especially the United States, take on their responsibilities for strong near-term actions.

US Climate Policy Post-Kyoto. In the months since Kyoto, the Clinton administration has acknowledged the challenges and opportunities of climate protection, even though its actual actions and policy proposals have not been sufficiently strong. Administration officials understand that advanced, energy-efficient, and low-carbon technologies can be at the heart of a national economy that will be more productive, less polluting, less oil-dependent, and consistent with global climate protection. They understand that market barriers and pricing failures impede these technologies from diffusing more rapidly, dampen the process of technological progress through learning-by-doing and scale economies, and thereby sacrifice deep long-term benefits in favor of short-term gain. They know that policy instruments are available that could reduce these barriers and unleash creative human, technological, institutional, and economic forces. Finally, they understand that the United States has an opportunity to be a leader in 21st-century technologies, sustainable-development assistance, and fair and responsible international stewardship of the global commons.

Nevertheless, the administration's policy recommendations to date are not fully consistent with its understanding of the need for, and benefits of, timely action to reduce emissions. Although its proposals for increased research and development and tax incentives for climate-friendly technologies have great merit and should be enacted by Congress, they do not go nearly far enough. Much more is needed—particularly in the electric utility and transportation sectors—to ensure that the United States can meet its commitments for the First Budget Period under the Kyoto Protocol. Fortunately, several recent technology-based studies have shown that it is indeed possible for industrialized nations, including the United States, to significantly reduce their greenhouse-gas emissions, while continuing to prosper and maintain healthy economies.

Carbon Reduction Potential in the United States

Since the early 1990s, a number of analyses have shown compellingly that technologies, resources, policies, and measures are available to reduce the carbon emissions of industrialized countries, and of the United States in particular. These analyses are based on detailed representations of existing energy-use patterns and technologies, and well-understood existing and near-term alternatives to them, by sector, subsector, end-use, and process.

In the United States, key studies include *America's Energy Choices* (ASE 1991), by four internationally recognized NGOs; a study by the Office of Technology Assessment of the US Congress (OTA 1992); *Policy Implications of Greenhouse Warming* (NAS 1991), by the National Academy of Sciences; *Scenarios of US Carbon Reductions* (DOE 1997), by five US National Laboratories; *Energy Innovations* (ASE 1997); and *Policies and Measures to Reduce CO_2 in the US* (Tellus 1997, 1998).

In Europe and Japan, recent analyses include *Policies and Measures to Reduce CO_2 Emissions by Efficiency and Renewables* (WWF 1997), by the Department of Science, Technology, and Society at Utrecht University; *Energy Policy in the Greenhouse* (Krause et al. 1993); and *Key Technology Policies to Reduce CO_2 Emissions in Japan: An Indicative Survey for 2005 and 2010* (Tsuchiya et al., 1997).

In this section, we first briefly summarize the three studies of the early 1990s (ASE 1991, OTA 1993, and NAS 1991). We then turn to a more detailed discussion of the three more recent US studies (ASE 1997, DOE 1997, and Tellus 1997 and 1998). As part of this section, we explicitly compare the results from two of these studies to the US emissions-reduction target under the Kyoto Protocol. Finally, we provide a brief comparison among the recent studies of Europe and Japan.

Three US Studies of the Early 1990s. The table below summarizes the carbon-reduction results of the Office of Technology Assessment (OTA), the National Academy of Sciences (NAS), and *America's Energy Choices* (AEC). We have expressed the results in overall and average annual percentage reductions, in order to render them more comparable, as they use somewhat different baselines and show results for different years.

Percent Reduction from Baseline in Year
(linear percent per year from start year)[a]

Study	**Start Year**	**-Year of Projection-** **2010**	**2015**
AEC	1991	53 (2.8)	61 (2.5)
OTA	1987	----------	47 (1.7)
NAS	1989	58 (2.8)[b]	----------

[a] The gross percentage given is the ratio of the carbon reductions in the year to the baseline projections in that year; the annual percentage reductions are simply this figure divided by the number of years from the start year for the policies.

[b] The NAS study is a static analysis of the potential for carbon reductions in 1988. We assume that the 22 years between 1988 and 2010 would provide sufficient time and equipment stock turnover to realize these savings.

These three studies have broadly similar findings. Each shows that known energy-efficient and low-carbon technologies could be brought into widespread energy production and use, thereby yielding substantial carbon emissions reductions. Each study also finds that these reductions could be realized with overall net monetary savings, even though some measures with net costs would be needed to achieve the full level of reduction.[1]

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[1] Overall savings in fuel and facility construction from

energy-efficiency investments exceed the incremental costs of these investments and alternative fuels.

America's Energy Choices, for example, finds that by 2030, projected carbon emissions could be reduced by about 80 percent, with more than $500 billion ($1990 PV) in cumulative savings.[2] The marginal cost of achieving these reductions is about $25 per ton of CO_2 saved, for low-carbon fuels and technologies in the electric sector. At the same time, the study shows that the steps required to achieve these carbon reductions would also produce other environmental and public health benefits. For example, emissions of the air pollutants, such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x), would be reduced more than one-third below baseline projections by 2010 and about 75 percent below by 2030. The study did not quantify the economic benefits of reducing air pollution levels, but these would certainly reduce health care costs by a significant amount.

The NAS study provides two cases, one in which a carbon reduction of 29 percent is realized using only those measures with net economic savings, and one (shown in the table) in which about twice that level of reductions is achieved by also including some measures with net positive costs. Nevertheless, this more ambitious scenario still saves about $34 billion per year on average, while its marginal or highest cost measures, in the electricity supply sector, average about $40 per ton of CO_2 saved. The OTA study finds average annual costs ranging from about $20 billion to $150 billion per year.

Three Recent US Studies. Three new studies released since June 1997—*Scenarios of US Carbon Reductions* (DOE 1997), *Energy Innovations* (ASE 1997), and *Policies and Measures to Reduce CO_2 in the US* (Tellus 1997, 1998)—provide policies and measures to achieve carbon reductions between about 25 and 35 percent of baseline projections by 2010. The *Policies and Measures* study builds upon *Energy Innovations*. Both formulate and model a set of targeted and complementary policies to overcome market barriers to technological diffusion and innovation, and to guide the US economy towards lower carbon emissions, based on lower-cost, less-polluting, more-secure, and more-sustainable ways of producing and using energy. *Policies and Measures* strengthens, accelerates, and supplements the policies identified and analyzed in *Energy Innovations*, yielding an augmented policy package that captures greater near-term carbon-reduction opportunities. While it contains some policies in common with *Energy Innovations* and *Scenarios of US Carbon Reductions* (by a DOE interlaboratory working group), its full policy package is larger and more aggressive than either. *Policies and Measures* consequently achieves about 50 percent greater carbon reductions by 2010 than these two studies.

Percent Reduction from Baseline in Year
(linear percent per year from start year)

Study	Start Year	Reduction in 2010[a]
Energy Innovations	1996	26 (1.8)
Interlaboratory Group[b]	1998	23 (1.9)
Policies and Measures	1998	36 (3.0)

[a] Energy Innovations finds deeper reductions in later years: 46 percent below the baseline projection in 2020 and 62 percent below in 2030.
[b] This is the study's high-efficiency, low-carbon (HE/LC) scenario.

All three recent studies show net overall economic savings from their respective carbon-reduction policy packages, with net positive costs at the margin to achieve the reductions.[3]

Energy Innovations and the Interlaboratory study obtain similar carbon-reduction results with similar overall net economic benefits. The latter study does not go as far at the margin to achieve these results, partly because it identifies greater cost-effective savings opportunities in buildings and industry. Also, it does not go as far in the electricity-supply sector, where very large reductions are possible, albeit at

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[2] This assumed a real annual discount rate of 7 percent, to broadly reflect private discount rates in the economy; with a social discount rate of 3 percent per year, the study finds net savings of about $2 trillion cumulative over the 40 year period.

[3] Here, the marginal cost is taken as the highest average (or levelized) cost of all the policies and measures in the scenario package over the study period to achieve the carbon emissions reduction. This cost can be regarded as the market clearing price for carbon permits in a cap and trade system implemented in conjunction with the other policies.

Carbon Reductions and Net Savings for Three Recent US Studies

	Carbon Reductions in 2010 (MtC)[a]	Average Annual Net Savings (1995 \$ in billions)	Marginal Cost (1995 \$/ton CO_2)
Energy Innovations	414	\$27[b]	\$38
Interlaboratory Working Group	394	\$9-\$34	\$11
Policies and Measures	593	\$17[c]	\$56

[a] Million metric tons of carbon

[b] The study reports \$218 billion cumulative present value net benefits discounted to 1993 in 1993 dollars; using its 5 percent annual discount rate, inflating to 1995, and levelizing over the study period gives the \$27 billion result provided here.

[c] The study reports \$136 billion cumulative present value net benefits discounted to 1993 in 1993 dollars; using its 5 percent annual discount rate, inflating to 1995, and levelizing over the study period gives the \$17 billion result provided here.

rising marginal costs. *Energy Innovations* accepts higher marginal costs in the near term for implementing a greater amount and more diverse mix of wind, solar, biomass, and other renewable electric generation technologies. Its aim here is to move these technologies along their learning and scale-economy curves so that greater carbon- and pollution-reduction benefits could be realized at lower costs over the long term.

Energy Innovations estimates the impacts of its policy package on employment, personal income, and gross domestic product (GDP). It finds a net increase of about 770,000 jobs per year by 2010 relative to business-as-usual, representing a 0.4 percent increase, along with a 0.27 percent increase in aggregate annual income and a 0.03 percent increase in annual GDP. These benefits are small but nonetheless noteworthy, given claims to the contrary that climate change action would lead to job losses and economic decline.[4]

Energy Innovations also quantifies the ancillary air pollution reductions stemming from these carbon-reduction policies. It finds that SO_2 would be decreased by about 60 percent, NO_x by about 20 percent, and fine particulates by about 20 percent below their projected baseline 2010 levels. By improving public health and the environment, such reductions in air pollution decrease the effective costs of cutting carbon emissions. Accounting for these co-benefits in the electric-supply sector—which, unlike the other sectors, requires positive net costs to reduce its carbon emissions—reduces the cost of the policies from about \$18/ton of CO_2 to about \$13 per ton of CO_2.

Because *Energy Innovations* and the Interlaboratory study take somewhat different approaches, a combination of their policies could realize greater carbon reductions, while still maintaining net economic benefits. This is essentially what is embodied in *Policies and Measures*, which realizes about 50 percent greater carbon reductions by 2010 while maintaining about two-thirds of the net economic benefits of *Energy Innovations*.

How the Studies Compare to the Kyoto Targets. The Kyoto Protocol would require the United States to reduce its greenhouse-gas emissions to 7 percent below 1990 levels by the 2008–2012 period. The engineering end-use studies described above demonstrate that the United States can meet this target at a low cost, or even with net economic savings. To illustrate this, we will explicitly compare the *Policies and Measures* and Interlaboratory study results with the 7 percent reduction from 1990 levels required of the United States under the Kyoto Protocol. However, we must first take account of changes in the US baseline energy and carbon projections made since these studies were completed (EIA 1997). Unfortunately, these projections predict higher baseline carbon emissions in the future due to increased energy demand, especially for transportation and electricity.

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[4] They do not include potential further economic benefits, such as productivity enhancement, and further technological innovation, spurred by these policies. On the other hand, some sectors would likely experience net declines in the context of this overall net economic improvement, with the largest declines occurring in electricity supply and oil and gas extraction.

	Baseline Projection MtC	Carbon Reductions MtC	Reductions vs Baseline %	Reductions vs 1990 %	Reductions vs 1990 (Revised Baseline) %
Interlaboratory Study	1730	394	-23%	0%	(4%)
Policies and Measures	1634	593	-36%	-22%	13%

We have therefore used the results of the two recent studies as a point of departure, and have estimated how they would be adjusted in accordance with the higher levels of baseline energy use and carbon emissions now projected by EIA. These results are given in the last column of the table below, following the summary results of the studies themselves. Here, we assume that the energy-efficiency policies in the two studies would reduce carbon emissions under the higher, more recent baseline by the same percentage as in the two studies themselves (which use lower carbon baselines). Similarly, we assume that the fuel-switching policies would reduce carbon emissions under the higher baseline by roughly half as much as in the two studies, again on a percentage reduction basis.

The table above shows that with the full set of policies in *Policies and Measures*, the United States would surpass its Kyoto target of 7 percent below 1990 levels in 2010, attaining 13 percent reductions, most likely with net economic savings. This means that if the full set of policies were implemented, the United States could meet its treaty target entirely through domestic energy-related carbon reductions, and without recourse to emissions trading, the use of carbon sinks, or the Clean Development Mechanism established by the Kyoto Protocol. Moreover, if the United States chose to meet its Kyoto target but do no more, the most costly measures included in the *Policies and Measures* study could be avoided, thereby increasing the net economic benefits.

	Kyoto Protocol	**Policies and Measures**	**Interlab Study**
2010 Baseline	**1803 MtC**	**1803 MtC**	**1803 MtC**
2010 Target	1244 MtC	1164 MtC	1394 MtC
2010 Reduction	559 MtC	639 MtC	409 MtC
2010 % Reduction	-31 %	-35 %	-23 %
% Reduction vs. 1990	- 7 %	-13 %	+ 4 %

The *Policies and Measures* results also indicate that it would remain economical for the United States to pursue a carbon-reduction path that exceeded its Kyoto target. Despite the greater cost, this more ambitious path would spur greater technological innovation, and would generate additional public health and productivity benefits. Moreover, if the United States were to exceed its required reductions, it would, of course, further reduce the chances of catastrophic climate change, and would provide a powerful demonstration of US leadership in this area.

Once adjusted to the new EIA baseline projections, the Interlaboratory results take the United States most of the way toward achieving the Kyoto target. At 23 percent below projected levels by 2010, rather than the 31 percent required to meet the target, the carbon reductions would still be quite impressive and ambitious. The shortfall relative to the Kyoto target could be made up by use of one or more of the flexibility mechanisms afforded by the Kyoto Protocol. It would, however, also be feasible and economical to make up this difference through domestic energy-related measures, since the measures embodied in the Interlaboratory study do not exhaust all of the carbon-reduction options available. Because the *Policies and Measures* study assembled a larger set of measures, some of them could be added to those of the Interlaboratory study to achieve the US Kyoto target, most likely at a modest cost.

Detailed Comparison. In this section, we compare *Policies and Measures* and the Interlaboratory study in more detail. For simplicity, we leave out *Energy Innovations*, since its measures are largely incorporated into the more aggressive *Policies and Measures* study. Specifically, the latter study adds industrial combined-heat-and-power, cellulosic ethanol blends with gasoline for light-duty vehicles, and biomass co-firing with coal electric generation, in the pre-2010 period.

Both *Policies and Measures* and Interlaboratory study take what is referred to in the energy analysis literature as the "bottom-up" approach. They are based, to the greatest degree feasible, on end-use and technology-specific representations of energy supply and demand for the various sectors and subsectors of the economy. They reflect stock turnover and price-related energy-consuming and -producing behavior in some detail. While both studies take an engineering end-use approach to assess the technical and economic potential of the carbon-reducing technologies, *Policies and Measures* takes the further step of modeling the actual policies that would promote such technologies in all sectors of the economy. Many of the specific technologies are common to both studies; here, we reflect the way in which each study is structured and presented — with policies for *Policies and Measures* and technologies for the Interlaboratory study.

Industry

Policies and Measures study. Accelerates adoption of industrial combined-heat-and-power (CHP) systems, by refining siting protocols and ensuring market access to fairly reflect the technology's economic and environmental benefits. Provides tax credits to expedite investment in new manufacturing equipment with modern, energy-efficient technologies and processes. Supports research, development, and technical assistance for energy efficiency and alternative-fuels use. Promotes use of high-quality recycled feedstocks by eliminating favorable tax treatment of virgin materials, supporting development of innovative collection and separation technologies, and promoting public acceptance.

Interlaboratory study. Identifies and estimates near-term technical and economic potential of energy-efficient technologies and processes for reducing electricity use by about 15 percent and fossil fuel use by about 10 percent, by 2010; about two dozen known and proven process technologies are identified as examples. Identifies the potential for advanced turbine systems used for CHP and fueled by natural gas to replace grid electricity and steam boilers, combining notable overall efficiency improvements with opportunities for switching from high- to low-carbon fuels. Recommends encouraging the use of black liquor in integrated gasification combined-cycle (IGCC) turbines in the paper and pulp industries as another low-carbon option.

Transportation

Policies and Measures study. Improves fuel economy and emissions through standards, pricing reform, incentives, land-use policy, demand management, and RD&D; more than 50 percent improvement in new light-duty vehicle miles per gallon (mpg) by 2010 is achieved through these measures. Establishes a carbon/renewable content standard for motor fuels, phasing into a 10 percent zero-emissions requirement by 2010, and provides R&D support for cellulosic ethanol.

Interlaboratory study. Identifies more than a dozen proven new technologies, designs, and materials that would improve the fuel economies of light-duty vehicles, heavy trucks, and locomotives; includes advanced direct injection in gasoline and diesel engines, advanced drag and friction reduction, and materials substitution. As with *Policies and Measures*, new light-duty vehicle mpg increases by over 50 percent by 2010. Identifies several alternative or hybrid-fuel vehicle options; the most promising for near-term carbon-reduction measures are cellulosic ethanol and electric vehicles (in combination with a shift to low-carbon electricity generation).

Electricity Supply

Policies and Measures study. Sets sector-wide generation performance standards (or pollutant emissions caps), with more stringent limits on SO_2 emissions (another 60 percent reduction beyond current requirements by 2010); limits on NO_x and fine particulate emisisons effectively equivalent to EPA's New Source Performance Standards by 2010; and carbon-intensity standards set at one-third below current levels by 2010, using permit trading systems.

Establishes a renewable portfolio standard with tradable credits, phased in to a requirement of at least 10 percent nonhydro renewable generation in the national mix by 2010. Requires at least 10 percent co-firing of biomass in coal power plants by 2010, with a trading system to allow for the most economical deployment of biomass.

Interlaboratory study. Identifies as options retirement of older coal plants; repowering of coal plants with natural gas; co-firing of biomass in coal plants; implementing renewable generating technologies (wind and hydropower); improving generation, transmission, and distribution efficiencies; carbon-based dispatch; and nuclear plant life extension.

Buildings

Policies and Measures study. Establishes new and more stringent appliance and building standards to set norms for equipment, design, and performance, and to reduce the energy required to provide services in homes and offices. Provides market transformation incentives, including technology demonstrations, manufacturer incentives, and consumer education to reduce barriers to energy savings and renewables.

Interlaboratory study. Identifies proven near-term, cost-effective building shell improvements and technologies for greater energy efficiency in more than two dozen end-uses, resulting in about a 15 percent reduction in electricity consumption and a

Carbon Reductions and Cost of Saved CO_2 in 2010 by Sector and Policy

	Policies and Measures			Interaboratory Study	
	Reductions (MtC)	Costs ($/ton)		Reductions (MtC)	Costs ($/ton)
Industry					
CHP Initiatives	40	-$ 31	Efficiency	62	-$ 32
RD&D for Efficiency	18	-$ 28[a]	Other	31[b]	+$ 8
Tax Incentives	57	-$ 28			
Recycling	2	-$ 42			
Subtotal	**117**	**-$ 29**	**Subtotal**	**93**	**-$ 19**
Transport					
Efficiency Standards	90	-$115	Efficiency	87	
Renewable Standards	32	+$ 48	Ethanol	16	
Demand Management	61	~ 0			
Subtotal	**183**	**-$ 48**	**Subtotal**	**103**	**-$ 39**
Electricity					
Renewable Std	37	+$ 26			
Biomass Co-firing	27	+$ 29	Fuel Etc.	81[c]	+$ 9
SO_2 Cap	44	+$ 27			
NO_x/PM Cap	34	+$ 10			
Carbon Cap	82	+$ 59	CO_2 Disp	55	+$ 8
Subtotal	**224**	**+$ 36**	**Subtotal**	**136**	**+$ 9**
Buildings					
Residential Efficiency	9		Efficiency	59	-$ 82
Commercial Efficiency	51		Fuel Cell	3	+$ 8
Subtotal	**70**	**-$62**	**Subtotal**	**62**	**-$ 78**
TOTAL	**593**	**-$15**	**TOTAL**	**394**	**-$ 24**

[a] For the cost-of-saved-carbon calculations, the tax credit and RD&D policies were combined.

[b] This figure includes 17 MtC for CHP and 14 MtC for renewables.

[c] This category includes about 17 MtC from biomass co-firing, 11 MtC from other renewables, 40 MtC from coal retirements and repowering with gas, and 8 MtC from power plant efficiency.

5 percent cut in fossil fuel use by 2010. Includes fuel cells for large commercial buildings.

The table above compares the *Policies and Measures* and the Interlaboratory studies in greater detail, showing the carbon reductions realized in 2010 by policy or set of policies in each sector.[5] The cost of saved CO_2 emissions is negative for some policies and positive for others. Where the cost is negative, it is because many energy-efficient, advanced technologies save enough energy to more than compensate businesses and households for the incremental costs of purchasing and installing them. In those other cases where there is a net cost for reducing carbon emissions, the policies cause the market to begin to accept energy technologies and resources that are currently more costly than the norm, in order to realize even deeper carbon reductions.[6] As noted earlier, the negative cost options outweigh the positive cost options in both of these studies, and thus the overall costs of the policy packages are negative; that is, these policies result in net economic benefits for the economy.

Some have argued that the US should only implement those policies and measures that produce net savings. There are at least six reasons, however, why this approach should be rejected, and a wider range of policies and measures embraced.

First, environmental and health co-benefits from policies aimed primarily at reducing carbon are not included in the cost-of-saved-carbon figures, even though this would yield additional monetary benefits. Second, some of the process improvements and advanced technologies spurred by carbon-reduction policies would also increase industrial productivity. Third, reduced dependence on imported oil would improve the security of energy supply to our economy and lessen the likelihood and impacts of oil price shocks. Fourth, particular communities, states, and regions could derive economic benefits from developing their local energy resources, such as wind, solar, or biomass. Fifth, bringing some technologies with near-term costs into the market could lead to future cost reductions, performance improvements, and innovations and inventions.

Finally, the United States should be willing to incur costs at the margin for the carbon reductions needed to ensure climate protection, because of the absolute necessity of avoiding serious ecological and socioeconomic damage. Seizing the attractive technological, economic, environmental, and social opportunities that lie ahead should be viewed as a low-cost societal insurance policy against these potential impacts.

Comparison with Studies of Europe and Japan

Recent technology-based bottom-up studies conducted in Europe and Japan have produced broadly similar results. These studies identify known technologies and processes, and evaluate them in the context of specific sectors, end-use energy requirements, costs, and prices. The policies and measures adopted in these studies are largely based upon so-called no-regrets options, whose net costs are negative. For example, the authors of the Worldwide Fund for Nature’s 1997 report *Policies and Measures to Reduce* CO_2 *Emissions by Efficiency and Renewables*, state that: “The options included in our scenario have—with few exceptions—net economic benefits, i.e., the benefits of the measures are higher than the costs (including interest, depreciation and operation, and maintenance costs).” (WWF 1997)

These results are similar to those of the US studies, in which overall net economic benefits were achieved, with some net cost incurred at the margin, particularly as a result of bringing renewable technologies into the solution. The table below compares the results of the various studies.

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[5] Note that the emissions-reduction number shown for each policy is the total that results from that sector-specific policy, no matter in which sector the emissions are reduced. Thus, market transformation for energy efficiency in buildings (and building equipment) reduced emissions from fuel use on-site and from combustion at power plants; similarly, vehicle efficiency and alternative fuels will reduce emissions at the tailpipe and in oil refineries.

[6] The term “currently” used here implies that the costs of these more advanced technologies could decline (and their performance improve), through technological innovation and scale economies stimulated by these policies.

Percent Reduction from Baseline in Year
(linear percent per year from start year)

Study	Start Year	Reduction in 2010[a]
United States		
Energy Innovations	1996	26 (1.8)
Interlaboratory Working Group	1998	23 (1.9)
Policies and Measures	1998	36 (3.0)
European Union	1998	30 (2.5)
Japan		
CASA (Technology Only)	1998	26 (2.2)
Tsuchiya/Morita (Mid)	1998	31 (2.6)

[a] Energy Innovations finds deeper reductions in later years, 46 percent below the baseline projection in 2020, and 62 percent below in 2030.

Why Some Top-Down Studies Are Problematic

The results obtained by the technology-based studies differ from the predictions of climate policy skeptics and of some conventional economic models. We believe, however, that the technology-based studies provide a realistic view of the economics of climate change abatement and should be given greater credence than the unduly pessimistic assessments of the skeptics.

Climate policy skeptics have predicted sharp declines in employment, income, and GDP resulting from actions to reduce carbon emissions because their studies are based upon pessimistic and unrealistic assumptions about energy technologies and the economy itself. A number of economists have persuasively documented the undue pessimism and shortcomings of conventional economic models (Repetto 1997, DeCanio 1997, Grubb 1997, Azar 1997, Amano 1997, and Dowlatabadi 1997). Some economists have also argued that technology-based studies are too optimistic. Krause (1996), however, has rebutted the notion that technology-oriented studies are too optimistic in their economic assessments, by showing that such studies do, in fact, include many biases that tend to overestimate the costs of actions to mitigate climate change.

In general, those economic models that predict the highest costs for climate change action reflect an economic or policy paradigm that, in effect, assumes that we are already in the “best of all possible worlds,” or will soon get there through normal market forces. Such models pay little attention to technologies themselves, or to technological innovation, the institutional conditions and market barriers that impede the diffusion of new technologies, and the process of technological learning and scale economies. These can all be affected by a variety of pricing and other policies, such as standards, incentives, information and technical assistance, regulation, R&D, and infrastructure improvement. These models unnecessarily assume continuity of structural, technological, institutional, and behavioral relationships, permitting only marginal changes before assumed costs are incurred. Yet history shows that nonmarginal changes can occur, with overall economic, environmental, and social benefits. Climate protection is a new challenge that requires such change, not merely continuity with past relationships under a business-as-usual future.

Repetto, Azar, and Krause have performed comparative analyses of a wide variety of climate policy modeling studies. They have shown that several factors account for the fact that conventional “top-down” economic models, which were designed for other types of analyses, cannot capture the technological realities and associated results of “bottom-up” engineering end-use analyses. For example, top-down studies underestimate the extent to which new energy technologies and resources can replace old ones, and overestimate the future costs of nonfossil energy sources.

In perhaps their most blatantly implausible assumption, some of the top-down assessments assume that carbon reductions are achieved only by imposing high energy taxes, with no other taxes being reduced to compensate for these increases. In contrast, the technology-based models use a variety of measures, not just taxes, to reduce carbon emissions. Moreover, in those cases where the technology-based models recommend new taxes, they assume that other taxes (for example, taxes that discourage employment and investment) would be reduced by a comparable amount, thereby maintaining essentially the same overall tax levels.

Not only does this assumption yield a much more favorable economic result, but tax shifting could have other economic and environmental benefits, as has been shown by Hammond et al. (1997), Repetto et al. (1992), and Bernow et al. (1996a and b). Repetto concludes plausibly that “under a reasonable standardized set of assumptions, most economic models would predict that the macroeconomic impacts of a carbon tax designed to stabilize carbon emissions would be small and potentially favorable.”

Other Factors Relevant to Modeling of Climate Change Policy. It is well known and documented that there exist a variety of barriers to full market penetration of cost-effective clean technologies. These barriers include lack of full consumer information on life-cycle costs and savings; disconnects between those (such as landlords) who pay the higher front-end costs for energy-saving technologies, and those (such as renters) who would benefit from reduced energy costs; and regulatory barriers, such as those that make it difficult for industrial self-generators of electricity to sell their surplus power into the grid without being subject to utility regulation.

DeCanio (1998) has performed empirical studies of firm behavior showing that near-term economic (that is, profit-making) opportunities are often not seized because of institutional barriers. These barriers could be overcome with interventions such as the effective management consulting of EPA’s green lights program.

Both private and public sector spending on energy technology R&D, which could help to bring down costs and improve performance of new technologies, is quite low relative to other major sectors of the economy. In addition, technological inertia, the slow rate of capital equipment turnover, and the short time horizons for payback in most industrial firms make it difficult to reap the productivity, environmental-compliance, and related benefits of investments in more advanced efficient and clean technologies and processes. As a consequence of these factors, diffusion of more efficient and cleaner technologies is impeded, which in turn slows down the processes of learning, scale economies, and innovation.

Rates of technology diffusion and innovation can be greatly enhanced by policies. For example, a renewable portfolio standard for electric generation with tradable credits would ensure higher market penetration (at lowest near-term cost), which would reduce costs over the longer term as a result of scale economies and learning. This, in turn, would further accelerate market penetration of clean, renewable technologies. The prices for energy technologies, resources, and uses in current markets do not reflect their social, environmental, and health impacts. Policies to incorporate the costs of these impacts, or “externalities,” in market prices garner widespread support in both the economics and environmental communities. However, “getting the prices right” is not by itself sufficient. For example, even if the prices of vehicle fuels were “corrected” to account for environmental and health damages, factors such as congestion, other social impacts, limits in alternative modes, inadequate infrastructure, and existing urban form would impede appropriate changes in behavior. Thus, attending to these ambient factors would amplify the response of consumers to “corrected” market prices.

All of these phenomena, which have been known for some time by economists, are only recently beginning to attract attention in the debates about the modeling and economic impacts of climate policy. The notion of a unique, stable, optimal equilibrium—the core assumption of most of the “top-down” models that project huge costs in reducing emissions—makes no sense in the real world of institutional barriers, long-standing government support for conventional energy technologies, energy prices that fail to reflect true social costs, and the proven potential for rapid technology shifts through targeted policy intervention.

Examples of Technologies

Advanced technologies that are currently available or under development could provide energy services to each sector of our economy more economically and with less environmental damage than the current mix of technologies. Here are just a few examples.

Combined-Heat-and-Power (CHP). Normally, an industrial facility—which needs both electricity and process thermal energy (for example, steam) for its manufacturing processes—will produce the process heat with an on-site boiler or furnace, while purchasing the electricity from an electric supplier via the transmission-and-distribution grid. Both the on-site heat and the off-site electricity require conversion of fuel into energy forms useful to the manufacturing process. This energy conversion inevitably comes with losses at the boiler (around 30 percent), the electric power plant (about 60–70 percent), and the transmission system (up to about 10 percent). At the same time, this conversion results in emissions of CO_2, SO_2, NO_x, fine particulates, and various hazardous air pollutants. Thus, enormous amounts of primary energy resources are wasted, while they nonetheless contribute to pollution and global warming.

Recent advances in the design and manufacture of microturbines have made the cogeneration of heat and electricity (combined-heat-and-power, or CHP) an attractive option for industrial firms, as well as large or aggregated district residential and commercial energy users. Thus, instead of producing electricity and heat in separate and wasteful energy-conversion processes, they can be produced on-site in a CHP turbine, at a much greater overall efficiency with only about 15 percent losses. With appropriate assistance, and siting and regulatory reform, CHP could provide net economic benefits to firms; it could also reduce pollution and carbon emissions, which could bring additional monetary value.

For a quantitative example, suppose an industrial firm that produces process steam on-site uses 50,000 MMBtu per year of coal in a boiler with an efficiency of 70 percent, and purchases 7,000 MWh per year of electricity from the grid (assuming clean natural gas combined-cycle generation). If that firm were to install an advanced turbine CHP system using natural gas to simultaneously produce steam and electricity, it would save between $50,000 and $100,000 per year (implying a 1.7 to 3.3 benefit-cost ratio). At the same time, it would reduce net CO_2 emissions by about 4,000 tons, SO_2 by about 27 tons, NO_x by about 9 tons, and particulates by about 2 tons. Assuming that markets would value these reductions at $25, $250, $500, and $5,000 per ton, respectively, an additional $100,000 annual savings could be realized by the firm.

Selected Residential and Commercial Buildings Technologies. The Interlaboratory study identifies a number of more advanced technologies that can provide the same services as new 1997 technologies, with much less energy use and with energy cost savings at or above the incremental equipment costs. The examples below from the Interlaboratory study (DOE 1997, 3.10) show end-uses for which more advanced technologies could dramatically reduce energy use and costs.

In addition to these near-term technologies, the study identifies new technologies and practices, many in their early stages of development and application today, that could become attractive cost-effective options under the stimulus of policies such as RD&D and market barrier reduction. Short-sighted modeling and policies would miss such opportunities. The six areas for such "evolutionary and aggressive technology improvements" are advanced construction methods and materials, environmental integration and adaptive envelopes, multifunctional equipment and integrated system design, advanced lighting systems, controls communications and measurement, and self-powered buildings. These approaches combine advanced materials and technology, microcomputer control (smart) systems, and sophisticated design integration with older practices using natural resources such as sunshine, air, shade, and insulating and thermal storage materials.

End-Use	Cost-Effective Energy Savings Potential Advanced versus New 1997
Residential	
Gas clothes dryers vs. electric	59%
Lighting	53%
Refrigeration	33%
Gas water heating vs electric	29%
Freezers	28%
Electric space cooling	16–23%
Commercial	
Electric and fossil space heating	48%
Electric and gas space cooling	48%
Ventilation	48%
Refrigeration	31%
Lighting	25%

Personal Transportation: Light-Duty Vehicles. The current (EPA test) average fuel efficiency of cars and light trucks is about 25 mpg, a large increase from the 1960s due in large measure to the technological advances induced by Corporate Average Fuel Economy (CAFE) standards. A strengthening of these standards through CAFE or an equivalent policy could raise the fleet average to 45 mpg (an 80 percent improvement) in the near term at an average retail price increment of about $760 per vehicle. For 20,000 miles of travel per year at $1.00 per gallon of gasoline, the fuel savings would be about $350 per year, for a total of about $1,750 over a five-year period. Thus, a policy to induce the production of more efficient vehicles could allow industry to recover its incremental investment costs and still provide consumers with significant economic savings. Similar opportunities are available in truck and air transport.

A variety of alternative-fuel (low-carbon and/or low-pollution) vehicles (AFV)—including natural gas, electric and hybrid-electric, fuel cell, alcohols, and so on—are under development or are in limited production and use. These AFV programs could be expanded, along with the necessary refueling and maintenance infrastructure for such vehicles. On intermediate and longer term time frames, current developments, evolutionary improvements, innovations, and breakthroughs, coupled with better price signals, infrastructure, and regulation, could bring some of these vehicles into wider use at attractive costs and performance levels, with lower carbon and pollutant emissions. Increased expenditures and efficiencies in private and public R&D would assist this process.

With an effective policy regime, ethanol derived from woody biomass and used in high blends could soon become competitive with gasoline in cars and light trucks, providing carbon, pollution, and electricity co-benefits and offering new sources of farm income. Some fuel cell buses are already in service, and the recent consortium of Ford, Ballard, and Daimler-Benz promises affordable fuel cells in several years. These near-term developments may pave the way for the widespread use of hydrogen as an energy carrier for transportation.

Electricity Generation. The deregulation of electricity generation promises to lower retail prices. These lower prices could, in turn, increase demand for electricity, and thereby exacerbate carbon and air pollutant emissions. This is especially the case since many of the existing coal plants are among the lowest cost generators of electricity. New advanced and very efficient combined-cycle turbines using low-carbon natural gas are becoming available at attractive costs; however, they are competitive primarily as new resources that are needed to meet growth in demand.

The increasingly attractive economics of gas-fired technologies—due to falling gas prices, efficiency improvements and capital cost reductions—also make them generally more competitive than renewable resources. While wind power costs have fallen to about 4¢/kWh for many sites, combined-cycle gas units can now generate electricity at less than 3.5¢/kWh, with further reductions in sight. Reductions in the retail price of electricity also render the economics of attractive zero-carbon energy-efficiency options on the demand side less favorable. This, in turn, provides a barrier to future cost and performance improvements in demand-side efficiency that could be realized through scale economies and learning.

When pollution reduction, scale economies, and the longer view are taken into account for both electricity production and climate protection, policies that are complementary to electric industry restructuring are warranted. Such policies would include generation performance standards, implemented through cap and trade programs, to ensure acceptable levels of air pollution and carbon emissions; renewable portfolio standards to move these technologies more quickly along their paths of learning and scale economies; and perhaps power-supply-efficiency standards. It would also be important to ensure fair market access and backup power rates for on-site industrial and commercial cogeneration (CHP), which is already economically attractive to many firms. Finally, public benefit funds could be used for the promotion of efficiency and for the targeted support to certain renewable technologies, to obtain sufficient market penetration in the near term so that their longer term economic and environmental benefits can be realized. Some of these measures have already been enacted in various states, and have also been included in a number of proposals for federal utility restructuring legislation.

Conclusions

The studies we have examined show that large reductions in US greenhouse-gas emissions can be achieved in the near term with net economic savings or at little cost. Steps to lower greenhouse-gas emissions would set the stage for the greater reductions needed for climate protection over the longer term. Well-chosen policies and measures can overcome market barriers to the rapid and widespread diffusion of energy-efficient and low-carbon fuel technologies, can induce learning-by-doing and scale economies to gradually lower the costs of these advanced technologies, and can stimulate technological innovation and invention. Our analysis of these studies leads to a few simple and clear conclusions:

1. Claims that compliance with the Kyoto Protocol would be prohibitively expensive and would destroy the American economy are sharply overblown.

2. By encouraging the diffusion of new and better technologies, and by adopting measures that encourage efficient use of energy, the United States can make significant reductions in its greenhouse-gas emissions, with overall economic savings or at a modest cost. Indeed, many such measures could strengthen the economy and save consumers and businesses money.

3. Opponents of action ignore the potentially large economic costs of climate change. When these risks and costs are accounted for, measures to reduce the threat of global warming become even more desirable from a strictly economic standpoint. Opponents of action also ignore the fact that global warming could produce numerous social, demographic, and political dislocations that cannot be easily quantified in an economic model.

4. Steps to reduce US CO_2 emissions would produce considerable health and environmental co-benefits from reductions in dangerous air pollutants.

5. Because so many of the measures for reducing domestic emissions are cost effective, the United States could viably meet all or most of the Kyoto Protocol's mandated emissions reductions through domestic actions. The two most recent studies show that the United States could essentially meet its Kyoto Protocol obligations entirely through domestic, energy-related CO_2 reductions, with net economic benefits. Additional savings may be available through the emissions-trading mechanisms in the Kyoto Protocol, but the United States need not rely on those provisions to achieve its commitment.

6. The United States should not be unduly worried about losing out competitively on the world stage from taking steps to reduce emissions. Because the United States can take these first steps at a very low, or even no, net cost, our nation's competitive position in most industries would be largely unaffected. Moreover, the United States stands to benefit from attaining leadership in technologies that will become increasingly important in the 21st century.

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