America's Global Warming Solutions

A Study for:

World Wildlife Fund
and Energy Foundation

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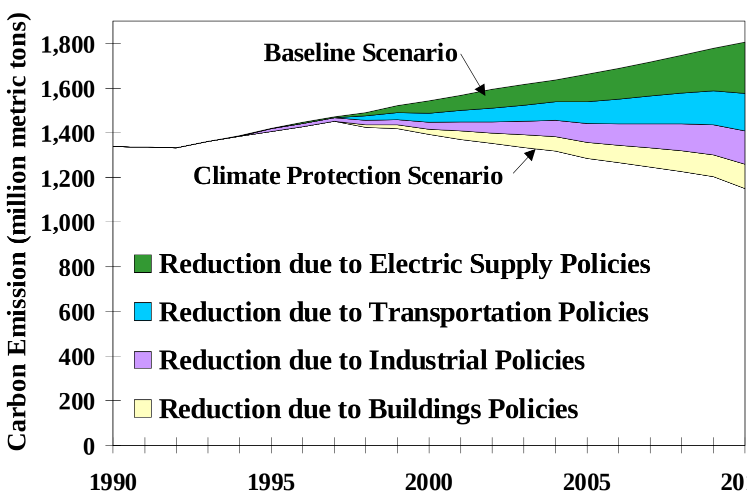
Summary

Climate disruption from continuation of current practices in the U.S. and around the world threatens deep and long-lasting economic costs, ecological degradation and social disruption. Averting this threat requires that global greenhouse gas emissions, largely from fossil fuel combustion, be reduced substantially over the coming decades. This conclusion is based on a broad scientific consensus that led to the Framework Convention Climate Change and its Kyoto Protocol to which the U.S. is a party. To meet this challenge while maintaining economic vitality will require policies and measures to stimulate greater use of efficient and low carbon energy technologies and resources, and to spur innovation in these and related technologies. Such technologies, policies and measures have been shown to exist in both analysis and practice.

Figure S.1: Carbon Emissions Reductions in All Sectors Under the Climate Protection Scenario



The U.S. has a major role to play in climate protection. It leads the world's countries in contributions to atmospheric carbon dioxide accumulations, while it is also a leader in economic strength and technological innovation. A major study by Tellus Institute (Bernow *et al*, 1998) showed how the U.S. could reduce its carbon dioxide emissions to about 20 percent below 1990 levels by 2010, with substantial net savings in the cost of meeting its energy needs. Since that study was completed, the baseline projections of U.S. carbon dioxide emissions have increased, making it more difficult to effect comparable emissions reductions relative to 1990 levels.

The new study reported here examines essentially the same set of integrated policies and measures under the new baseline projections. These policies and measures are targeted within each sector of the economy to stimulate more rapid and widespread use of low-carbon resources and advanced, highly efficient energy-using technologies, techniques and systems.

This study finds that the U.S. could reduce its carbon emissions to its Kyoto target and, indeed, to significantly below that target. Moreover, this can be achieved with overall net savings in the costs of energy and energy-using equipment. The figure above shows the results of this study. It shows that we can bend the carbon emissions curve from the dangerous upward path upon which it is headed. Emissions can be set on a path that declines to about 14 percent below 1990 levels by 2010, with momentum downward towards climate protection. The contribution to that course-correction from policies in each sector of the economy is shown in the figure.

Overall, these policies and measures will produce net economic savings to households and businesses, and the economy as a whole. Annual net savings in energy costs would grow steadily over the next twelve years. These savings would average about $46 billion per year for reductions in carbon emissions to the Kyoto target of 7 percent below 1990 levels by 2010, and about $43 billion

Table S.1: Summary of Policy Impacts under Kyoto Co Scenarios

	1990
End-use Energy *(Quads)*	63.9
Primary Energy *(Quads)*	84.6
Renewable Energy *(Quads)*	
Non-Hydro	3.5
Hydro	3.0
Carbon Emissions *(Million metric tons)*	1,338
Other Emissions *(Million tons)*	
SO_2	21.9
NO_x	19.3
PM_{10}	1.7
Net Annualized Savings	
Total *($ billion per year)*	-----
Per household *($)*	-----

per year for reductions (shown in the figure) to about 14 percent below 1990 levels. This translates into national energy cost savings that increase through 2010, averaging almost $400 per household per year. Moreover, by 2010 wage and salary earnings would increase by about $27 billion, with almost 900,000 net new jobs created, relative to the baseline. The largest estimated job gains are in services and construction, with additional large gains in education, metal durables, miscellaneous manufacturing, transportation and communications, agriculture, finance and government. The table below summarizes the major results of the analyses.

The policies and measures would have other important benefits. They would reduce emissions of air pollutants, which undermine ecosystems and damage human health, especially of young children and the elderly. They would decrease our dependence on imported oil and its threat of price shocks. They would spur technological innovation, modernization and productivity improvements in our economy. They would stimulate the development of new clean technology industries and jobs to meet growing demands in national and international markets. Finally, they would demonstrate clearly to the rest of the world the seriousness with which the U.S. is acting to meet its climate protection responsibilities and, thereby, to help advance the goals of the climate convention.

1. Introduction

Years of research by the world's scientific community have demonstrated the serious risk of dangerous climate disruption in the twenty-first century if we do not dramatically reduce emissions of greenhouse gases. These emissions, largely carbon dioxide (CO_2) from the combustion of fossil fuels and the destruction of forests, have thus far accumulated in the atmosphere to about 30 percent above pre-industrial levels. Growing atmospheric concentrations of greenhouse gases could trap more incoming solar energy than has been the norm for millennia, which will likely change global temperatures and climate. It is also widely understood that the magnitude of such climate change could unleash other complex physical, ecological, economic and social disruptions that would seriously undermine the well being and resilience of the natural environment, societies, and human beings for generations to come. U.S. scientists have played a major role in establishing the consensus on these conclusions.

Since the industrial revolution, greenhouse gas (GHG) concentrations have increased by about 30%. If the trend continues, global warming is likely to become an increasingly dangerous threat.

Fortunately, policies and measures that have already been proven effective in the U.S. and other parts of the world, would allow current and new technologies, practices and resources to be mobilized to meet the challenge of climate change. Strong and sustained action to reduce the risk of climate change to acceptable levels could also reap economic benefits and help to usher in a new technological and institutional renaissance consistent with the goals of sustainable development. Here we focus on the U.S., which emits about one-fourth of global carbon dioxide emissions, and which has the responsibility and the capability to take the lead in climate protection.

Implementing existing policies and measures would reduce the risk of serious climatic disruptions, while boosting the economy and encouraging technological innovation.

In December 1997, the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol to the Convention. This was an important step towards stabilizing concentrations of greenhouse gases in the atmosphere and thereby reducing the risk of dangerous climate change. Among its provisions, the Protocol establishes binding greenhouse gas emissions targets for the period 2008-2012 for the industrialized (Annex I) countries. These limits average about 5 percent below their collective emissions in 1990. For the U.S., the target is 7 percent below its 1990 levels, for Japan 6 percent and for Europe 8 percent.

The Kyoto Protocol, adopted by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan, in December of 1997, is an important first step toward reducing the threat of global warming. Industrialized countries must reduce their GHG emissions by an average of about 5% below 1990 levels by 2010. The reduction target for the U.S. is 7% below 1990 levels.

The Protocol also provides flexibility mechanisms that would make it possible for Annex I countries to satisfy their obligations by means other than reducing their domestic energy-related carbon emissions. These mechanisms include emissions trading amongst the Annex I countries, and offsets of Annex I carbon dioxide reduction obligations by reductions of other greenhouse gases, by creation of incremental forest and other biomass-based carbon sinks, and by measures taken in developing countries. But this report shows that, given the economic advantages of

While the Protocol provides for flexible market mechanisms that parties could use instead of domestic reductions, it is feasible and economically attractive to concentrate on reducing emissions domestically.

strong targeted policies and measures, the U.S. need not make more than sparing use of these mechanisms to meet its targets, and that it should focus instead on making carbon dioxide reductions at home.

This report provides the first major update and refinement of *Policies and Measures to Reduce CO_2 Emissions in the U.S.* (Bernow *et al*, 1998), a report by Tellus Institute for the World Wildlife Fund, since the Kyoto Protocol. It is a response to the Protocol, to new conditions affecting the earlier analysis and its results, and to the ongoing challenge of climate protection. It answers the following questions:

- Can the U.S. meet its Kyoto targets by reducing its energy-related carbon emissions?
- What sets of policies would effect this result?
- What costs would be incurred and what benefits realized?

This report also analyzes options for the U.S. to take the lead and go beyond its Kyoto commitments to ensure climate stabilization and spur technological innovation.

The report also examines whether, with which policies, and with what results, the U.S. could go beyond its Kyoto obligations. This focus on domestic energy-related emissions reductions reflects concern about the longer-term requirements for climate stabilization. This includes the need for deeper reduction commitments, for overcoming technological inertia with policy-induced technological innovation and diffusion, and for an equitable developed-developing country climate rapprochement.

The earlier study evaluated a set of policies with which the U.S. could reduce its carbon emissions by over 20 percent below 1990 levels by 2010, with substantial net economic savings, i.e., reductions in fuel costs that exceed the incremental costs of more efficient equipment. Since that study was completed, changes have occurred which increase the baseline projections of carbon emissions and make it more difficult to effect comparable decreases. Nonetheless, the new results broadly confirm those of the earlier study.

Implementing policies and measures like energy efficient technologies and use of low carbon resources could translate into average savings of US$400 per year for U.S. households and 900,000 new jobs by 2010.

This new study examines essentially the same integrated set of policies and measures under the new baseline conditions. These policies and measures are targeted to overcome barriers to more rapid and widespread use of low-carbon resources and advanced, highly efficient energy-using technologies, techniques and systems. It finds that with these policies and measures the U.S. could reduce its carbon emissions to meet its Kyoto target, and indeed to significantly below that target, with net economic savings. Annual net savings in energy costs would grow over the next twelve years, averaging about $46 billion for reductions in carbon emissions to the Kyoto target of 7 percent below 1990 levels by 2010, and about $43 billion for reductions to about 14 percent below 1990 levels. This translates into increasing national annual savings that average almost $400 per household per year. As a consequence of these savings and other economic factors, almost 900,000 net additional jobs could be created by 2010.

The policies and measures would have other important benefits. They would reduce emissions of air pollutants, which damage human health and threaten ecosystems. They would decrease our foreign oil dependence and its threat of price shocks. They would spur technological innovation, modernization and productivity improvements in our economy. They would stimulate the development of new clean technology industries and jobs to meet growing demands in national and international markets. Finally, they would demonstrate clearly to the rest of the world the seriousness with which the U.S. is acting to meet its climate protection responsibilities and, thereby, to help advance the goals of the climate convention.

Reduced air pollution, technological innovation and lowered dependence on foreign oil are some of the additional benefits to domestically reducing emissions of carbon dioxide (CO_2), the principal gas responsible for global warming.

2. The Risk of Climate Change

At the 1992 Earth Summit in Rio de Janeiro, signatories to the Framework Convention on Climate Change (UNFCCC) committed to achieving "…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system." Since that time, however, emissions of greenhouse gases have continued to rise, even as the community of climate scientists has moved toward the consensus, expressed by the Intergovernmental Panel on Climate Change, that already "…human activities are having a discernible impact on global climate" (IPCC 1996). Concentrations of CO_2 in the atmosphere are now approximately 360 parts-per-million (ppm), about 30 percent above pre-industrial levels; this is unprecedented in many tens of millennia.

Despite the 1992 Rio Earth Summit commitment to start reducing greenhouse gas emissions, countries' emissions have continued to increase, causing GHG concentrations in the atmosphere to rise steadily.

Annual global CO_2 emissions (measured as carbon) are about 6 billion tons from fossil fuel combustion and 1 billion from land-use changes (mainly burning and decomposition of forest biomass). Under a business-as-usual future, in which no special efforts are made to avert climate change, annual emissions of carbon would likely continue to increase about threefold by the end of the next century (IPCC 1996), driven by conventional economic development and increasing population. Cumulative emissions would be about 1400 billion tons over that period, and atmospheric concentrations would approach three times pre-industrial levels (IPCC 1996). This would cause global average temperature to rise between 1.4 to 2.9 degrees Centigrade (2.5 to 5.2 degrees Fahrenheit), with even greater increases in some regions (IPCC 1995; 1996).

Without action, annual emissions of carbon are projected to increase threefold by the next century. If measures are not implemented to change the trend, global average temperatures could rise by 2.5 - 5.2 degrees Fahrenheit.

The potential consequences of such change are myriad and far-reaching. Sea level could rise between 19 to 86 centimeters (IPCC 1995; 1996), 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 geophysical, ecological, economic, health, social, and political disruptions. The pre-

Among the serious potential impacts of global warming are rising sea levels, leading to coastal flooding and habitat loss, more extreme weather events, shifts in regional climate and the spread of tropical diseases to previously unaffected areas.

cise timing, conditions and character of such impacts remains uncertain. Under the stresses courted by business-as-usual, such complex systems as our climate and ecological systems could undergo very large and irreversible changes. Unlike simpler more predictable systems with "normal" probability distributions, in complex systems the probabilities of such extreme outcomes are not extremely small (Shlyakhter *et al.* 1995). In some runaway climate change phenomena, global warming itself would increase the rate of greenhouse gas accumulation, and thus accelerate global warming and it impacts. Examples include release of methane from a thawing of the arctic tundra and decreased uptake of carbon by a warming of the oceans. There are many examples of rapid devolution of ecosystems or social systems under stress.

Changes in climate could occur very rapidly, reducing our ability to adapt. Early action is essential in order to avoid costlier, and possibly ineffective, mitigation efforts later on.

Moreover, large and irreversible changes could occur very rapidly. Recent scientific evidence from pre-historic ice cores shows that major climate changes have occurred on the time scale of about a decade (Schneider 1998; Severinghaus *et al.* 1998). Rapid change could cause additional ecological and social disruptions, limiting our ability to adapt. This could render belated attempts to mitigate climate change more hurried, more costly, less effective, or too late. Consequently, early and sustained action, across many fronts, is needed to induce the technological, institutional and economic transitions to protect global climate and the ecological and social systems that depend on climate stability.

3. Climate Stabilization

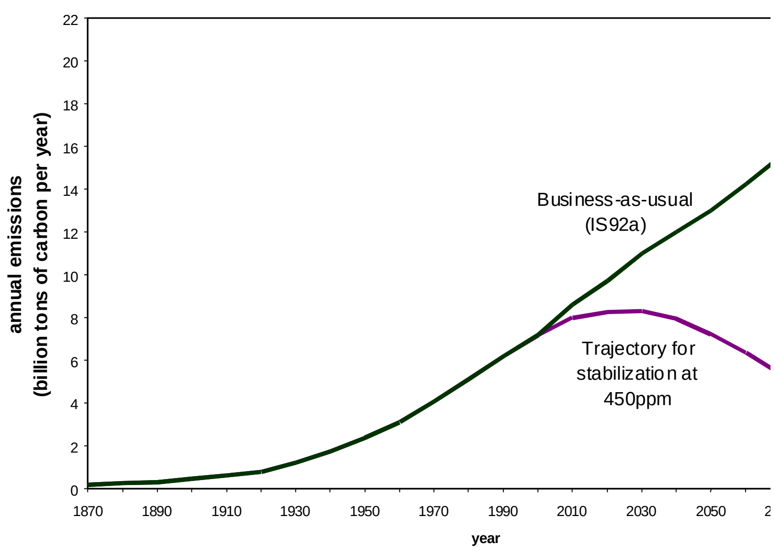
Stabilizing CO_2 concentrations at 450 ppm is a feasible objective to prevent dangerous climate change. Although this concentration would still probably result in increased global average temperatures, and sea levels would still rise, the changes might be gradual enough to allow some ecosystems to adapt to the changing environment.

What would climate protection require? An aggressive strategy to stabilize greenhouse gas concentrations at 450 ppm over the next century, about 60 percent above pre-industrial levels, would likely result in a global average temperature increase by about 0.7° to 1.4° C (higher in some regions) and a sea-level rise by about 10 to 65 cm (IPCC 1995; 1996). If this temperature increase were gradual, at about 0.1° C per decade, it would still exceed natural variability, but could allow some, but not all, ecosystems to adapt (Rijsberman and Swart 1990). While 450 ppm still risks potentially problematic climate change, suggesting stabilization at even lower concentrations still more difficult to achieve, we use it here as indicative of what might be an acceptable climate protection trajectory.

To stabilize atmospheric concentrations at 450 ppm, annual global carbon emissions would have to be at least halved by the end of the next century, to less than 3 billion tons (about 0.25 tons per capita) rather than the 20 billion projected by the IPCC (almost 2 tons per capita). Figure 1 shows these trajectories.

The industrialized countries now emit about 70 percent of global annual carbon, at about 3.3 tons per capita. The developing countries emit the rest at only 0.5 tons per capita; as their economies grow, their carbon

Figure 1. Global carbon emissions from fossil fuel combustion (1860-2100) – Business-As-Usual trajectory (IPCC IS92a scenario) and a trajectory for stabilization at 450 ppm



To achieve the long tem goal of stabilization at 450 ppm, global emissions would have to be reduced by at least half of current rates by 2100.

emissions would likely increase in the near term. Stabilization at 450 ppm, with eventual equalization of national per capita emissions, one of the potential bases for establishing equitable long-term commitments, would require that industrial countries decrease their per capita emissions more than tenfold over the next century. Since the U.S. currently emits at about 6 tons per capita, stabilization and equalization would require it reduce more than twenty-fold over that period. Thus, it is essential that the industrialized countries, and the U.S. in particular, begin early and continue steadily to decrease their emissions on a trajectory to meet these climate protection requirements.

Early action by the U.S. and others is essential to achieving equitable long term solutions to global warming.

Eventually, the developing countries would need to halve their per capita emissions relative to today's levels, notwithstanding the considerable economic growth that they are expected to realize over the century as they industrialize. Achieving this would involve economic development predicated upon significant use of advanced energy-using technologies and low-carbon resources, a "leapfrogging" over the fossil-based economic development that has occurred in the industrialized countries. This could be achieved with technology and related cooperation among developing countries, and between developing countries, the U.S. and other industrialized countries.

Technological cooperation between industrialized and developing countries is needed to meet the challenges that climate change poses.

4. The Kyoto Protocol

The Third Conference of Parties to the UNFCCC in Kyoto in December 1997, was an historic event. Although only a small first step, it provides a pivotal opportunity to reverse the course towards climate disruption upon which the world is now headed. Whether this promise is realized depends in part on how the details of the Protocol are worked out and implemented, and how the industrialized nations, and the U.S. in particular, take on their responsibilities for strong near term actions at home and cooperation with the developing world.

The Kyoto Protocol is a small first step toward solving the threat of global warming. However, the Protocol is merely a framework, and more is needed to achieve climate stabilization. It is up to countries like the U.S. to take the lead in implementing early domestic actions to reduce GHG emissions.

At Kyoto, signatory nations to the UNFCCC agreed to GHG reduction targets that would be legally binding on industrialized nations when ratified. The Kyoto Protocol provides a comprehensive and integrated framework for GHG mitigation responsibilities and actions; but it takes only a small first step towards the level of reductions needed to stabilize the earth's climate. These factors are important in order to assess what actions are available, feasible and necessary for the U.S. to take in the near and longer term.

The Kyoto Protocol requires that emissions during the period 2008 to 2012 be below 1990 levels by 7 percent for the U.S., 6 percent for Japan, 0 percent for Russia, and an average of 8 percent for the European Union. The Protocol affords the U.S. and other industrialized nations considerable flexibility in meeting these reduction targets. These options include offsets amongst different greenhouse gases, offsets from biomass carbon sinks, the Clean Development Mechanism (CDM) that could create offsets from actions in developing countries, Joint Implementation projects, and industrialized nation (Annex I) trading of emissions allocations. Exploiting such options could allow the U.S. to undertake correspondingly lower reductions in carbon emissions from its energy sector while still meeting its 7 percent net reduction commitment, at lower near-term costs.

Flexibility mechanisms in the Protocol, such as offsets from carbon "sinks," the Clean Development Mechanism (CDM), Joint Implementation projects and emissions trading could allow the U.S. to meet its 7% target with little action at home. If problems with these mechanisms are not resolved before their large-scale implementation, their use could threaten the environmental integrity of the Protocol.

However, these flexibility mechanisms have problems that need to be resolved before implemented on a large scale; otherwise they could seriously threaten environmental integrity and the credibility of the Kyoto Protocol. For example, the huge amounts of carbon stored in forests, soils and other forms of biomass, provide both a challenge and an opportunity to climate protection. But the biophysical processes involved and the consequences of intervention are still too poorly understood, and the climate, biodiversity and human implications too important, to permit early access to this offset option (GACGC 1998). As a consequence of these uncertainties and concerns, the IPCC is developing a special report on carbon sinks.

Moreover, given the rather modest reduction targets of the Protocol relative to the much deeper long-term reductions needed for climate protection, use of the flexibility mechanisms may permit too slow a start, and too weak a signal, for the necessary technological transition in energy production and use. This could be exacerbated for the U.S. and Europe, with purchase of cheap carbon allowances from the Russian Federation and Ukraine, whose negotiated targets are far above what their faltering economies are likely to reach by 2010 even without reduction efforts. Such "hot-air" allowances could be sufficient to permit U.S. emissions to increase to above its 1990 level by 2010, rather than to decrease as the Kyoto target implies. While the overall Kyoto target might be met with such Annex I trading, the first budget period of the Protocol could end with an upward (or insufficiently downward) trajectory of carbon emissions in the U.S. and a slower rate of technological development than would be needed for the longer term. As a consequence of these factors, more than very modest use of the flexibility mechanisms could result in both higher long-term costs for the U.S. and lower greenhouse gas reductions than specified by the Kyoto Protocol.

Using the flexibility mechanisms too early may undermine efforts to make the deeper, long term reductions needed for climate stabilization.

The attraction and rhetoric of solutions that lie outside the borders of the industrialized countries is misguided at this time. To be sure, there are important opportunities to help developing countries advance along a low carbon path under the paradigm of sustainable development. But unlimited use of such projects by the U.S. and other industrialized countries as offsets to their requirements, thus limiting their domestic reductions, would be a head-in-the-sand approach to climate protection, given the risks of climate change identified above. The quantity of such offsets should be limited and their quality guaranteed. Procedures should be established to help ensure that the various mechanisms conform to the aims of the Protocol and the principles of sustainable development. These include consistency with local ecological, cultural, and economic conditions and constraints, human and institutional capacity-building goals, strong and equitable relationships for technology cooperation, and acceptable procedures for monitoring, verification and accreditation of offset actions and transactions. Until then it is premature to rely on the CDM for more than a very small part of the required emissions reductions.

In the future, developing countries will need to make serious domestic reductions. But action is needed immediately on the part of industrialized nations, both to reduce their domestic emissions, as well as to help developing countries grow along a more efficient and less carbon intensive path.

Large-scale use of emissions trading and other forms of flexibility in the near term could limit the degree of institutional and technological learning, scale economies, innovation and invention that could be stimulated by policies directed towards U.S. energy production and consumption (WWF 1998). The U.S. could find itself approaching the 2008-2012 budget period with insufficient domestic carbon reductions, and unrealized or unverified offsets; this could lead to more hurried and costly actions and limit the potential for sales of offsets in later periods as the mechanisms become more established.

Overuse or abuse of flexibility mechanisms in the Protocol could render the U.S. less competitive in the long term, and end up being much more costly than early domestic action.

If the U.S. relies heavily upon imported reduction credits from trading, which may have no multi-year permanence, or upon Joint Implementation and CDM projects, which have verifiability risks, it could find itself in a poorer position to launch efforts to meet the stricter commitments expected for subsequent budget periods. The nation could become a fol-

The U.S. could risk losing its leadership in energy and related technologies, both domestically and internationally, if it buys its reductions abroad. The Kyoto Protocol should be seen as an opportunity to take the lead globally, while ensuring a sound economic future.

lower rather than a leader in advanced energy and related technologies in domestic and world markets. Thus, it could miss the opportunity provided by the Kyoto Protocol for a national technological and economic "renaissance" with cleaner energy, processes and products in the coming decades.

5. U.S. Climate Policy, Post-Kyoto

For the U.S. to make the most of the opportunities offered by the Kyoto Protocol, it must develop integrated policies and measures. Without them, innovations could be inhibited, putting the U.S. at a disadvantage in the long run.

The U.S. can meet and exceed its Kyoto obligations with modern, energy-efficient and low-carbon resources, technologies, practices and systems, which already exist or are in various stages of development and commercialization. To do this it must develop an integrated set of complementary policies and measures to overcome market imperfections, institutional barriers and pricing failures that impede these advanced technologies from diffusing more rapidly into the economy. In the absence of enabling policies, innovations in technologies, processes and infrastructure can be impeded. For the conventional options, this is due to long equipment lifetimes, scale economies, and institutional and user know-how. For the advanced options, it can result from high start-up costs, uncertainty and inexperience. This phenomenon (known as "lock-in" and "lock-out") amplifies the short-run cost and other advantages of conventional options, while undermining development of the more advanced options which, with sufficient market diffusion and scale economies, would be superior to the conventional options in the long-run (see, e.g., Arthur 1994; Cowan and Kline 1996).

Economic development and improved living standards often occur only when spurred by policy interventions. Implementing such policies can result in both short- and long term benefits.

Economic development and improvement in human well being occur in the context of inertia and uncertainty in the social, institutional and technological systems upon which they rely, and have often required policy intervention to stimulate innovation (Bernow 1997). Policies to stimulate innovation in energy resources and technologies include incentives, market creation and transformation, regulatory modernization, technical assistance, performance standards, research and development, land-use and infrastructure improvement, and price, tax and subsidy reform. A robust mix of such policies would stimulate technological diffusion and innovation, providing near-term benefits to households, businesses and citizens, and unleashing the social and entrepreneurial creativity upon which the long-term future of our economy and society could rely.

Further, the U.S. has an opportunity to be a leader in 21st century technologies, sustainable development assistance, and fair and responsible international stewardship of the global commons. The industrialized countries, and the U.S. in particular, have both the responsibility and capability to rise to this challenge. While the developing countries have an essential role to play, even heroic mitigation actions on their part would still leave the industrial countries with the need to reduce their carbon intensities by an order of magnitude. This would require a major technological transition, with corresponding political, institutional and economic changes.

While ultimately both developed and developing countries must participate in a decades long climate protection initiative under the UNFCCC, it is essential that the industrialized countries begin early and sustained action. The argument from some quarters that industrial growth in China, India and other developing countries will wipe out emissions reductions in developed countries is spurious, an instance of "the prisoners' dilemma." Even if emissions in developing countries were to vanish instantly, implying a nightmarish devolution, industrialized nations would still need to almost halve their emissions for climate protection. And continued economic growth in the developing countries, a desirable and likely path, will make greater reductions necessary in developed countries. There is no way around the responsibility of the industrialized world, and of the U.S. in particular, to take the lead in greenhouse gas reductions.

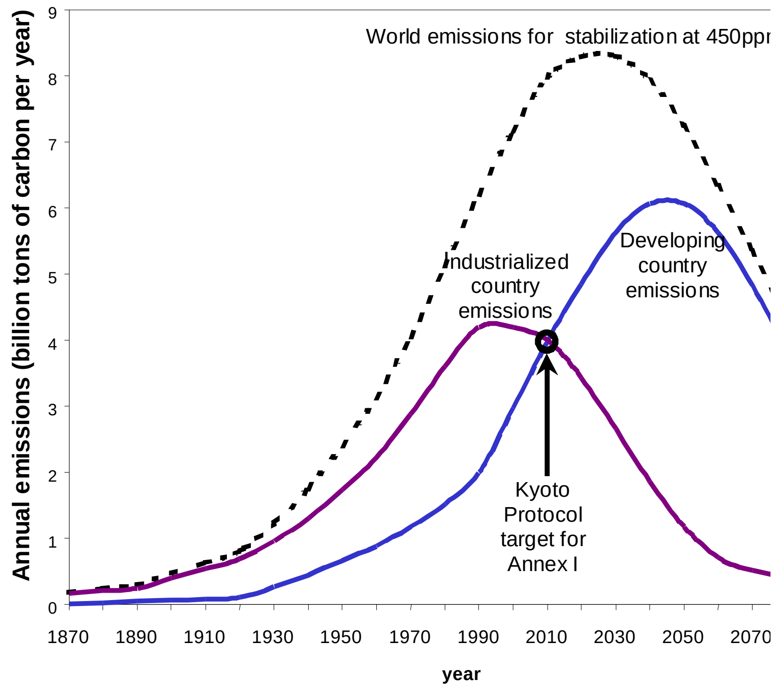
Ultimately, both developed and developing countries will have to participate in a climate protection effort, but it is essential that industrialized countries begin early and sustained action.

Recognition of such inter-national and inter-temporal capabilities and responsibilities could lead to a practical and equitable solution. One approach to allocation of the global emissions budget consistent with stabilization at 450 ppm, which could lay the groundwork for meaningful participation of the developing countries in climate protection, is convergence over the next century towards equal per capita national emissions budgets. Figure 2 shows a global carbon trajectory for stabilization at 450 ppm, as shown in Figure 1, broken out into emission paths for both industrialized and developing countries. In this illustrative allocation, emissions converge to the same per capita emissions (~0.25 tC per capita) by the end of the 21st century. Emissions from developed countries would begin to decline immediately, while emissions from the developing world would grow in the near term, allowing time for economic development and transition to lower-carbon technologies, and then decline rapidly during the latter half of the century.

One equitable option for long term climate protection could be for a convergence toward equal per capita national emissions budgets. This would necessitate domestic reductions in industrialized nations, as well as meaningful participation from developing countries. This approach would allow the Kyoto targets to be met, while giving the U.S. the opportunity to show leadership and reap economic benefits, as well as for developing countries' economies to grow.

Stabilization and equalization would thus be served by a dual technological transition in which industrialized countries can take the lead, by providing exemplary response to the climate challenge and by engaging in the first wave of technological innovation and diffusion from which both developed and developing countries could benefit. Technology transfer and cooperation, with associated financial assistance would be at the heart of this transition. The U.S., with its high energy use and carbon emissions, its great economic resources, and its traditions and capabilities for technological innovation, could provide leadership on all fronts.

Figure 2. Carbon emissions for stabilization of atmospheric greenhouse gas concentrations at 450 ppm, showing emissions from industrialized and developing countries. Cumulative emissions (1990-2100) are ~700 GtC, and an emission rate in 2100 below 3 GtC/yr.



6. Policies, Analyses and Results

This study shows how to reduce CO_2 emissions in the U.S. by both 7% and 14% below 1990 levels by 2010.

Two U.S. climate policy scenarios were constructed and analyzed, the first a *Kyoto Compliance* scenario, in which carbon dioxide emissions are reduced to 7 percent below 1990 levels by 2010. The second, a *Climate Protection* scenario which achieves 14 percent reductions, is the scenario of *Policies and Measures to Reduce CO_2 Emissions in the U.S.* (Bernow *et al.* 1998), refined and updated to account for new national baseline projections of energy use and carbon emissions (EIA 1998). Both scenarios realize their carbon emissions reductions entirely through domestic energy-related policies and measures, most of which reduce carbon emissions with net economic savings. The more ambitious carbon reduction scenario comprises all of the policies of the less ambitious scenario, plus some strengthened and additional policies. Both policy scenarios achieve emissions reductions with overall net economic savings to households and businesses.

6.1 Policies and Measures

We analyzed the impacts of policies and measures within each sector that would stimulate faster adoption of more energy-efficient technologies and low-carbon energy resources, and induce innovation, learning and further diffusion. These included a robust mix of complementary approaches including incentives, market creation and transformation, regulatory modernization, technical assistance, efficiency and performance standards, research and development, and tax reform. Specifically they were:

Policies in each sector were analyzed to assess how to achieve the reductions.

For transportation:

- A vehicle efficiency initiative, including: progressively stronger fuel economy standards for cars and sports utility vehicles; an efficiency and emissions based feebate system for vehicle purchases; R&D for improved design, materials and technologies; and public sector market creation programs for cleaner and more efficient vehicles; standards and incentives for freight trucks and other commercial modes.

Increase the number of miles a car or light truck can travel on a gallon of gasoline.

- Urban/regional transportation demand management and related incentives; pricing reforms, including congestion and emissions-based pricing; land-use and infrastructure planning for improved access to alternative and complementary travel modes, including transit, walking and biking; facilitation of high speed intercity rail development; pricing, planning and informational initiatives to promote intermodal freight movement.

Provide incentives for public transit and more environmentally sound planning for cities.

- A progressively stronger cap on the carbon intensity of motor fuels, a 10 percent reduction by 2010 in the *Climate Protection* Scenario and half that in the *Kyoto Compliance* scenario; R&D for renewable fuels and associated vehicle technologies; renewable fuels commercialization programs in various market segments, including public sector procurement programs.

Reduce the amount of carbon in motor fuels.

For industry:

- Tax incentives to stimulate more investment in new more efficient energy-using manufacturing equipment, and RD&D to bring down the costs and speed the availability of more efficient equipment;

Provide incentives to use more efficient industrial equipment.

- Regulatory refinement and technical assistance to remove disincentives for industrial combined heat and power (CHP), whereby electricity is generated on-site, rather than imported from the grid, by using the same fuels that produce heat for manufacturing processes.

Remove barriers to combined heat and power (CHP).

For electricity generation:

- A progressively increased renewable portfolio standard, that would require suppliers to collectively provide 10 percent of generation by 2010 with renewable resources, with a credit trade system to ensure that the national target is met with a regional distribution that results in lowest cost.

Require utilities to have 10% of their electricity from renewable resources by 2010.

Reduce SO_2, NO_x and fine particulate emissions from power plants.

- A tightening of the 1990 Clean Air Act Amendment SO_2 cap, which now halves the sector's emissions from 1990 levels to 9 million tons by 2000, to more than halve them again to about 3.5 million tons by 2010. Also cap and trade systems for NO_x and fine particulates to bring their levels down. These pollution restrictions would reduce coal use and carbon emissions, while reducing pollution and improving air quality.

Use biomass as an energy source in coal plants.

- A requirement for co-firing of biomass in coal plants, with credit trading, which is progressively increased to 10 percent by 2010 in the *Climate Protection* scenario and half that in the *Kyoto Compliance* scenario, providing a near-term carbon reduction and stimulating development of that resource.

Cap CO_2 emissions for the fleet of power plants.

- A cap and trade (or tax) for carbon emissions to reduce the carbon intensity of the sector between 1990 and 2010 by about 30 percent in the *Kyoto Compliance* scenario and by about 40 percent in the *Climate Protection* scenario.

For commercial and residential buildings:

Establish standards for appliances and buildings.

- Appliance and building standards, which would establish norms for equipment, design and performance that, through purchases and practices, would reduce energy used to provide services in homes and offices.

Provide incentives to consumers to use energy efficient technology and/or renewables.

- Market transformation incentives including technology demonstrations, manufacturer incentives, and consumer education to reduce barriers to energy savings and renewables.

Expand the use of combined heat and power.

- Initiatives to expand the use of combined heat and power for district energy systems in the *Climate Protection* scenario.

6.2 Methodologies: Energy and Carbon Emissions Analyses

Government models were used to do the analyses.

The analyses were undertaken using several models. The models used included the U.S. Department of Energy, Energy Information Administration (DOE/EIA) National Energy Modeling System: NEMS (EIA 1995; 1999) and the Argonne National Laboratory Long-Run Industrial Energy Forecasting (LIEF) model (Ross *et al.* 1993). For the most part, the price, cost and technology data and the behavioral assumptions embodied in these models were used in the analyses. Here we provide brief summaries of the models, methods and assumptions. More detailed discussion of the sectors and the analyses upon which this study was based can be found in *Energy Innovations* (EI 1997), the *Energy Policy Special Issue on Climate Strategy for the United States* (1998) and Bernow *et al.* (1998). Other recent studies with similar approaches and results include Brown *et al.* (1998), Koomey *et al.* (1998b) and Geller *et al.* (1998).

NEMS is a computer model that projects future U.S. energy consumption and supply based on energy technology and fuel choice for each sector and end-use, deriving from fuel prices, technology costs and characteristics, equipment turnover rates, and financial and behavioral parameters. The data and assumptions used were from EIA (1998). The Base Case, which served as the point of departure for computing the impacts of the policies investigated in this study, was the NEMS computer run consistent with the EIA (1998) projections. NEMS was used for modeling of the Base Case and policy scenarios for the Residential and Commercial buildings sectors, Electricity Supply, and the integration of demand and supply. Its Base Case was also used for benchmarking all other models used in this analysis, in particular for Transportation and Industry.

The National Energy Modeling System (NEMS) is a computer model that projects future U.S. energy consumption and supply, based on a number of factors.

The Residential and Commercial sector modules in NEMS represent energy technologies and demand by fuel type for each major end-use, including air conditioning, space and water heating, and various types of equipment and appliances, based on building and technology characteristics and costs. Policies are modeled though changes in the availability of new more efficient technologies, and changes in energy prices and financial parameters (including "hurdle" discount rates to reflect nonfinancial factors affecting consumer choice). The incremental investment costs for the technology choices induced by the policies modeled were derived from the detailed NEMS data for the technologies selected. The energy cost savings were based on the decreased energy demands owing to these technology choices and the prices of residential and commercial fuels and electricity. NEMS does not represent district energy explicitly. We assumed off-line that an aggressive initiative to promote district energy systems using combined-heat-and power (CHP) for high-density commercial buildings would result in 19 GW net additional capacity by 2010, and about 150 TWh net additional generation, based on Spurr (1998). This result was combined with the results for building sector efficiency and industrial sector efficiency and CHP, and fed back into NEMS to integrate electricity demand and supply and obtain the avoided costs and avoided emissions.

The NEMS model was used for the building sector, electricity supply and the integration of demand and supply.

LIEF was used for Industry, starting with benchmarking to the NEMS Base Case (EIA 1998), because of its more detailed sub-sectoral representation of empirical industrial energy choices based on fossil and electricity prices and financial parameters. LIEF was used to represent energy efficiency investments based on cost-of-saved-energy (COSE) equations under different assumptions for energy prices, capital costs and financial parameters. We assumed that a high effective discount rate of 27.8 percent in the Base Case, owing to market and institutional barriers, would be brought down to 12.3 percent with technical assistance and information, tax credits and R&D. The incremental investment costs were extracted from these LIEF COSE curves and the energy cost savings

The Argonne National Laboratory Long-Run Industrial Energy Forecasting (LIEF) model was used for industry.

from the decreased energy demands and industrial fuel and electricity prices. Analyses of combined-heat-and-power (CHP) with advanced micro-turbines at industrial sites was conducted off-line of NEMS, assuming that by 2010 20 percent of existing manufacturing steam demand would shift to cost-effective gas-fired cogeneration and 50 percent of existing cogeneration in the paper and pulp industry would retrofit to advanced turbines. This results in about 38 GW new capacity, at $900/kWe (1997$) and 236 TWh electricity generated on site by 2010.

The Electricity Supply module of NEMS starts with the detailed fleet of existing power plants in all thirteen Electric Reliability Council regions of the U.S., plus neighboring Canadian regions. It dispatches these plants, and builds and dispatches new ones, based upon the aggregated sector demands in each region, bulk power exchanges between regions, and the characteristics and costs of existing and new electricity supply options. The module takes account of the sulfur dioxide cap and trade regime based on the Clean Air Act Amendments of 1990, and the alternative emission cap assumptions of our policy scenarios. It also takes account of cost reductions of new power plants with increased units in operation (learning and scale economies); consequently, policies such as renewable portfolio standards can cause technology learning and thus reduce long-run costs. Carbon taxes (or caps) and taxes are also modeled in the NEMS Electricity Supply module. We assumed a hybrid of a system benefits charge (SBC) and renewable portfolio standard (RPS). We determined in an off-line analysis that a 2 mill per kWh SBC used to buy-down non-hydro renewables costs would result in about 10 percent of generation in 2010 from these new resources (consistent with NEMS runs for a 10 percent RPS by 2010). These additions were then considered as planned capacity inputs in subsequent NEMS module runs. In addition, the costs and carbon savings from biomass co-firing with existing coal were computed off-line, assuming a standard of 10 percent biomass content by 2010, and thus a corresponding reduction in coal combustion, which could be met by a tradable credit system. Finally, we assumed with EIA (1998) that nuclear power plants would retire on their normal schedules of license expiration, with little impact on the change in generation mix by 2010; policies affecting the fate of the existing fleet of nuclear plants were not addressed here.

The electricity supply module of NEMS was used with assumptions for implementing particular policies, such as a hybrid of a system benefits charge and renewable portfolio standard.

In the Transport sector, off-line analyses were used, benchmarked to the AEO98 Base Case. For light duty vehicles, we assumed a fuel efficiency standard incrementing by 1.5 mpg average increase per year from 1998 through 2010, combined with an empirically-based cost-of-saved-energy curve (incremental cost per mpg increase). We also assumed a 10 percent contribution of cellulosic ethanol as a blend with gasoline by 2010, based on a carbon content standard and RD&D expenditures of $150 million per year for five years. The delivered cost of ethanol comes down to about $1.75 per gallon gasoline equivalent by 2010. The energy cost savings were based on the policy-induced mileage improvements and projected miles traveled. For freight transport (i.e., heavy-duty trucks) we assumed fuel efficiency improvements relative to AEO98 of about 8 percent. We estimated annualized costs of efficiency improvements based on the costs of conserved energy and the stock fuel savings. For air transport, we assumed a threefold improvement (i.e., seat-miles per gallon) relative to AEO98 in 2010. We estimated annualized costs of the improvements based on the costs of conserved energy and fuel savings.

The transport analysis utilized off-line analyses, which were benchmarked to the AEO98 Base Case, and included a number of policy assumptions.

The availability and costs of biomass for co-firing in coal-electric power plants and cellulosic ethanol for gasoline vehicles were developed from Walsh *et al*. (1997). The biomass requirements for the *Kyoto Compliance* scenario reach 40 million dry tons for cellulosic ethanol and 60 million for co-firing by 2010. This would be obtained from agricultural residues and delivered for about $1.80 per million Btu by 2010. For the *Climate Protection* scenario the requirements would rise to about 118 million dry tons for cellulosic ethanol and 103 million for co-firing, at about $2.60 per billion Btu, with some of the additional resources coming from dedicated energy crops (35 million tons) and wood wastes (15 million tons). At these levels, assuming three dry tons per acre, about 12 million acres of new cropland (well within levels available from the Conservation Reserve Program) would be brought under energy production.

6.3 Summary of Results

The baseline projections of the U.S. Department of Energy 1998 Annual Energy Outlook (EIA 1998) show carbon emissions growing from 1338 MtC in 1990 to 1806 MtC by 2010. For *Kyoto Compliance*, emissions in 2010 would be 1244 MtC, 7 percent below 1990 levels; this would require that the policies and measures cause a 562 MtC (or 31 percent) decrease in emissions below the baseline projection in that year. The policies and measures of the *Climate Protection* scenario cause emissions to decline to 1150 MtC in 2010, 14 percent below 1990 levels; this entails a decrease of 656 MtC (or 36 percent) below the baseline projection in that year. Table 1 summarizes the results of these analyses.

To reach 7% below1990 levels by 2010, 562 MtC must be reduced through policies and measures.

To achieve 14% below 1990 levels by 2010, 656 MtC must be reduced.

The policies reduce overall energy use by about 18 percent and electricity use by about 30 percent in 2010 for both policy scenarios, owing to energy-efficient technologies and practices, and combined-heat-and-power in industries and large buildings. Non-hydro renewables increase almost threefold between 1990 and 2010. Other impacts are noteworthy. The absolute amount of oil in the policy scenarios is roughly the same as 1990 levels despite economic growth, and about 27 percent below baseline projections for 2010, implying much lower imports. While the *percentage* of natural gas in the primary fuels mix increases over time and with the policies, the policies result in lower overall gas requirements. Both

The policies reduce overall energy use by about 18%, and electricity use by about 30%, with varying impacts on oil, gas and coal.

Table 1. Summary of Results

	1990	2010 Base Case	2010 Kyoto Complianc
End-use Energy *(Quads)*	63.9	85.5	70.0
Primary Energy *(Quads)*	84.6	113.3	89.8
Renewable Energy *(Quads)*			
Non-Hydro	3.5	5.6	8.2
Hydro	3.0	3.2	3.2
Carbon Emissions *(Million metric tons)*	1338	1806	1242
Other Emissions *(Million tons)*			
SO_2	21.9	12.9	6.8
NO_x	19.3	17.5	13.8
PM_{10}	1.7	1.6	1.3
Net Annualized Savings			
Total *($ Billion per year)*	-----	-----	$46
Per household *($)*	-----	-----	$393

the percentage and absolute amounts of coal are radically reduced, as much as 62 percent below projections for 2010 and 52 percent below 1990 levels for the *Climate Protection* scenario.

To reach 7% and 14% below 1990 levels, CO_2 emissions must be reduced by 31% and 36% from future projections by 2010.

Carbon emissions are reduced by 31 and 36 percent in 2010, and thus by 7 percent and 14 percent below 1990 levels, respectively, for the *Kyoto Compliance* and *Climate Protection* scenarios. This arises from energy efficiency, CHP and demand management at the end-use, and switching to zero and low carbon fuels, particularly renewables and gas for electricity, renewables in transportation, and gas in industry.

The policies to reduce carbon emissions also bring about substantial environmental and health benefits. This is due to large reductions in SO_2, NO_x and particulates.

The policies would reduce national, regional and local pollution, owing to reduced fossil fuel use, providing important environmental benefits and health benefits, especially for small children and the elderly. Sulfur-dioxide emissions are about 50 percent lower in 2010 in the policy scenarios, and about 70 percent below 1990 levels. Nitrogen oxides are 21 and 25 percent lower in 2010 for the two policy scenarios, and about 30 percent below 1990 levels. Particulates are almost 25 percent lower in 2010 for the policy scenarios, and about 30 percent below 1990 levels. Figure 3 shows the impacts of the *Climate Protection* policies over time. The large reductions in particulates emissions arise from the substantial decrease in coal generation in the policy cases. Sulfur-dioxide decreases in the baseline projections arising from the cap/trade provisions of the 1990 Clean Air Act Amendments, are augmented by the policies. Similarly, baseline declines in nitrogen oxides, volatile organic compounds and carbon monoxide, which arise from tailpipe emissions standards as new cars enter the fleet, are augmented by the policies.

Finally, net annual savings will increase over time, with the average annual savings in fuel costs throughout the economy exceeding the additional costs of the new equipment by over $40 billion per year, or nearly $400 per household. By 2010 about 900 thousand net additional jobs could be created, owing to these savings and related economic factors.

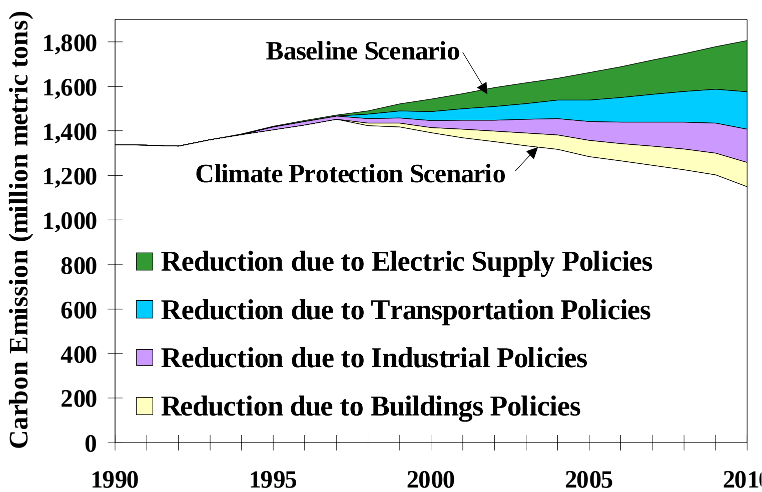
6.4 Sector/Policy Impacts

Figure 3 shows the changed U.S. carbon emissions trajectory for the *Climate Protection* scenario. The 36 percent reduction below baseline projections for 2010 translates into a 14 percent decline from 1990 levels by that year. It is noteworthy that the overall carbon emissions reductions comprise significant contributions from policies in each sector.

By implementing these policies, net annual savings to the economy will be over US$40 billion per year, and national net savings would average US$400 per household per year,

The vehicle efficiency and demand management initiatives realize the carbon emissions reductions with net economic savings, fuel savings in excess of incremental investment costs. While the carbon content standard (met by cellulosic ethanol) incurs a net cost, it is a measure that begins a process of progressive technological improvement to provide a viable

Figure 3: Carbon Reductions in All Sectors Under the Climate Protection Scenario



Reductions from individual policies in the electric supply, transportation, industrial and buildings sectors add up to achieve the 14% reduction option.

and economic option for the deeper carbon emissions reductions needed later. The overall net economic benefit achieved when all the transportation policies and measures are combined provides an opportunity to pursue this forward-looking policy.

The transportation policies bring about an overall net economic benefit.

By themselves, the electric sector policies, which would shift the generation mix away from coal and towards renewable and advanced gas generating technologies, would achieve their carbon emissions reductions at a net economic cost. This is primarily because continued operation of existing coal plants, and construction and operation of new ones, remain economically attractive in the emerging price-competitive restructured industry, in the absence of such new environmental and climate policies.

The electric sector policies, combined with other trends in the electricity market, could bring about an overall reduction of costs for electricity services.

However, when combined with major reductions in electricity generation and new construction requirements, owing to the energy efficiency and CHP achieved by policies and measures in the buildings and industrial sectors, the net impact on electricity prices is contained, while the overall costs of electricity services is reduced.[1]

A large reduction in energy consumption in buildings is achieved.

Energy consumption in buildings is about 15 percent below the baseline scenario by 2010, over 20 percent in commercial buildings and 12 percent in residential. Purchased electricity savings are about 35 percent in commercial buildings in the *Kyoto Compliance* scenario and reach almost 50 percent in the *Climate Protection* scenario owing to the introduction of combined-heat-and-power district energy systems (DES). By 2010, overall energy use is reduced by about 15 percent and electricity use by about 30 percent in industry, while transportation energy use is reduced by about 23 percent.

Table 2: Carbon reductions in 2010 by sector and policy

	Carbon Savings (MtC)	
	Kyoto Compliance	**Climate Protection**
Residential & Commercial Sectors	**100**	**110**
Building efficiency	100	100
District energy systems	0	10
Industrial Sector	**111**	**111**
Incentives	62	62
Capital cost	15	15
Cogeneration	34	34
Transportation Sector	**181**	**201**
Fuel efficiency	105	105
Cellulosic ethanol	11	31
VMT reductions	65	65
Electric Sector	**172**	**233**
Sulfur dioxide cap	23	23
Environmental externalities	42	42
SBC/RPS	40	40
Carbon cap/tax	50	103
Biomass co-firing	17	25
Total Carbon Savings	**563**	**656**

Table 2 provides a breakdown of the carbon emissions reductions from the various sectoral policies and measures for both the *Kyoto Compliance* and *Climate Protection* scenarios. It is noteworthy that the overall reductions comprise a robust mix of contributions across sectors and policies. Moreover, these results reflect and embody cross-sectoral impacts. Energy efficiency and combined heat and power policies in the residential, commercial and industrial sectors, will reduce electricity demand and change the mix of fuels and thus the

[1] The national average electricity price is estimated to increase by about 0.8 cents per kWh by 2010 owing to the *Climate Protection* policies; this would be offset by the price decrease projected by EIA (1998) between 1997 and 2010.

carbon-intensity of electricity generation. Carbon reductions from the electricity supply policies shown here, are reflected in lower carbon intensities and thus lower carbon emissions caused by sectoral demands. In the analyses these effects are integrated. Also, transportation policies bring about efficiency improvements, demand management and use of renewables, reducing gasoline usage. This includes reductions at refineries (about 20 percent), which are an industrial sub-sector. (The Appendix shows both energy and carbon emissions and reductions as they occur in each sector, rather than by policy as shown here.)

Reductions come from a wide range of sectors and policies, and bring benefits across-the-board.

6.5 Air Pollution Reductions

A variety of air pollutants, associated with the use of fossil fuels, can cause or exacerbate health problems and damage the environment. Reducing use of fossil fuels would reap important local health benefits by lowering the amount of air pollutants inhaled. Recent scientific findings confirm that pollutants such as fine particulates, carbon monoxide, ozone (formed by a mix of volatile organic compounds and nitrogen oxides in presence of sunlight) can lead to health impacts that include premature mortality and morbidity effects. Research shows that small children and the elderly are particularly at risk from these emissions (Dockery et al., 1993; Schwartz and Dockery, 1992).

Reduction of fossil fuel combustion translates into local health benefits from reduced air pollution.

The methodology to calculate emissions of criteria pollutants in each of the sectors is as summarized below:

Methods to calculate reductions in air pollution are based on a number of models and analyses.

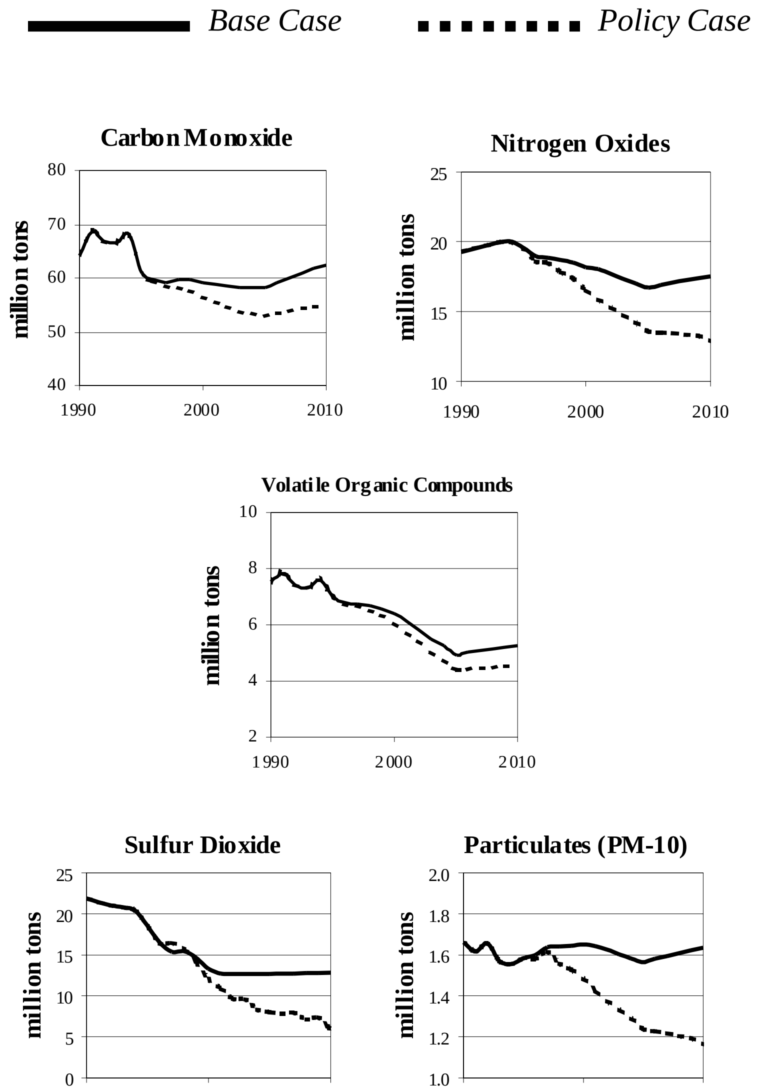
- For the residential, commercial, and industrial sectors, we determined base year emission factors by fuel from EPA and EIA sources. Total emissions are based on USEPA (1998) and total fuel consumption is based on historical energy data for 1995 from EIA (1998). We applied these emission factors to future year levels of fuel consumption in the Base and Policy cases.
- For the electric sector, which is subject to provisions of the 1990 Amendments to the Clean Air Act for future reductions in emissions of SO_2 and NO_x, we used direct NEMS outputs for sulfur oxides in the base and policy cases, and for nitrogen oxides in the base case. In the policy case, we applied annual NO_x emission factors by fuel derived from AEO98 outputs to future fuel consumption levels.
- For off-road modes in the transport sector (i.e., air, marine, and rail), we determined base year emission factors by fuel from the same EPA and EIA sources. We then applied these emission factors to each future year's consumption in the Base and *Climate Protection* cases. For on-road vehicles (light duty vehicles, freight trucks), we determined base year emission factors (in grams per mile) by vehicle type from the same EPA and EIA sources. We then applied a stock turnover model to fold in changes in fleet composition and future emission standards.

Figure 4 below illustrates the impacts of the policies and measures on total U.S. combustion-related emissions of criteria air pollutants, showing the AEO98 Base Case and the *Climate Protection* scenario.

To summarize the factors behind these curves:

- Emissions of carbon monoxide and volatile organic compounds are dominated by the transport sector. For both the Base and *Climate Protection* cases, the post-2005 upturn in emissions is due to a combination of increased VMT, vehicle turnover, and a regulatory regime where more stringent standards do not come into effect until after 2010.

Figure 4. Emissions of major air pollutants: 1990-2010, Base Case and Policy case



- A similar though less pronounced trend exists for nitrogen oxides, for which the transport sector contributes a smaller share of overall emissions.
- Sulfur dioxide emissions are driven by the electric sector. In the Base Case, emissions stabilize in the post-2000 period due to compliance with levels mandated by the Clean Air Act Amendments. In the *Climate Protection* scenario, overall emissions continue to decline in this period due to the imposition of a more stringent emissions cap.
- Emissions of fine particulates slightly increase in the Base Case due to higher levels of fuel consumption. The Climate Protection Case shows a relatively steep decline in emissions, driven mostly by reductions in the electric sector.

These policies and measures would bring about significant cuts in other pollutants.

6.6 Economic Impacts

Utilizing the incremental investment and savings data from the *Climate Protection* scenario, three sets of economic impacts were estimated for the years 2005 and 2010. These impacts were estimated using IMPLAN (Impact Analysis for Planning), an input-output (I-O) model that represents interactions between different sectors of the economy. Changes in each sector's spending patterns—owing to changes in fuel consumption and energy technology investments—induce changes in other sectors' level of output (and inputs), and these are reflected in appropriate sectoral multipliers (jobs per dollar spent). The analytical approach used here is similar to that in Geller, DeCicco and Laitner (1992), Laitner, Bernow and DeCicco (1998), and Goldberg *et al.* (1998).

The IMPLAN model was used to estimate impacts on each sector of the economy from changes in fuel consumption and energy technology investments.

Table 3 provides an estimate of the net national benefits of the accelerated use of energy efficiency and renewable technologies for the two benchmark years. As that table indicates, the impacts are positive for employment, incomes and GDP. By the year 2010, wage and salary earnings increase by over $27 billion, while almost 900,000 net new jobs are created, relative to the Base Case. At the same time, relative to the Base Case, GDP is projected to increase by almost $14 billion in 2010. Major contributions to these employment benefits arise from purchases of energy efficient equipment and the re-spending of net energy bill savings by businesses and households.

Table 3. Macroeconomic Impacts of the Policy Scenario

	2005	2010
Net change in Jobs *(actual)*	461,200	870,532
Net Change in Wage & Salary Compensation *(Million 1996 $)*	$14,600	$27,316
Net Change in GDP *(Million 1996 $)*	$8,840	$13,671

Table 3 shows the net benefits to the nation of this set of actions from energy efficiency and renewable technologies for 2005 and 2010.

While these increases are significant, the impacts are relatively

By the year 2010, wage and salary earnings increase by over US$27 billion, while almost 900,000 net new jobs are created, relative to the Base Case. GDP is projected to increase by almost US$14 billion in 2010.

small in comparison to overall economic activity. For instance, increasing the nation's GDP by $14 billion in 2010 represents only 0.15 percent of the $9.6 trillion (1996$) projected GDP in that year.

The analysis tracks expenditures on more efficient lighting, high efficiency motors, more efficient automobiles, and other technologies that reduce combustion of high carbon fuels. These expenditures, in turn, create income and jobs for the manufacturers and workers who produce the equipment and the industries and workers who supply and service those producers. In addition, these expenditures result in benefits to the offices, firms and households who utilize the more efficient technologies, by reducing their energy bills. The re-spending of these energy bill savings creates additional income and jobs in the industries and services (and their suppliers) in which these savings are spent. For a set of policies that gives rise to large net savings, such as those analyzed here, these positive job impacts create new opportunities that far exceed the losses that might occur in some of the traditional energy supply sectors. At the same time, as these traditional energy suppliers undergo internal restructuring, they may offset some of the potential losses if they move aggressively into the energy efficiency and renewables business.

The re-spending of these energy bill savings creates additional income and jobs in the industries and services in which these savings are spent.

Table 4 provides detailed results for the 23 sectors analyzed in this study, for the year 2010. The table shows how each of the major economic sectors are affected in the year 2010 in the Climate Protection Scenario. It should be noted that the results in this table are not intended to be precise forecasts of what will occur, but rather approximate estimates of overall impact. The table shows that three sectors—services, construction, and miscellaneous manufacturing—have the greatest net benefits.

As might be expected, the energy supply industries incur net losses. But these results must be tempered somewhat as the energy industries themselves are undergoing internal restructuring. For example, with electric sector restructuring some electric utilities may engage in more energy-efficiency services and alternative energy investments, while new electricity supplier and energy service firms may arise. These will undoubtedly employ more people from the business services and engineering sectors. Hence, the negative net employment impacts in these sectors should not necessarily be seen as job losses; rather they might be more appropriately seen as a redistribution of jobs in the overall economy and future occupational trade-offs.

The energy supply industry findings are consistent with ongoing trends.

Many of the outlays for energy efficiency investments do not begin to pay for themselves through energy bill savings by 2010; this tends to limit the increase of GDP owing to the policies in the time-frame of this analysis. Moreover, while the models used for the energy analyses capture some policy-induced technology innovation, this is limited primarily to the electric sector. In addition, the analysis does not include the potential produc-

Table 4: Macroeconomic Impacts of Climate Protection Scenario by Sector, 2010

Sector	Net Change in Jobs	Net Change in Wage and Salary Compensation (Million 1996$)	Net Change in GDP (Million 1996$)
Agriculture	37,031	$341	$1,261
Other Mining	5,957	$407	$858
Coal Mining	(13,574)	($1,538)	($3,165)
Oil/Gas Mining	(63,052)	($2,866)	($13,592)
Construction	255,827	$7,146	$9,885
Food Processing	6,058	$263	$514
Other Manufacturing	80,413	$3,985	$6,890
Pulp and Paper Mills	7,588	$515	$872
Oil Refining	(1,193)	($146)	($431)
Stone, Glass, and Clay	21,209	$1,183	$1,682
Primary Metals	14,251	$1,104	$1,475
Metal Durables	42,831	$3,618	$5,270
Motor Vehicles	23,693	$2,066	$2,751
Transportation, Communication, and Other Utilities	48,131	$2,654	$5,159
Electric Utilities	(59,533)	($5,553)	($26,851)
Natural Gas	(4,782)	($487)	($1,881)

tivity benefits that could stem from the investments in new and more efficient equipment, and associated changes in organization, knowhow and inter-industry interactions. Industrial investments that improve energy efficiency could be accompanied by improved product quality, lower capital and operating costs, increased employee productivity, easier and less costly environmental compliance, and entry into niche markets (see, e. g., Elliott *et al* 1997; Laitner 1995; OTA 1993; Porter and Van Linde 1995).

Table 4 shows the effect of these policies on each major economic sector in terms of net change in jobs, wages and salaries, and GDP.

These analyses assume that available labor, plant and materials are not fully employed. They do not account for feedback through final demand reductions and input substitution owing to price changes, nor for feedback from inflation, and constraints on labor and money supplies.

A number of timing and technology issues must be taken into account when assessing the impacts of such policies on various sectors.

There are a number of uncertain elements in the analyses, such as feedback loops. It would be valuable to develop tools and refine the analyses to take account of some of these factors, to obtain more detailed characterization of the results. It would also be useful to develop such tools and analyses to explore a range of policy instruments, including tax and fiscal policies, combined with targeted sector and technology-based policies.

State-by-state impacts

Further tools are needed to refine the analysis.

The analysis suggests that the policies embodied in the *Climate Protection Scenario* would induce accelerated use of cost-effective energy efficiency and renewable technologies that entail a significant net employment gain at the national level. Yet, providing estimates of state level impacts could provide important additional insight into the benefit of such a policy initiative.

Quantitative estimation of the distribution of these national economic benefits in specific states requires further analysis. However, it is reasonably safe to say that, but for the oil and coal states, the large net benefits would be rather widely and evenly distributed. In the oil and coal states, the losses to fossil fuel related businesses would be accompanied by gains in other sectors, owing to expenditures on more efficient equipment and energy bill savings. While the overall economic benefits will likely be positive at the state as well as national level, some industries may face losses in the near term before they can take action. It is thus important that some of the savings realized from implementing the policies be used for assistance in a *just transition* for workers and communities affected.

State level information could provide additional insight to the benefits of such a policy initiative.

The detailed distribution of the national employment impacts across the states is difficult to predict. Some impacts are associated with the direct expenditures made for more efficient equipment and renewable technologies and renewable fuels. Manufacturers and venders of appliances and equipment, building materials, etc. may not be uniformly spread across the states, they are rather widely dispersed. For example, New York is home to Carrier Corporation (compressors, chillers, air conditioners and refrigeration equipment), Osram Sylvania (compact fluorescent lighting) and Phillips Lighting (efficient lamps); Pennsylvania has Shuller International (insulation); New Jersey has Duro-test (efficient incandescents and compact fluorescents); Illinois has Honeywell's microswitch division, Motorola Lighting, and Siemens and Furnas controls; Ohio has reliance electric (motors), whirlpool (efficient clothes washers) and General Electric (efficient lamps); and so on. Equipment distributors, retailers and installers tend to be local.

Manufacturers of advanced power plants, including gas turbines, natural gas combined cycle systems and fuel cells are located in various regions of the country. Equipment for CHP is manufactured throughout the U.S., with concentrations in the Midwest, Northeast and California, while the location of industrial equipment manufacture will tend to vary by industry. Wind turbine manufacturers such as Enron (Zond), Vestas and NEG-Micon, are currently concentrated in California and the Midwest. As demand for wind electric machines grows in other regions, some firms might locate near those sites. Major solar photovoltaic cell and array manufac-

Manufacturers of advanced, more efficient energy using equipment would benefit in states like New York, Pennsylvania, Ohio and Illinois.

turers are located in Massachusetts (ASE Americas), Delaware (AstroPower), Texas (BP Solar), California (Kyoecera America, Siemens Solar, and Solec), Maryland (Solarex) and Michigan (Energy Conversion Devices). Major solar power electronics and inverter manufacturers are located in New York (Advanced Energy Systems) Wisconsin (Omnion) and Washington (Trace Engineering), while firms that build structures, install solar systems and interconnect them to the grid are more widely dispersed.

Manufacturers of gas turbines, wind turbines and renewable technologies would benefit in states like California, Texas and Wisconsin.

Manufacture of more efficient and alternative fueled automobiles would likely be located largely with current manufacturers. Biomass fuels for transport and power generation would come from states with farm and managed forest resources and institutions. Petroleum companies with experience in industrial chemistry could play a role in providing cellulosic ethanol. Biomass resource needs could also provide revenues to municipalities with recycling programs that separate wood products. In some states, farms could become sites for wind electric generators and derive income from these facilities.

Farm states would benefit from increased use of biomass fuels.

The major contribution to the overall national employment increases is the net savings to households and businesses — fuel bill reductions greater than the investments to effect them — which are re-spent across the economy. That re-spending occurs broadly across all sectors based on typical spending patterns, with much of it local. Thus, the national job increases—in construction, services, education, finance, government, miscellaneous manufacturing, agriculture, etc.—would likely be widespread throughout the country.

The major contribution to the overall national employment increases arises from the net savings to households and businesses, which are re-spent across the economy.

Although the large net benefits would be rather widely and evenly distributed, a just transition for some industries that are likely to face near term losses must be found. The planning for a just transition should be guided by the principle of fair treatment of workers and their communities.

A just transition for workers and industries that might suffer near term losses must be found.

To take these factors into account, we developed indicative estimates of the distribution of the approximately 870,000 net national jobs gained by 2010 across the fifty states and the District of Columbia. Absent a more detailed analysis of each individual state or region, the authors utilized the national impacts and weighting of key variables to accomplish the overall state-by-state assessment. This estimation reflects the significant energy and economic differences among each of the states. The key variables used in this assessment include: differences in energy prices; the level of energy consumed for each dollar of economic activity in the state; the number of energy-related jobs as a percent of total state employment;and the number of state jobs as a percent of national employment. The results are presented in Table 5, which shows a positive net job impact in each state, ranging up to a high of about 68,000 in Texas.

Key variables to accomplish the state-by-state assessment include differences in energy prices, the level of energy consumed for each dollar of economic activity in the state, the number of energy-related jobs as a percent of total state employment and the number of state jobs as a percent of national employment.

Table 5. State-by-state Employment Impacts

State	Net Job Gain	State	Net Jol
Alabama	15,200	Montana	
Alaska	2,400	Nebraska	
Arizona	13,700	Nevada	
Arkansas	8,800	New Hampshire	
California	94,900	New Jersey	
Colorado	11,300	New Mexico	
Connecticut	10,500	New York	
Delaware	2,500	North Carolina	
District of Columbia	2,500	North Dakota	
Florida	44,500	Ohio	
Georgia	25,200	Oklahoma	
Hawaii	3,600	Oregon	
Idaho	3,900	Pennsylvania	
Illinois	39,200	Rhode Island	
Indiana	23,500	South Carolina	
Iowa	10,200	South Dakota	
Kansas	7,900	Tennessee	
Kentucky	12,500	Texas	
Louisiana	18,300	Utah	
Maine	4,600	Vermont	
Maryland	15,200	Virginia	
Massachusetts	19,800	Washington	
Michigan	33,200	West Virginia	
Minnesota	16,000	Wisconsin	
Mississippi	8,400	Wyoming	
Missouri	18,200	**U.S. Total**	**8**

Results in Table 5 show a positive net job impact in each state.

States such as Texas, which are large energy producers and have relatively low energy prices, compared with the national average, still enjoy a large benefit. As Table 5 indicates, the state of Texas, which currently leads the nation in total energy consumed, and is second only to California in total energy expenditures, could expect to have a net gain of approximately 68,000 jobs in 2010 if the national policy initiatives are adopted. This gain in employment occurs despite the large numbers of people employed in the more traditional energy and energy-related industries that serve demand both outside and within the state. To further assess the sector specific job impacts for each of the states would require significantly more analysis, well beyond the scope of this study.

7. Conclusions

The U.S. can fulfill its responsibility and become a leader in a coordinated international effort to meet the challenge of climate change. The risks to coming generations of our citizens and people everywhere are too great to delay early, steady and sustained actions. Technological and policy opportunities exist for the U.S. to exceed its Kyoto target and help put the world on a path towards climate stabilization. This study has analyzed a set of policies and measures that could reduce U.S. carbon emissions to 14 percent below 1990 levels by 2010, exceeding its Kyoto target, while reducing pollution, saving nearly $400 per household per year, and creating additional jobs and incomes.

While implementing this set of policies and measures and achieving the associated carbon emissions reductions is an ambitious undertaking for the next decade, it has important long term benefits. Most importantly, by focussing on domestic, energy-related carbon emissions, going beyond the Kyoto target, and including cutting-edge technologies in an overall cost-effective portfolio, it serves as an effective transitional strategy to meet the long-term requirements of climate protection. It takes a precautionary approach to the potential large-scale and irreversible impacts that could arise from increasing greenhouse gas emissions sooner and more rapidly than expected, and it builds technological and institutional momentum for the much deeper long-term emissions reductions needed for climate protection. It could stimulate technological and institutional learning, economies of scale, and further innovation and invention, enhance economic productivity, and establish the basis for entering markets for clean technologies and pursuing technology cooperation and transfer. Finally, it reflects an acknowledgment by the U.S. of its historic responsibility, capability and commitment to take the lead against climate change, to set an example that would strengthen implementation of the Framework Convention on Climate Change, and to contribute to the well-being of future generations of its citizens.

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