THE KYOTO PROTOCOL AND THE PRESIDENT'S POLICIES TO ADDRESS CLIMATE CHANGE:

ADMINISTRATION ECONOMIC ANALYSIS

July 1998

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EXECUTIVE SUMMARY

The primary purpose of this analysis is to examine costs and benefits of taking action to mitigate the threat of global warming. In particular, we examine costs and benefits of complying with the emissions reduction target for the United States set forth in the Kyoto Protocol on Climate Change, negotiated in December 1997. For reasons discussed at length in this paper, it is our conclusion that, with the flexibility mechanisms included in the treaty, and by pursuing sound domestic policies, the United States can reach its Kyoto target at a relatively modest cost. Moreover, the benefits of mitigating climate change are likely to be substantial.

Before considering the economics of taking action, however, we ought to step back and ask the threshold question -- whether taking action to mitigate global climate change is necessary in the first place.

The Rationale for Taking Action

The great weight of scientific authority suggests that climate change is a serious problem and that prudent steps to mitigate it are in order. In essence, we need to take out an insurance policy with reasonably priced premiums. As long ago as 1992, the National Academy of Sciences, in a study entitled *Policy Implications of Greenhouse Warming*, concluded that "...even given the considerable uncertainties in our knowledge of the relevant phenomena, greenhouse warming poses a potential threat sufficient to merit prompt responses....Investment in mitigation measures acts as insurance protection against the great uncertainties and the possibility of dramatic surprises" (p. 68).

What the science tells us is that greenhouse gases are rapidly building up in the atmosphere as a result of the burning of fossil fuels and deforestation; that the concentration of these gases is 30 percent higher than it was at the beginning of the industrial revolution; and that this concentration is expected to reach almost twice current levels by 2100 -- a level not seen in 50 million years. Theory and computer models suggest that this increased concentration of greenhouse gases could warm the Earth by about 1.8 to 6.3º F by 2100. By way of comparison, the last ice age was only about 9º F colder than today. Moreover, much evidence suggests that warming is already underway. For example, we know from ice cores and other data that we are living in the hottest century since at least 1400, that the nine hottest years since records were first kept in the late 19th century have all occurred since 1987, and that 1997 is the hottest year on record.

Scientists predict a range of likely effects from global warming. For example, the rate of evaporation is expected to increase as the climate warms, leading to increasingly frequent and intense floods and droughts. Sea level is projected to rise 6-37 inches by 2100. A 20-inch rise could inundate about 7,000 square miles of U.S. territory. Warmer temperatures would be expected to increase the risk of mortality from heat stress, aggravate respiratory disease, and increase the range and rates of transmission of some infectious diseases.

Scientific opinion is not unanimous on these points, but most independent climate scientists believe that global climate change poses real risks. A few scientists contest the notion that increasing concentrations of greenhouse gases will warm the planet, while a few others concede that the earth is indeed getting warmer, but argue that this is a good thing -- "a wonderful...gift from the industrial revolution," in the words of one. But these are distinctly minority views. The prevailing view is that the risks of climate change warrant prudent and prompt action. Prompt because to wait for greater scientific certainty could have very large costs. Greenhouse gases are long-lived and the decisions being made by governments and firms in the next decade with respect, for example, to the kinds of power plants to build or the kinds of energy sources to develop, are likely to have significant consequences for our ability to limit the buildup of greenhouse gases.

Consequently, there is a substantial rationale for acting now. Our task is to act in a manner that responds appropriately to the scope of the risk while at the same time being economically sensible.

Domestic Policy

In October 1997, the President announced a domestic program designed to reduce greenhouse gas emissions. In essence, the program contemplated (a) a set of activities that made sense as good energy and environmental policy irrespective of whether an agreement were reached in Kyoto, and (b) a mandatory domestic emissions trading system that would take effect in the 2008-2012 period if an agreement in Kyoto were reached and approved by the U.S. Senate.

The Kyoto Protocol

The Kyoto Protocol, which requires the advice and consent of the Senate, commits industrialized nations to take on binding targets for greenhouse gas emissions, and includes three basic kinds of flexibility provisions that were proposed by the United States. These provisions -- commonly referred to as "when", "what", and "where" flexibility -- have great potential to significantly lower the costs of meeting the Kyoto targets. "When" flexibility appears in the form of a multi-year commitment period (2008-2012), and allowance for "banking" of emissions reductions. The freedom for countries or companies to delay or accelerate reductions within an agreed upon time frame can help lower costs. "What" flexibility is provided by both the inclusion of all six greenhouse gases -- enabling reductions in emissions of one gas to be used to substitute for increases in emissions of another -- and the coverage of certain "sink" activities, such as afforestation or reforestation, that absorb carbon. Most important, the Protocol incorporates "where" flexibility in the form of international emissions trading and joint implementation among countries that take on binding targets, coupled with a "clean development mechanism" allowing industrial countries or firms to earn credits for projects in the developing world that reduce emissions. These mechanisms can provide opportunities for industrial countries and firms to secure low-cost reductions and for developing countries to achieve sustainable growth.

Developing countries did not take on binding emissions targets at Kyoto, although they did agree to provisions for the Clean Development Mechanism. The President has said that he will not submit the Protocol to the Senate without meaningful participation from key developing countries. While the Clean Development Mechanism provides a down payment on such participation, the Administration is actively seeking greater developing country engagement.

Costs and Benefits of Mitigation

Analyzing the costs and benefits of mitigating climate change is a difficult undertaking for three reasons. First, uncertainties remain about significant details of certain provisions in the Protocol. Second, available models have inherent limitations in their abilities to analyze even short-term costs and benefits. Third, it is extremely difficult to quantify the long-term economic benefits of climate change mitigation. Thus, while we have summarized the literature, we have not calculated a monetary value of these benefits.

Recognizing these difficulties, our conclusion is that the costs for the United States to meet its Kyoto emissions target are likely to be modest if those reductions are undertaken in an efficient manner employing the flexibility measures of emissions trading (both domestic and international), joint implementation, and the Clean Development Mechanism. This would be so even without considering the direct benefits of mitigating climate change or the impact that key additional factors -- such as the President's domestic climate change proposals, the ancillary benefits of improved air quality, or the inclusion of sinks -- could have on lowering the net costs of mitigation.

Our conclusion concerning the costs of complying with the Kyoto Protocol is not entirely dependent upon, but is fully consistent with, formal model results. For example, given the flexibility measures noted above, with key developing countries participating in trading, and *excluding* both the benefits of mitigating climate change and the key additional factors just noted, estimates derived using Battelle's Second Generation Model (SGM) suggest that the resource costs of attaining the Kyoto targets for emission reductions might amount to $7-12 billion per year in 2008 to 2012, or just 0.1 percent of projected GDP. The same model predicts that emission permits in 2010 would cost between $14 and $23 per ton of carbon equivalent -- which would translate into an increase of about 4 to 6¢ per gallon of gasoline. The increase in energy prices would raise the average household's energy bill in 2010 by between $70 and $110 per year -- a relatively small amount compared to typical energy price changes. Moreover, this increase would be substantially offset by the decline in electricity prices resulting from the Administration's electricity restructuring proposal.

These numbers are instructive. They demonstrate the importance of flexibility measures like emissions trading and the potential for meeting our Kyoto target at a relatively modest cost. However, it is just as important to understand what these numbers do *not* say. They do not tell us about either (a) the economic *benefits* of mitigating climate change or (b) the potential for any other domestic policy measures (aside from emissions trading) to reduce costs further and/or to increase the percentage of greenhouse gas reductions we can accomplish at home. The reason is that the SGM model we used to generate these numbers does *not*, by its terms, account for either of these factors.

Benefits of mitigating climate change. There are substantial long-term benefits of mitigating global climate change. Monetary estimates of damages from the environmental, health, and economic impacts of global warming during the next century range in the tens of billions of dollars per year. One noted economist, William Cline, has estimated that a doubling of pre-industrial concentrations of greenhouse gases would cost the U.S. economy about 1.1% of GDP annually -- some $89 billion a year in today's terms. Moreover, these estimates do not reflect the potential costs of so-called "non-linearities" -- the risk that global warming will lead not to gradual and predictable problems, but to relatively abrupt, unforeseen, and potentially catastrophic consequences. Although we do not think the benefits of mitigating climate change are, at this stage, quantifiable with adequate precision, they are nonetheless likely to be real and large in the long run.

There are also ancillary benefits of reducing greenhouse gas emissions -- in particular, the corresponding reductions in conventional air pollutants like sulfur dioxide or nitrogen oxides. These benefits alone could produce savings equal to about a quarter of the costs of meeting our Kyoto target.

The impact of policies not included in illustrative analysis. Following on the President's October 1997 policy announcement, the Administration is pursuing a number of domestic initiatives that will help reduce greenhouse gas emissions. These initiatives -- all of which are consistent with our commitments under the 1992 Framework Convention on Climate Change, which the Senate approved that same year -- could reduce costs and/or increase the amount of reductions accomplished through domestic action. First, the Administration's $6.3 billion budget proposal to promote energy efficiency and renewable energy should help increase the rate of technology development and diffusion. Many of the components of this initiative reflect recommendations made in an October 1997 report by the President's Committee of Advisors on Science and Technology (PCAST), which concluded that "the inadequacy of current energy R&D is especially acute in relation to the challenge of responding prudently and cost-effectively to the risk of global climatic change...." (PCAST 1997, p. i).

Second, the Administration's electricity restructuring proposal is estimated to reduce greenhouse gas emissions in the United States by about 25 to 40 million metric tons per year. Competition would provide a direct profit incentive for generators to produce more electricity with less fuel and improve energy efficiency. Several specific provisions in the Administration's proposal would yield further emissions reductions.

Third, the Administration is conducting industry consultations aimed at promoting voluntary agreements with major energy-intensive industries, energy providers, and others to yield further emissions reductions. One such agreement, the Partnership for Advancing Technology in Housing (PATH), announced in May, established goals for voluntary improvements in home energy use that would reduce emissions in 2010 by about 24 million metric tons of greenhouse gas emissions.

Fourth, the Administration is pursuing an active program to reduce emissions produced by the federal government, the nation's largest consumer of energy.

As noted above, models like SGM, while well equipped to assess policies such as a tradable permit program, do not assess policies like these. To the extent that policies like these boost the rate at which energy efficiency improves, the United States could lower the cost of mitigation and increase the amount of reductions made domestically.

Finally, our illustrative analysis, based on the SGM model, did not account for the effects of carbon sinks in reducing net greenhouse gas emissions. Opportunities to reduce net emissions through carbon sinks could further reduce the costs of achieving the Kyoto target and increase domestic reductions.

Conclusion

The current state of the science provides a powerful rationale to take prompt, prudent action to mitigate climate change. The agreement negotiated in Kyoto includes flexibility mechanisms that will allow the United States to meet its Kyoto target at a modest cost. Additional factors not included in the modeling effort -- such as the President's domestic climate change policies, the inclusion of sinks and the ancillary benefit of improving air quality -- could lower costs even further and increase the percentage of reductions made through domestic action. The benefits of mitigating long-term impacts of global climate change, while not precise enough to quantify at this stage, are likely to be very important. In short, this is an insurance policy we should buy and it is one we can buy for reasonably priced premiums.

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INTRODUCTION

The earth's surface appears to be warming as a result of the accumulation of greenhouse gases from myriad sources worldwide. None of the emitters of these gases currently pays the cost to others of the adverse effects of warming. No individual firm, nor any single country, has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to "free ride" on the efforts of others. Without an international agreement limiting emissions abroad, even if one country sharply reduces its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly reduced. The complex nature of the climate change problem requires global cooperation and a long-term solution.

In June of 1992, the Framework Convention on Climate Change, the first international agreement to address the risks of climate change, was signed during the Earth Summit in Rio de Janeiro. This treaty, ratified by the United States with the advice and consent of the Senate in October 1992, established the following ultimate objective:

> "[To achieve] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (Framework Convention on Climate Change, Article 2).

The Framework Convention laid the foundation for international cooperation to reduce emissions of greenhouse gases. The treaty encouraged industrial countries to return their greenhouse gas emissions to their 1990 levels by 2000.

Since the Framework Convention entered into force, the world's scientists have continued to warn of the potential negative environmental and economic effects of climate change. In 1995, the Intergovernmental Panel on Climate Change (IPCC), jointly established by the World Meteorological Organization and the United Nations Environment Programme, and representing the work of more than 2,000 scientists, concluded that "the balance of evidence suggests that there is a discernible human influence on global climate" (Houghton et al. 1996, p. 5). Without measures to abate the expected increase in greenhouse gas emissions over the next century, the IPCC projected that average global temperatures would increase by 1.8 to 6.3° F (1 to 3.5° C), resulting in coastal damage from rising sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.

To address these climate change risks better and to build on the existing treaty, approximately 160 countries met in Kyoto, Japan in December of 1997 and agreed to take substantial steps toward meeting the Convention's ultimate objective. The Kyoto Protocol, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal types of greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). The Protocol embraces several flexible, market-based approaches to allow for the emissions targets to be achieved at least cost. While the Protocol includes some participation by developing countries -- for example, through the Clean Development Mechanism[1] -- it does not currently include adequate participation by key developing countries, and the Administration is working to promote such participation.

The Administration will continue its efforts to promote meaningful participation by key developing countries and will work for effective implementation rules for international trading, the Clean Development Mechanism, and joint implementation. The risks of climate change are global and thus they require a global effort. The President will not submit the Kyoto Protocol to the Senate for advice and consent until key developing countries agree to participate meaningfully.

Independent of the agreement reached in Japan, the Administration has proposed a suite of measures to reduce emissions domestically.

- Corresponding to the first stage of the three stage domestic strategy that the President announced in October 1997, the Administration has proposed a five-year, $6.3 billion package of tax incentives and R&D investments to improve energy efficiency and spur the development of renewable energy; commenced a set of consultations with our energy-intensive sectors aimed at achieving voluntary agreements on reducing greenhouse gas emissions; submitted a proposal for electricity restructuring that will reduce greenhouse gas emissions; and commenced an intensive review of how to improve the Federal government's own energy use and procurement.

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[1] For a discussion of the Clean Development Mechanism, see p. 35.

Complementing these measures are the second and third stages of the Administration's plan that would be implemented subsequent to ratification of the Kyoto Protocol.

- The second stage will include a review of our program and an evaluation of the next steps as we prepare for a market-based trading system for greenhouse gas emissions. The details of the domestic trading system would be refined and possibly tested.

- In the final stage (2008-2012), emissions reductions would occur through a domestic trading program, integrated with international flexibility mechanisms, including international trading of emissions allowances, the Clean Development Mechanism, and joint implementation.

The international agreement that was reached in Kyoto this past December is a crucial step forward in addressing global climate change. But it is only one step in a journey. Since the international effort to reduce greenhouse gas emissions is still in some respects a work-in-progress, it is not yet possible to provide a full authoritative analysis of it. However, key elements of the Kyoto Protocol and the Administration's policy, such as international emissions trading, meaningful developing country participation, inclusion of carbon sinks and six categories of gases, as well as domestic initiatives, can ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth.

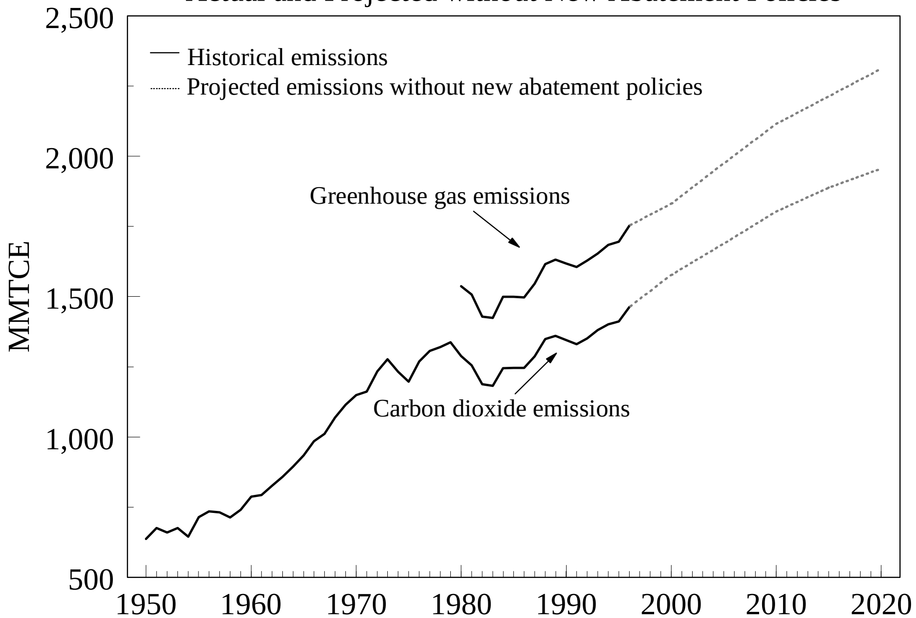
This report provides the reasoning underlying the Administration's conclusion that, with the flexibility represented by key provisions of the Kyoto agreement, and through the pursuit of sound economic policies, the economic impacts of complying with the Kyoto Protocol are likely to be modest. First, the report provides a discussion of trends in greenhouse gas emissions, both in the United States and internationally. Second, it presents a brief survey of the scientific literature on the risks of climate change. Third, it provides an overview of the Kyoto Protocol, with emphasis on its flexibility mechanisms, and the evidence in the economic literature for cost-savings through these mechanisms. Fourth, it describes the methodology used to provide illustrative cost estimates of the Administration's policy to address climate change and presents the results of this illustrative cost analysis. In addition, it discusses important elements -- such as the benefits of mitigation and the potential impact of domestic policies -- that are not factored into the model used in our illustrative cost analysis.

TRENDS IN GREENHOUSE GAS EMISSIONS

Historical Emissions

The increase in atmospheric concentrations of greenhouse gases reflects in part the growth in anthropogenic emissions of these gases. In the United States, emissions of carbon dioxide have increased more than 2 ½ times since 1950, and are projected to continue to increase over the next twenty years absent any new emissions abatement policies and efforts (see Figure 1). Most of the projected increase in domestic greenhouse gas emissions results from anticipated growth in carbon dioxide emissions; emissions of methane and nitrous oxide are likely to remain roughly flat over the next decade (Energy Information Administration 1997a; Climate Action Report 1997).[2] More than 98% of all carbon dioxide emissions in the United States

Figure 1. U.S. Greenhouse Gas Emissions, Actual and Projected without New Abatement Policies



Sources: Energy Information Administration 1997a, 1998b; Climate Action Report 1997.

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[2] A recent draft report by the Environmental Protection Agency (1998) indicates that N_2O emissions may have been higher in the past than previously reported, based on (continued...)

result from the combustion of fossil fuels (Energy Information Administration 1997b).[3] Although emissions of the synthetic gases, HFCs, PFCs, and SF_6, are projected to increase, they will still comprise only a small share of total U.S. greenhouse gas emissions in 2010 (Climate Action Report 1997).[4]

The pattern of emissions growth in the United States is similar to that of most other Annex I nations (see Figure 2) (Marland and Boden 1998).[5] In many cases, the emissions increases have tracked the output of these nations' economies. For example, the rapid development of Japan since World War II resulted in a large increase in carbon dioxide emissions in spite of that economy's high energy efficiency. Further, the nations of the Former Soviet Union have experienced a decline in their carbon dioxide emissions since the beginning of this decade because of the significant fall in economic output during their transitions to market economies.

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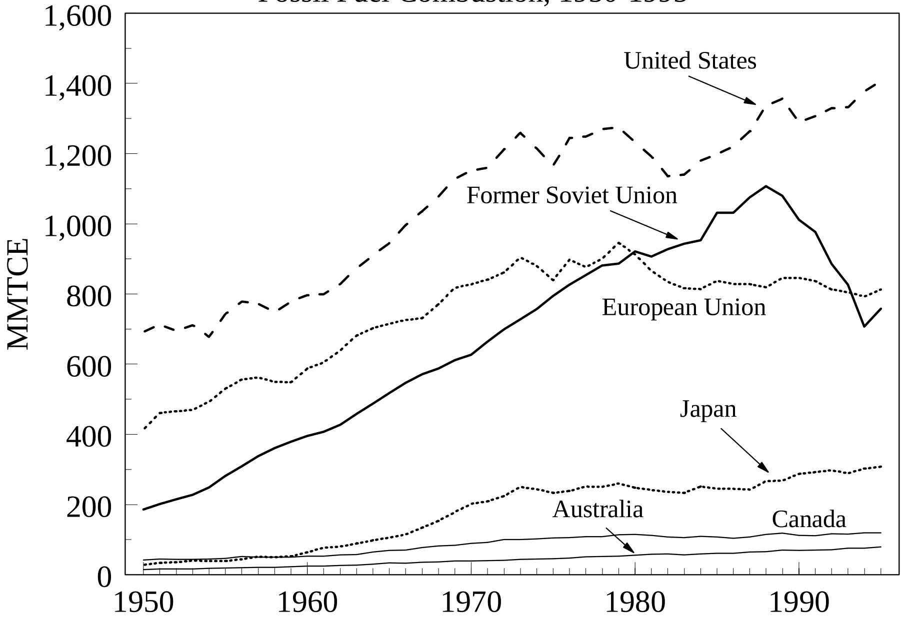
[2](...continued)
a new emissions accounting methodology. This analysis implies that future N_2O emissions may grow.

[3] Measures of carbon dioxide emissions from the Energy Information Administration and Marland and Boden (1998) do not include the effects of land use change (such as reforestation, afforestation, and deforestation) on total net emissions of carbon dioxide.

[4] Emissions of greenhouse gases are presented in terms of million metric tons of carbon equivalent (MMTCE). Carbon equivalence is based on the 100 year global warming potentials for greenhouse gases (see Table 2 for a review of global warming potentials).

[5] Annex I includes most of the world's industrial countries (see Appendix A for a description of Annex I and a list of these countries).

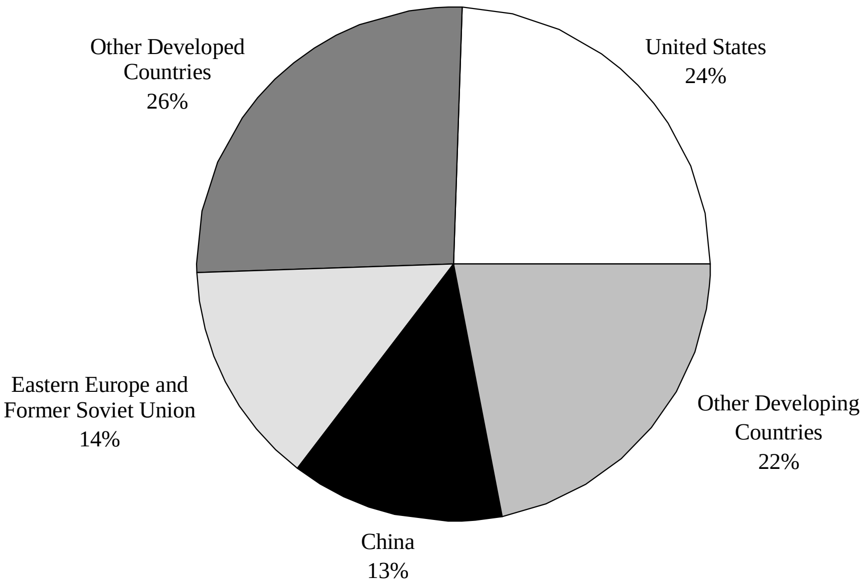
Figure 2. Major Annex I Countries' Carbon Dioxide Emissions from Fossil Fuel Combustion, 1950-1995



Source: Marland and Boden 1998.

In 1996, the industrial countries emitted a majority of the world's energy-related carbon dioxide. The United States emitted approximately 1/4 of the world's carbon dioxide from fossil fuel combustion (see Figure 3). China, the world's second largest emitter, had emissions almost equal to those of all of Eastern Europe and the Former Soviet Union. The industrial world's share of global emissions has declined over time as developing countries' economies have grown (Energy Information Administration 1998a).

Figure 3. World Carbon Dioxide Emissions from Fossil Fuel Combustion, 1996

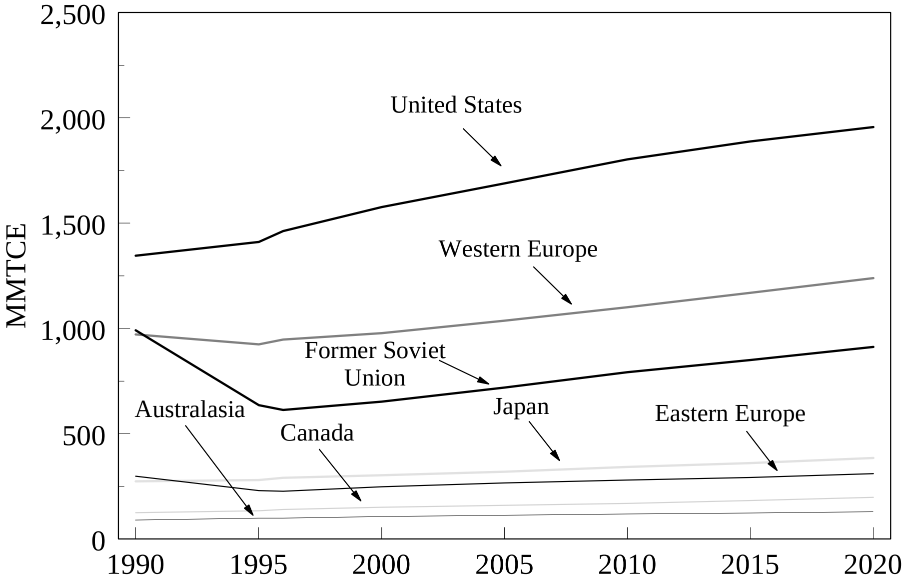


Source: Energy Information Administration 1998a.

Projected Emissions

Absent new measures to abate emissions in industrial countries, emissions of carbon dioxide will grow in all Annex I nations (see Figure 4).[6] The Energy Information Administration (1998a) projects that the United States will experience the largest absolute increase in emissions over the 1990-2020 period, while nations of the Former Soviet Union are not expected to achieve their 1990 carbon emissions level before 2020.

Figure 4. Projected Carbon Dioxide Emissions of Major Annex I Countries without New Abatement Policies



Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

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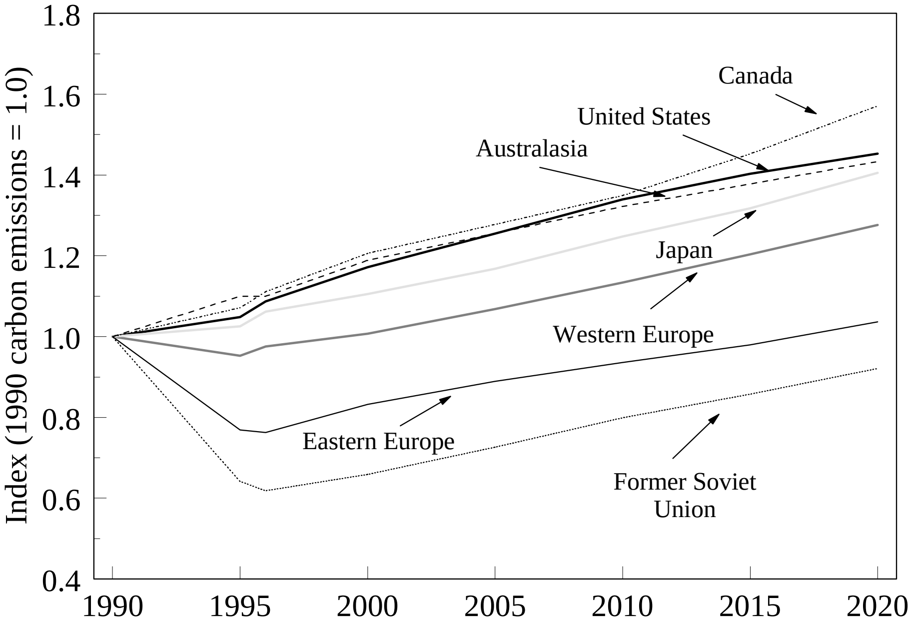
[6] The Energy Information Administration defines Australasia to include Australia, New Zealand, and U.S. Territories. Western Europe includes all of OECD Europe except for the Czech Republic, Hungary, and Poland.

The United States is projected to experience the second fastest rate of emissions growth among the major Annex I nations between 1990 and 2020 (see Figure 5). Canada is projected to experience the fastest growth rate. After declines in emissions during most of this decade, nations of the Former Soviet Union and Eastern Europe will also have comparable growth rates.

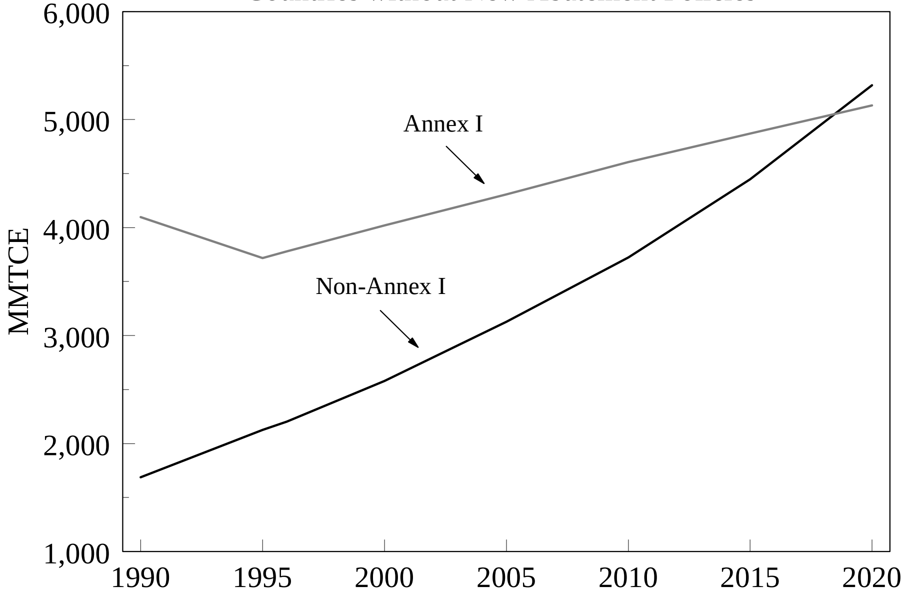
Figure 5. Projected Growth in Carbon Dioxide Emissions Among Annex I Countries without New Abatement Policies



Source: Energy Information Administration 1998a.

The Energy Information Administration (1998a) projects that Non-Annex I countries' emissions will surpass the emissions of Annex I countries between 2015 and 2020 (see Figure 6).[7]

Figure 6. Projected Emissions of Annex I and Non-Annex I Countries without New Abatement Policies

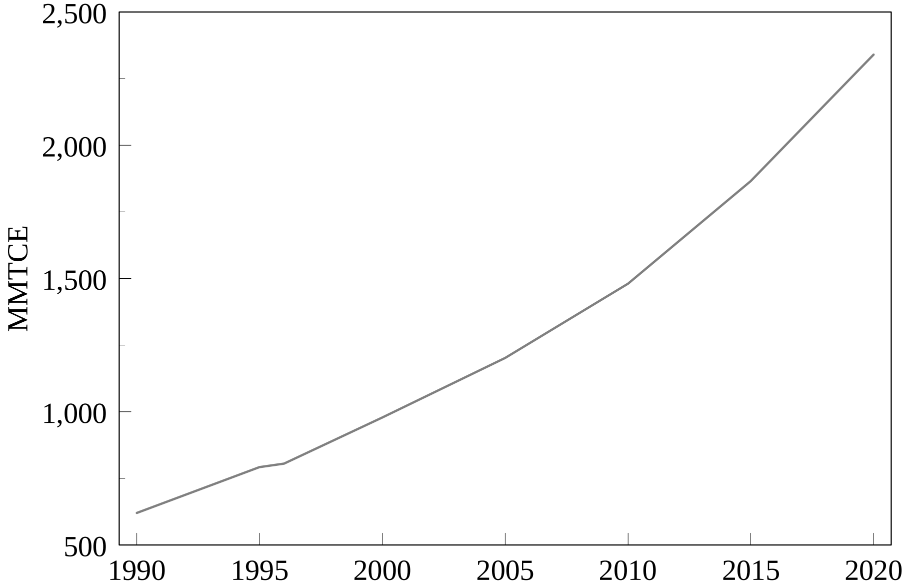


Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

[7] See Appendix A for a discussion of Annex I and Non-Annex I countries.

According to projections, China will surpass the United States as the world's largest annual emitter of carbon dioxide around 2015 (Energy Information Administration 1998a). China's emissions will surpass 2 billion metric tons between 2015 and 2020 because of its expected rapid economic growth and its reliance on its vast coal reserves (see Figure 7).

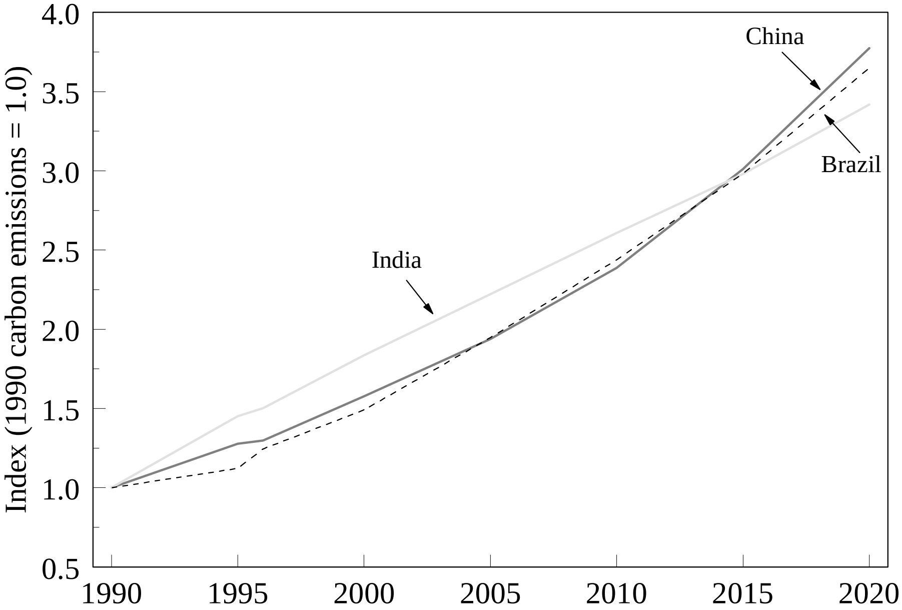
Figure 7. Projected Emissions of China without New Abatement Policies



Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

The rapid increase in Non-Annex I emissions is not solely the result of rapid emissions growth in China. The emissions of several other large developing economies are also projected to grow at nearly the same rate (Energy Information Administration 1998a; see Figure 8).[8]

Figure 8. Projected Growth in Carbon Dioxide Emissions of Several Developing Countries without New Abatement Policies



Source: Energy Information Administration 1998a.

The projected growth in emissions of carbon dioxide and other greenhouse gases can increase atmospheric concentrations of these gases, and further accelerate climate change. The next section details the risks associated with continuing along the business as usual (BAU) emissions path.

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[8] For additional country-specific energy and emissions data, refer to Appendix E.

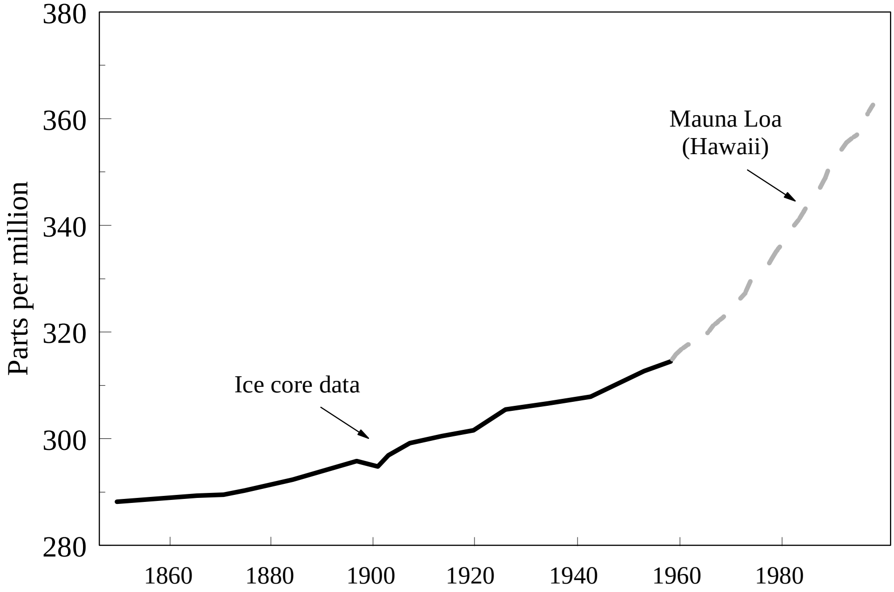
THE RISKS OF CLIMATE CHANGE

The greenhouse effect naturally warms the Earth's surface (see Figure 9). Without it, the Earth would be 60° F cooler than it is today -- uninhabitable for life as we know it. Water vapor, carbon dioxide, and other trace gases such as methane and nitrous oxide, trap solar heat by slowing the loss of heat by radiative cooling to space, thereby keeping the Earth's surface warmer than it otherwise would be.

Figure 9: The Greenhouse Effect

Since the beginning of the Industrial Era in the middle of the 19th century, the concentration of CO_2 in the atmosphere has been steadily increasing (Neftel et al. 1985, 1994; Keeling and Whorf 1997; see Figure 10). Beginning in 1958, continual measurements of atmospheric CO_2 concentrations have been made by scientists at an observatory on Mauna Loa, Hawaii (Keeling and Whorf 1997). The seasonal cycle of vegetation in Northern latitudes is evident in this record; each spring the vegetation "inhales" and absorbs CO_2, and each autumn most of that CO_2 is released back to the atmosphere. Overall, atmospheric CO_2 has increased over 30% from 280 parts per million (ppm) to over 360 ppm since 1860 (Schimel et al. 1996).

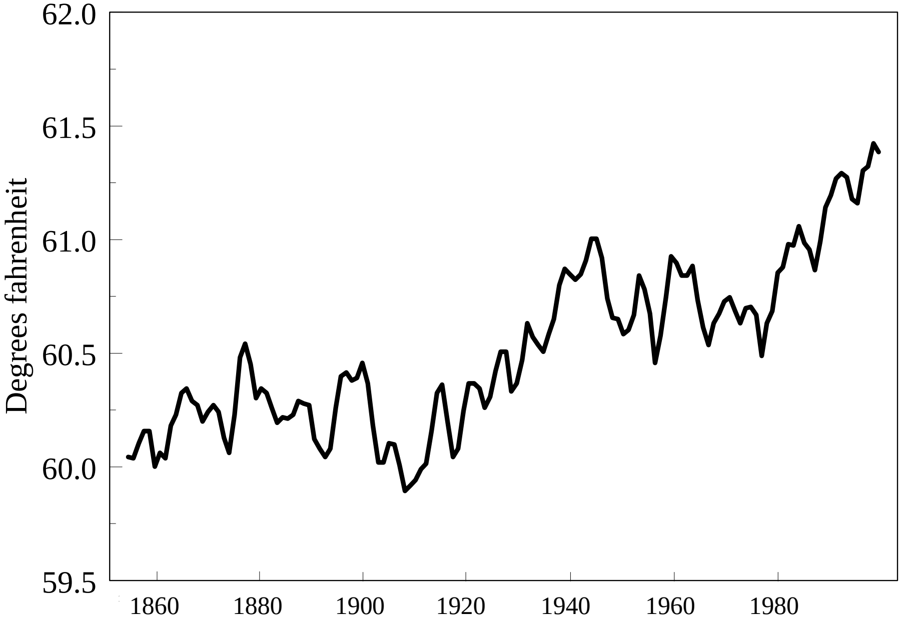
Figure 10. Atmospheric Carbon Dioxide Concentration



Sources: Neftel et al. 1985; Keeling and Whorf 1997.

Over the past century, the global average temperature has risen by approximately 1° F (Nicholls et al. 1996; Jones et al. 1998; see Figure 11).[9] Further, recent analyses have indicated that 1997 was the warmest year on record and that nine of the past eleven years have been the warmest on record (Quayle et al. 1998, Karl 1998). In addition, a recent study found that the Northern Hemisphere appears to have experienced its three warmest years since 1400 during the present decade (Mann et al. 1998).

Figure 11. Global Average Temperature



Note: Data are expressed as 3-year centered averages.
Source: Jones et al. 1998.

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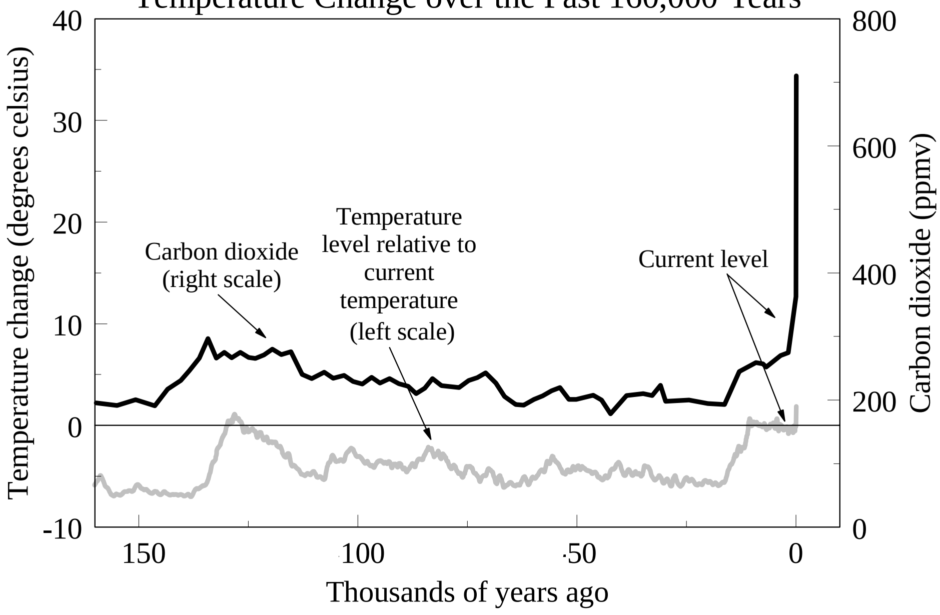
[9] The approximate 1° F temperature rise over the past century is derived from a regression analysis of the temporal data. Because the annual global average temperature is variable from year to year, it is inappropriate to simply select two years to quantify the increment. The trend or regression is a more appropriate means to calculate the century's temperature rise.

Temperature changes in recent decades bear out the close correlation between carbon dioxide concentration and temperature found in ice core data going back 160,000 years (Barnola et al. 1987, 1994). Since the beginning of the Industrial Era, the CO_2 level has increased steadily and is already outside the bounds of variability seen in the 160,000 year record (see Figure 12). Continuation of current levels of emissions is projected to raise concentrations to over 700 ppm by the year 2100, a level not experienced on Earth since about 50 million years ago. It is anticipated that if the CO_2 levels increase to this level, then the global average temperature will rise between 1.8 and 6.3° F by the year 2100 (Kattenberg et al. 1996). This range of temperature impacts was developed by the Intergovernmental Panel on Climate Change using a set of alternative plausible assumptions about climatic response to higher greenhouse gas concentrations, the effects of aerosols (such as sulfate particles) that can offset warming, and several economic parameters. In general, the temperature change experienced would be greater at higher latitudes than at lower latitudes, and greater over land than over the oceans (Kattenberg et al. 1996). Thus, temperature increases in much of the United States would be expected to be substantially greater than the average global increase.

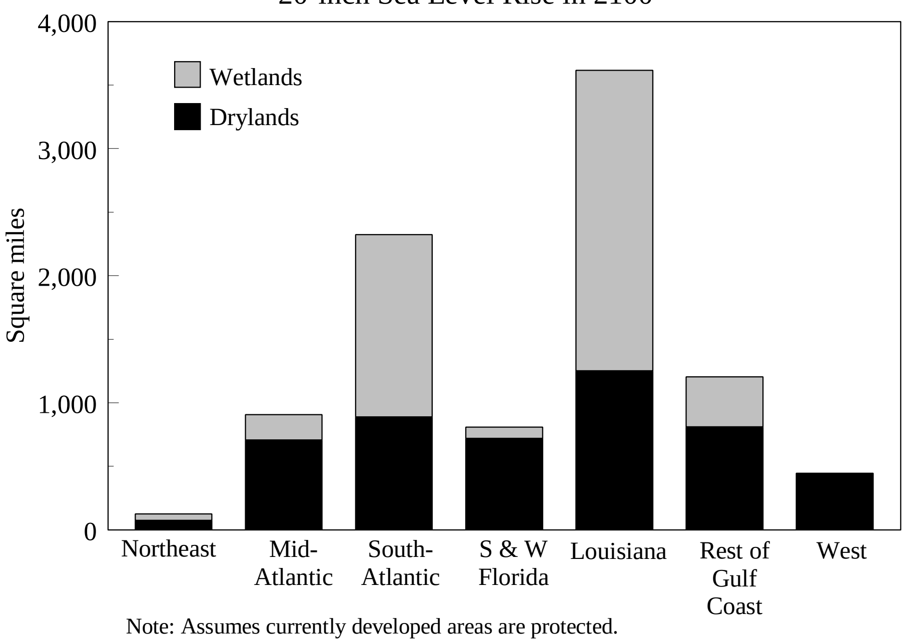
Figure 12. Atmospheric Carbon Dioxide Concentration and Temperature Change over the Past 160,000 Years



Sources: Barnola et al. 1994; Chapellaz and Jouzel 1992.

Global warming of the magnitude projected by the IPCC will have many effects due to changes in local temperature and precipitation patterns, an induced rise in sea level, and altered distribution of freshwater supplies. By 2100, sea level is expected to rise by 6 to 37 inches (Warrick et al. 1996). An average 20-inch sea level rise would result in substantial loss of coastal land in the United States especially along the southern Atlantic and Gulf Coasts, which are currently subsiding and are particularly vulnerable (Titus et al. 1991; Smith and Tirpak 1989; see Figure 13). Even if greenhouse gas concentrations were stabilized at about 560 ppm (double the pre-industrial concentration) within the next century, the sea level would continue to rise for several centuries because of the large inertia in the coupled ocean-atmosphere-climate system (Warrick et al. 1996). If the carbon dioxide concentration were to increase 1% per year until it reached approximately 560 ppm, and then were to stabilize, the sea level would continue to rise from thermal expansion alone (Manabe and Stouffer 1993, 1994).

Figure 13. U.S. Coastal Lands at Risk from a 20-inch Sea Level Rise in 2100



Note: Assumes currently developed areas are protected.
Source: Titus et al. 1991.

The effects of the global climate system described above do not include potential non-linearities in the relationships between greenhouse gas concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions among greenhouse gas emissions, the climate, and the economy. Three possibilities serve as illustrations. Warming of Northern tundra might release large amounts of methane from the subarctic permafrost, thereby acting as a positive feedback on the climate, leading to potentially devastating acceleration of an otherwise controllable global warming process (Nisbet and Ingham 1995). Second, evidence from the historic record suggests that some types of climate change might lead to abrupt changes in ocean currents, including displacement of the currents that warm Western Europe. Evidence from ocean core samples suggests such changes of ocean currents have occurred in previous ice ages (Broeker 1997). Third, warming might cause accelerated melting of the Antarctic ice sheet causing even more substantial increases in sea levels (Rott et al. 1996; Vaughan and Doake 1996). These potential nonlinearities strengthen the argument for taking prompt, reasonable steps to mitigate climate change.

OVERVIEW OF U.S. STRATEGY IN KYOTO NEGOTIATIONS AND BEYOND

The United States entered the negotiations, held December 1-11, 1997 in Kyoto, Japan, with three primary objectives. First, the agreement should include realistic targets and timetables for reducing greenhouse gas emissions among the world's major industrial nations. Second, the agreement should include an array of flexible, market-based approaches for reducing emissions. Third, the agreement should include meaningful participation of key developing countries. At the close of the Kyoto Conference, the Parties to the United Nations Framework Convention on Climate Change agreed to a Protocol to harness the forces of the global marketplace to reduce greenhouse gas emissions that reflected the first two of our objectives, and made an important down payment on the third objective.

The United States will continue its efforts to promote meaningful participation of key developing countries in bilateral and multilateral venues. In addition, the Administration will work with the other parties to the Protocol to develop rules for some of the important provisions in the agreement, including those related to international emissions trading, the Clean Development Mechanism, and carbon sinks. The Administration is working hard to make Kyoto a reality, to ensure that its critical flexibility mechanisms get up and running, and that its coverage becomes global. The following discussion details the Administration's three negotiating objectives, and their economic importance.

Realistic Targets and Timetables

The United States was committed to achieving realistic targets and timetables among developed countries that would represent a credible step in slowing the accumulation of greenhouse gases in the atmosphere, yet be measured enough to ensure continued economic prosperity. The specific limits adopted in the Protocol vary across countries, although those for the countries with the wealthiest economies are similar (see Table 1).

Table 1. Selected Annex I Countries' Emissions Targets

Country	**Emissions Target over 2008 to 2012**[10]
European Union	1990 minus 8%
United States	1990 minus 7%[11]
Japan	1990 minus 6%
Canada	1990 minus 6%
Russian Federation	1990 stabilization
Annex I Average	1990 minus 5.2%

Source: Kyoto Protocol, Annex B

Flexibility and Market Mechanisms

The ultimate economic cost to the United States and other countries of meeting the Kyoto Protocol targets depends critically on whether emissions reductions are pursued in a cost-effective manner. For this reason, the United States insisted that

[10] The 1990 base year actually refers to the 1990 levels for carbon dioxide, methane, and nitrous oxide and the choice of 1990 or 1995 levels for the three categories of synthetic greenhouse gases (Kyoto Protocol, Articles 3.1, 3.8). For some countries, their calculated "1990" target may thus be a hybrid of 1990 and 1995 emissions.

[11] The accounting system used in the Kyoto Protocol is different from the one used in the President's October 1997 proposal. As a result, the United States' Kyoto target represents emissions reductions no more than 3% greater than the President's October proposal (not 7%, as would appear from a surface comparison). First, the Protocol allows countries to use a 1995 baseline for the three types of synthetic gases, instead of the 1990 baseline used in the President's proposal. U.S. emissions of these gases were about 13 MMTCE higher in 1995 than in 1990 (Climate Action Report 1997). The change to a 1995 baseline for these gases implies that the Kyoto target is roughly equal to 1990 emissions minus 6%. Further, the Kyoto Protocol does not include carbon sinks in the calculation of the 1990 baseline, although certain carbon sinks will count toward meeting our 2008-2012 commitment. The omission of sinks from the Kyoto baseline changes the United States' target by about 50 MMTCE (about 3%) in comparison with the President's proposal (derived from Joyce 1995). Further, if U.S. forestry activities covered by the Protocol result in net carbon sequestration, the target will be still easier to attain.

the Protocol include flexible, market-based provisions designed to permit our environmental objectives to be accomplished at least cost. The mechanisms would do this by establishing an international market value for emissions reductions. This will create incentives for the reductions to be made in a manner that does not waste resources or impose avoidable costs on our people or industries.

The nature of the climate change problem suggests that flexibility and market mechanisms can substantially lower costs of achieving given levels of environmental protection. Indeed, 2,500 economists from academia, industry, and government stated in a letter signed last year advocating action on climate change that:

> "Economic studies have found that there are many potential policies to reduce greenhouse gas emissions for which the total benefits outweigh the total costs.... The most efficient approach to slowing climate change is through market-based policies" (Economists' Statement on Climate Change 1997).

The market mechanisms used to lower costs can be characterized in terms of three categories of flexibility: (1) "when" flexibility; (2) "what" flexibility; and (3) "where" flexibility, which may be the most important of all. Such methods have long been championed by economists interested in increasing the efficiency of environmental protection, as well as by those environmentalists interested in maximizing the environmental benefits of a given investment.

"When" Flexibility (Timing)

The freedom to delay or accelerate reductions within an agreed upon time frame -- while ensuring the credibility of emissions reductions -- can lower costs.

The Kyoto Protocol incorporates this principle of "when" flexibility in four ways:

- First, the period over which the initial emissions reductions occur begins and ends in a more realistic time frame than what had been proposed by many other countries. By adopting a gradual and credible path of reductions in the early years, adjustment costs can be greatly reduced while attaining the same ultimate environmental goals.

- Second, under the Kyoto Protocol, the emissions target is not stated in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012) (Kyoto Protocol, Article 3.1). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. Averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.

- Third, there is allowance for "banking" emission reductions within the 2008-2012 commitment period for use in a subsequent commitment period, although the emission targets of the subsequent periods have not yet been specified (Kyoto Protocol, Article 3.13).

- Fourth, Clean Development Mechanism (CDM) credits achieved between 2000 and 2007 can be banked for use in the first or subsequent commitment periods (Kyoto Protocol, Articles 12.10, 3.13).

"What" Flexibility (Gases and Sinks)

"What" flexibility relates to the form the emissions reductions take and is available across two dimensions. The first is the inclusion in the agreement of all six types of greenhouse gases (Kyoto Protocol, Annex A). Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Reductions in emissions of one gas can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects using IPCC conversion factors for all greenhouse gases, based on their global warming potentials (see Table 2). The Kyoto Protocol stipulates that countries with binding targets are to reduce their *total* greenhouse gas emissions by certain percentages (Kyoto Protocol, Article 3.1), but does not require specific reductions for specific gases. For instance, the global warming potential per unit mass of sulfur hexafluoride is about 24,000 times greater over 100 years than CO_2, suggesting that it might be cheaper to achieve the same environmental benefit by eliminating one ton of SF_6 rather than 24,000 tons of CO_2.

The second dimension of "what" flexibility is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. Certain kinds of sinks, in particular afforestation and reforestation net of deforestation, will be used to attain the target by offsetting emissions. Promoting afforestation and reforestation may reduce atmospheric concentrations of CO_2 at much lower costs than reducing emissions of greenhouse gases resulting from industrial activity. In addition, other carbon sinks, such as agricultural soils, could be added to the list of sink activities in the future (Kyoto Protocol, Article 3.4).

Table 2. Global Warming Potentials of Greenhouse Gases Included in the Kyoto Protocol

Chemical/Species	**Chemical Formula**	**Global Warming Potential (100 year time horizon; carbon equivalence) per unit mass**
Carbon Dioxide	CO_2	0.27
Methane	CH_4	6
Nitrous Oxide	N_2O	85
HFC-23	CHF_3	3,191
HFC-32	CH_2F_2	177
HFC-41	CH_3F	41
HFC-43-10mee	$C_5H_2F_{10}$	355
HFC-125	C_2HF_5	764
HFC-134	$C_2H_2F_4$	273
HFC-134a	CH_2FCF_3	355
HFC-152a	$C_2H_4F_2$	38
HFC-143	$C_2H_3F_3$	82
HFC-143a	$C_2H_3F_3$	1,036
HFC-227ea	C_3HF_7	791
HFC-236fa	$C_3H_2F_6$	1,718
HFC-245ca	$C_3H_3F_5$	153
Sulfur hexafluoride	SF_6	6,518
Perfluoromethane	CF_4	1,773
Perfluoroethane	C_2F_6	2,509
Perfluoropropane	C_3F_8	1,909
Perfluorobutane	C_4F_{10}	1,909
Perfluorocyclobutane	$c\text{-}C_4F_8$	2,373
Perfluoropentane	C_5F_{12}	2,045
Perfluorohexane	C_6F_{14}	2,018

Source: Houghton et al. 1996, p. 22 and adjusted based on carbon content of CO_2.

"Where" Flexibility (International)

Greenhouse gas emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto Protocol includes three important cost-saving provisions of this nature.

- First, it provides for countries that take on binding targets -- at present the industrial countries -- to trade greenhouse gas emissions allowances with each other (Kyoto Protocol, Article 17, initially referred to as Article 16bis). This market in emissions allowances could ensure that emissions reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- thus lowering costs without diminishing the level of environmental protection. It is worth noting that regardless of where the reductions take place, countries and their people will bear the cost of ensuring reductions sufficient to meet their specific Kyoto targets, while everyone will enjoy the environmental benefits.

- Second, the agreement provides for joint implementation by Annex I countries (Kyoto Protocol, Article 6). Thus if some industrial countries do not develop programs to trade allowances internationally, U.S. firms could nonetheless implement projects in those countries for which they could receive emissions reduction credits in the United States.

- Third, the agreement allows industrial countries or firms in those countries, through the Clean Development Mechanism, to invest in "clean development" projects in the developing world and use certified emissions reductions from these projects toward meeting their targets (Kyoto Protocol, Article 12). Investment in these kinds of projects would promote sustainable development in developing countries. Many such clean development projects may be quite inexpensive, measured in terms of the cost per ton of emissions avoided, as has been illustrated by the U.S. joint implementation pilot program. The low cost implies that both developing countries and industrial countries could benefit through these clean development efforts.

Opportunities for Cost-Savings through International Trade in Emissions Allowances

One of the primary principles of classical and neoclassical economics is that trade can make the participating parties better off. In the case of reducing greenhouse gas emissions, trade in emissions allowances could reduce the costs of firms and/or countries with higher abatement costs because they can choose to pay low-cost abaters to further reduce their emissions. Similarly, countries with lower abatement costs are better off by participating in international emissions markets because of the net income they can earn by selling emissions allowances abroad. This is no different from high-cost producers of any good wanting to buy at lower world market prices from willing exporters. If a firm finds it relatively costly to "produce" an emissions reduction, it may find it economically advantageous to purchase emissions from low-cost "producers". An international market for emissions also would create incentives for high-cost producers to innovate and find ways to become low-cost producers, and thus sellers of emissions. A wide range of both formal and anecdotal evidence shows that the flexibility mechanisms, particularly trade in emissions, would allow the world to achieve global emissions reductions at substantially reduced cost. Given the magnitude of the reductions necessary, an effective trading system would be needed to achieve our environmental goals while minimizing the cost and disruption to our people and firms.

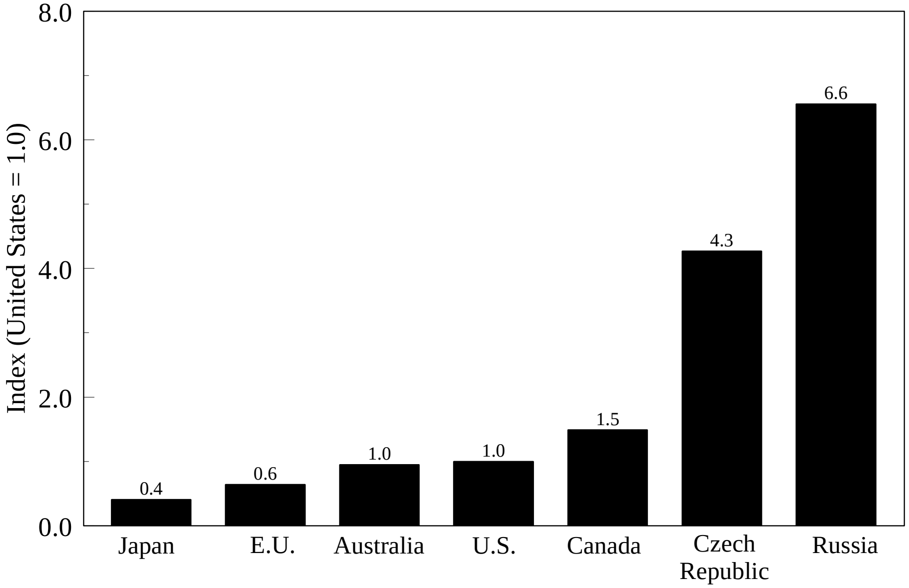
The benefits of achieving emissions reductions targets through international trading have been evaluated by numerous economists in the energy modeling community. Barrett (1992), for example, found that stabilizing emissions country-by-country could cost the European Union (E.U.) 50 times as much as stabilizing emissions for the E.U. as a whole. OECD's GREEN model shows that the costs of abatement vary among regions of the globe with comparable emissions targets by a factor of 10 (Burniaux et al. 1992). GREEN also indicates that allowing trade among regions would lower worldwide compliance costs by a factor of two.

The Stanford Energy Modeling Forum (EMF) conducts exercises with a set of energy-economic models to assess hypothetical energy policy scenarios. In the EMF-14 exercise, six models assessed two emissions pathways over the next 100+ years to achieve a 550 ppm carbon dioxide concentration target. For these two emissions pathways, the models calculated the economic costs of reducing emissions with and without international trading. While the magnitude of the cost-savings varied across models, the finding that trading reduces costs among the group of trading partners was very robust. In the six models included in the EMF exercise, international trading reduced the cost of meeting the global emissions targets by nearly 60% (Weyant 1997).

In addition to the results of formal economic models, several key descriptive statistics also clearly illustrate the opportunities for economic gains from the trade of emissions allowances. For example, several Annex I countries have higher energy-to-GDP ratios than the United States (see Figure 14). Since these countries are less energy efficient than the United States, they present potentially attractive opportunities for U.S. firms to engage in trading and joint implementation projects, thereby securing reductions at relatively lower cost than might be available in the United States.

Several other Annex I countries, including Japan and the European Union are, on average, more energy efficient than the United States. These countries may find it relatively more expensive than U.S. firms to reduce carbon dioxide emissions domestically because they have already "squeezed out" most of the inexpensive improvements in energy efficiency.

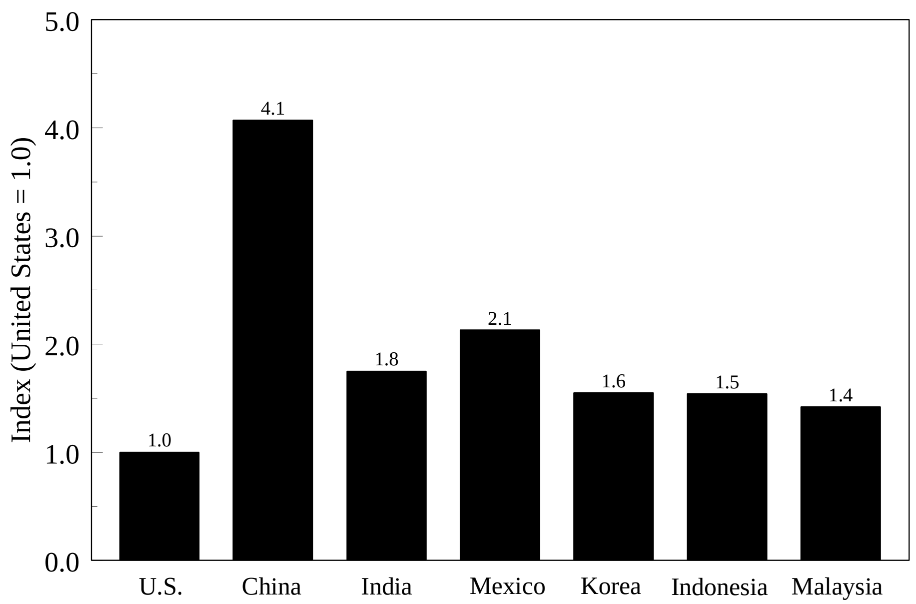
Figure 14. 1995 Energy/GDP Ratios for the U.S. and Several Other Annex I Countries



Source: Energy Information Administration 1997c.

Many large Non-Annex I countries also have much higher energy-to-GDP ratios than the United States (see Figure 15). A system of international emissions trading would provide the economic incentive for these countries to accelerate their transition to an energy efficient and carbon-lean economy. The very high energy intensity of many Non-Annex I countries suggests that many investments in energy efficiency would quickly pay for themselves, yielding negative-cost reductions. These low-cost opportunities could provide alternative options for U.S. firms to reduce emissions inexpensively through the Clean Development Mechanism, and, if developing countries adopted emissions targets, through international emissions trading. The Clean Development Mechanism and international trading would benefit both the industrial countries and the developing countries. For example, Chinese coal-fired boilers are about 25 percent less efficient than the norm for industrialized countries. If China's industrial boilers achieved typical international efficiency levels, then carbon emissions from these boilers would fall 15 to 20 percent and China's total emissions could fall by 5 percent (The World Bank 1996). A recent World Bank study concluded that China could reduce its coal consumption by 20 percent by adopting best practice technology in their power and industrial sectors (The World Bank 1997a). If China adopted a growth emissions target and undertook sensible "no regrets" actions to achieve these emissions reductions, they would make their economy better off even before they gain the benefits from selling their excess emissions in the international trading market.

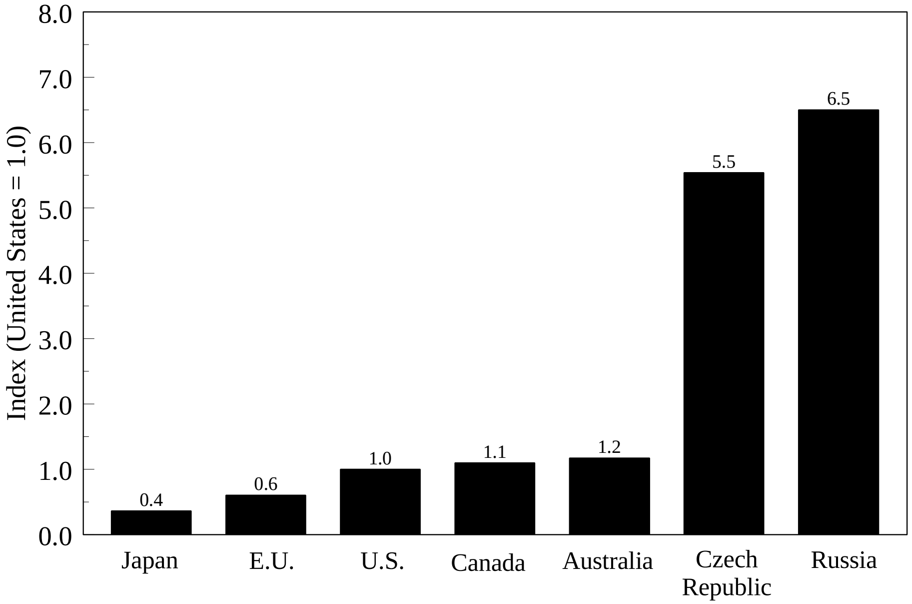
Figure 15. 1995 Energy/GDP Ratios for the U.S. and Several Developing Countries



Source: Energy Information Administration 1997c.

Similar to cross country comparisons of energy/GDP ratios, international comparisons of carbon dioxide emissions per unit of GDP provide insights on the opportunities for gains from trade. Countries vary by nearly two orders of magnitude in emissions of energy-related carbon dioxide per unit of GDP. At the low end are the poorest countries of sub-Saharan Africa: Rwanda, Burundi, Mali, and Chad. These are pre-industrial economies that still rely primarily on animal and human power supplemented by wood and crop wastes rather than commercial fuels and their energy markets are underdeveloped. The OECD countries lie in the middle of this range. Within the OECD, countries with low population density, an abundance of fossil fuels, a cold climate, or large average dwelling size use more energy per unit of GDP. Thus, Canada, Australia, and the United States are among the most carbon intensive in the OECD. Industrial countries undergoing an economic transition away from central planning are more carbon-intensive than most OECD countries. For every unit of output in Russia, more than six times the carbon is emitted than for the same amount of economic output in the United States (see Figure 16). These very high ratios in the former Soviet bloc countries are in part a result of the economic inefficiencies of central planning, including artificially low prices for coal and other fossil fuels, which in some cases still remain today.

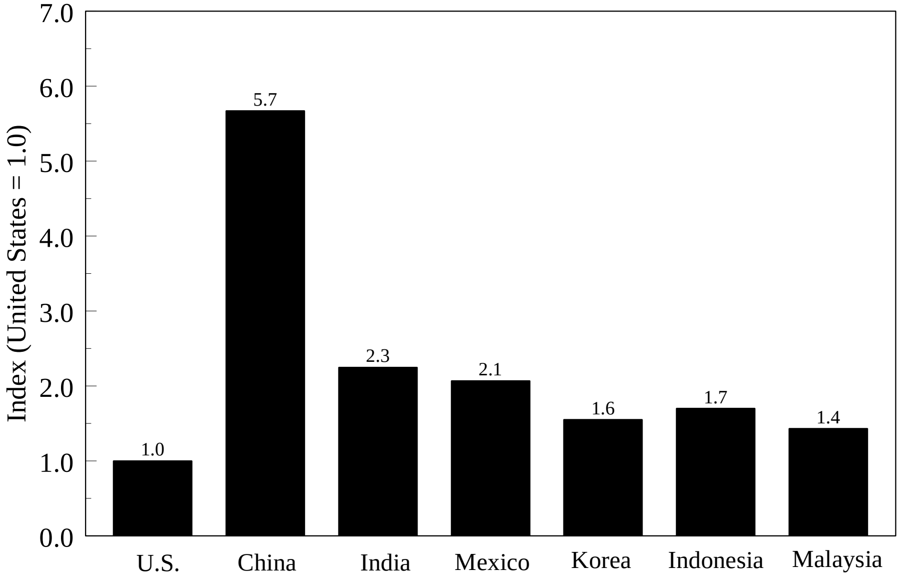
Figure 16. 1995 Carbon/GDP Ratios for the U.S. and Several Other Annex I Countries



Source: Energy Information Administration 1997c.

China's economy is also carbon-intensive, primarily because of its reliance on coal for electricity generation. Other countries with high carbon emissions per unit of GDP include India, Indonesia, and Mexico (see Figure 17). All these countries are in the middle stages of industrialization, and most have large coal or oil reserves.

Figure 17. 1995 Carbon/GDP Ratios for the U.S. and Several Developing Countries



Source: Energy Information Administration 1997c.

Making International Trading Work

Since the agreement in Kyoto, there have been several events signaling interest in transforming the concept of international trading into a practical, workable system. An early carbon emissions trade between two North American firms, a private sector proposal for an E.U. trading system, and cooperation among the Group of Eight countries illustrate this interest.

In March of this year, Niagara Mohawk Power of New York agreed to sell Suncor Energy of Canada 100,000 metric tons of greenhouse gas emissions reductions, with an option for up to 10 million tons over a 10-year period. The value for this agreement could potentially reach about $6 million. Niagara Mohawk plans to use some of the proceeds of the sale to undertake measures to reduce greenhouse gas emissions, such as improving power plant performance and energy efficiency and developing renewable energy resources. Suncor Energy will secure emissions reductions at a lower cost than what it would have to pay to achieve the same reductions through measures at their own facilities. A third party, the non-profit Environmental Resources Trust, will document the emissions reductions to be undertaken by Niagara Mohawk.

In May, the International Petroleum Exchange (IPE) of London submitted a proposal to establish a market in carbon dioxide emissions to the European Commission. The proposal calls for developing an emissions market in the United Kingdom and then expanding it throughout the European Union. The IPE recommends that free markets be allowed to evolve and anticipates that a bilateral over-the-counter market and a futures market would likely evolve. A tracking system for emissions permits would be designed, and the IPE would play a role in accounting for emissions data and reconciling trades. In terms of the nature of the tradable permit, this proposal recommends that permits be denominated in units of carbon dioxide emissions, where emissions would be calculated from the quantity of carbon-based fuels used.

Also in May, the G-8 Summit in Birmingham, England yielded an agreement to work cooperatively on international trading, other flexibility mechanisms, and developing country participation. The Final Communique of the Summit noted that the G-8 countries “aim to draw up rules and principles that will ensure an enforceable, accountable, verifiable, open and transparent trading system.” Continued cooperation among these countries could result in rules that would serve as the foundation for effective private sector trading in greenhouse gas emissions.

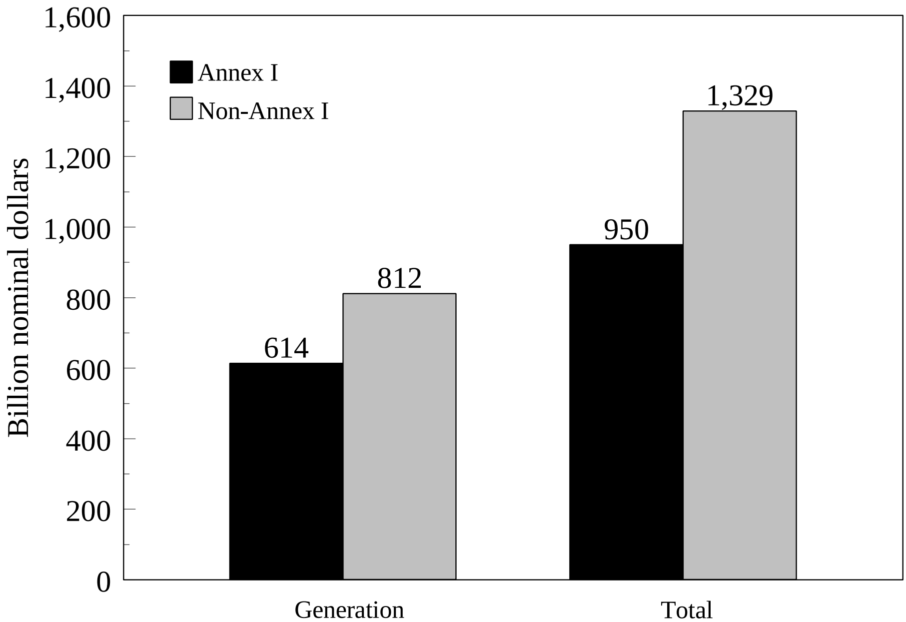
High Rates of Growth and Investment

Because of their high growth rates, developing countries have greater opportunities than the OECD to reduce emissions relative to baseline projections by installing new, carbon-efficient plants and adopting other new technologies. In contrast to retrofitting existing plants, new investment in carbon-efficient plants is a less costly approach to abate emissions.

Non-Annex I countries accounted for only 18 percent of world GDP in 1994 -- and only $790 in GDP per capita, compared to $12,200 for Annex I (Panayotou and Sachs 1998). At the same time Non-Annex I GDP grew at 5 percent annually (1990 to 1994), compared to 1.2 percent for Annex I. This has important implications for abatement opportunities.

Although Annex I countries still have, as a group, much higher economic output than Non-Annex I countries, the faster economic growth in Non-Annex I countries implies higher rates of investment. For example, investments in electric power generation are projected to be greater in Non-Annex I than in Annex I through 2010 (Energy Information Administration 1998a; see Figure 18). Many of these Non-Annex I investment projects are likely to increase total generation, while a larger share of Annex I investments will likely replace existing power plants. When a power company in an OECD country considers building a new plant to replace a plant that is not near the end of its useful life, it weighs the total cost of building a new natural gas plant against the variable cost of continuing to operate its existing coal plant. Unless coal prices jump, or the existing plant is in poor repair, only a large rise in coal prices will justify scrapping the old coal plant. In contrast, when a power company considers building a new plant in a developing country it weighs the total cost of building a new natural gas plant against the total cost of building a new coal plant. Here, a small rise in coal prices would be sufficient to justify the decision to build a gas plant.

Figure 18. Cumulative Projected Electric Power Investments, 1995-2010



Source: Energy Information Administration 1998a.

Market Distortions

Eliminating energy subsidies

Many developing countries and economies in transition continue to subsidize energy consumption. Elimination of such subsidies would represent opportunities to reduce government outlays and possibly taxes, while at the same time reducing carbon emissions and enhancing energy efficiency. Reduced reliance on fossil fuels would also reduce local air pollution, to the benefit of local public health and the local environment.

- Over 1995-1996, fossil fuel subsidy rates were 31 percent in Russia, 20 percent in China, and 19 percent in India (The World Bank 1997b). Eliminating these subsidies would substantially improve energy efficiency.

- Removing energy subsidies in Russia, China, India, Eastern Europe, Egypt, and Mexico and other non-OECD countries could decrease carbon emissions by 10 to 12 percent by 2010 (Larsen and Shah 1995). Removing these subsidies would also reduce SO_2 and particulate emissions significantly.

Management reforms

Another important opportunity for reducing carbon emissions lies in deregulation and reform of the energy sector. Reducing transmission losses for electricity, improving power quality, and better coordinating supply and demand in electric and gas systems can reduce private costs and carbon emissions at the same time. Individual customer metering, uncommon in many developing countries and economies in transition, would reduce needless energy consumption by providing an incentive for efficient use.

Opportunities for Cost-Savings through the Clean Development Mechanism and Joint Implementation

As noted, the Clean Development Mechanism (CDM) will allow companies in industrial countries to enter into cooperative projects to reduce emissions in developing countries -- such as the construction of high-tech, environmentally sound power plants -- for the benefit of both the companies and the developing countries (Kyoto Protocol, Article 12). The companies will be able to reduce emissions at lower costs than they could at home, while companies in developing countries will be able to receive the kind of technology that can allow them to grow more sustainably. The CDM will certify and score projects. This market-based mechanism provides opportunities for U.S. companies to meet emissions targets at lower costs and increases the opportunities to export energy and environmental protection technology to the emerging markets in developing countries. The CDM would build on the growing U.S. energy efficiency and environmental protection export industry (Berg and Ferrier 1997).

Joint Implementation (JI) will allow for companies in countries with emissions targets (Annex B countries) to invest in projects that reduce greenhouse gas emissions in other Annex B countries (Kyoto Protocol, Article 6). Like the CDM, this is a voluntary program that provides companies the flexibility and the opportunities to make good business decisions that result in emissions reductions at least-cost.

The CDM and JI will likely reflect many components of the existing Activities Implemented Jointly pilot program (AIJ). Under the 1992 Framework Convention on Climate Change, the U.S. government and others have commenced projects with characteristics similar to those that might be expected through the Clean Development Mechanism and Joint Implementation.

U.S. Efforts

To implement the pilot phase of the AIJ component of the Framework Convention, the Administration initiated the U.S. Initiative on Joint Implementation (USIJI) in 1993. The USIJI program supports the development and implementation of voluntary projects between U.S. and non-U.S. partners that reduce, avoid, or sequester greenhouse gas emissions. Projects are assessed based on a set of criteria that ensures proposed projects provide greenhouse gas reduction benefits and support the development goals of the host country.

As of June 30, 1997, the USIJI program had accepted 25 project proposals in 11 countries, helping U.S. firms tap the potential outside the OECD for low-cost greenhouse gas reductions while contributing to development goals in host countries (Environmental Protection Agency 1997). These projects include fuel switching, energy efficiency improvements, renewable energy, afforestation, reforestation, and improved agricultural management. A brief summary of a sample of these projects follows.

- In the Czech Republic, the District Heating Project converted the Bynov District Heating Plant from a lignite coal burning facility to a natural gas-fired plant. In addition, a cogeneration facility for steam and electricity generation have been constructed. The project developers have estimated that this activity implemented jointly will achieve total carbon emissions reductions of about 166,000 tons of carbon equivalent (Environmental Protection Agency 1997).

- In Costa Rica, the Klinki Forestry Project arranges with farmers to plant Klinki trees and other fast-growing, high-sequestration tree species on marginal farmland and pastures. Participating farmers, who sign a 40-year contract, receive tree seedlings, technical assistance, and a cash payment. The trees yield a high-grade industrial wood, suitable for utility poles and plywood, both of which continue to store carbon. Project sponsors estimate that this project will sequester nearly 2 MMTCE over its 46 year life (Environmental Protection Agency 1997).

- In Belize, the BEL/Maya Biomass Power Generation Project involves the construction of an 18 megawatt biomass waste-to-energy facility adjacent to a sugar mill. This facility will provide power to the mill, local orange processors, and an electricity distribution firm. The biomass power plant will displace diesel oil-fired power generation, and achieve total carbon emissions reductions of 1.2 MMTCE according to project sponsors (Environmental Protection Agency 1997).

- In Russia, the Fugitive Gas Capture Project involves the capturing of fugitive methane emissions from two natural gas compressor stations. Over the approximate 25 year lifetime of this project, sponsors indicate that sealing valves at the compressor stations could reduce methane emissions by more than 7 MMTCE (Environmental Protection Agency 1997).

Several European countries have also embarked on AIJ projects (Zollinger and Dower 1996).

- In 1996, the Netherlands set aside $51 million for AIJ projects in 5 countries: Bhutan, the Czech Republic, Ecuador, Hungary, and Uganda.
- Norway funds a coal-to-gas conversion project in Poland, through the World Bank and the GEF. Norway has another AIJ project with Mexico.
- Germany has 7 AIJ projects, in the Czech Republic, Indonesia, Jordan, Latvia, Portugal, and the Russian Federation. These focus on fuel switching, energy efficiency, and renewable energy.

In addition, at least 6 other developed countries have included activities implemented jointly in their national action plans: Canada, Japan, Denmark, Finland, Iceland, and Sweden. The group of potential host countries continues to grow. Projects have been launched or proposed in 17 countries. Thirty-two projects have received approval from both host and sponsor governments (Zollinger and Dower 1996). Bolivia, all 7 countries of Central America, Chile, Pakistan, and South Africa have signed statements of their intent to launch cooperative projects with the United States.

Developing Countries

Clearly, the challenge of climate change cannot be addressed adequately unless developing countries take measures themselves to limit greenhouse gas emissions. Our third objective in the Kyoto negotiations was to secure meaningful participation by key developing countries. The Kyoto Protocol does include a down payment on developing country participation through the Clean Development Mechanism (see discussion above) and other provisions. However, developing countries will need to do more to participate meaningfully in the effort to combat global warming. The President will not submit the Kyoto Protocol to the U.S. Senate for its advice and consent unless key developing countries more fully participate in the international efforts to address climate change.

It should be noted that the term "developing country" encompasses a wide range of nations which are at various stages of industrialization and contribute differently to global emissions. Accordingly, there is no one-size-fits-all approach to measuring developing country participation. A country with a relatively high per capita GDP or one that emits a proportionally large share of global emissions should be expected to do more than one that is extremely poor or whose emissions are negligible.

Meaningful participation implies different actions for different kinds of countries. For example, a developing country could voluntarily adopt an emissions target. Many developing countries were opposed to emissions targets during the Kyoto negotiations on the grounds that such targets would slow their economic development. However, emissions targets and approaches that reflect developing countries' needs to grow could facilitate their development while lowering the global costs of achieving the objectives provided in the Kyoto Protocol.

If a developing country chooses to adopt a growth target and participates in international emissions trading, it could potentially enjoy substantial economic and environmental gains. Because developing countries can achieve emissions reductions relatively cost-effectively, they could reduce emissions below their target and sell their excess allowances to firms in other countries that find it in their best interest to comply with emissions targets at the lowest possible cost. Even with this participation, a country's emissions could continue to grow beyond current levels, as economic development continues. More importantly, such an approach provides both an incentive for firms to invest in energy efficient technologies in developing countries and the opportunity to export emissions allowances. While the Clean Development Mechanism can result in similar activity, it would likely occur on a smaller scale than what would be anticipated under an emissions target with effective international trading.

A world with broad-based participation in international emissions trading, including participation by Non-Annex I countries with growth targets slightly below their business as usual projections, would likely result in lower global greenhouse gas emissions relative to a world with more narrow participation. Moreover, reductions in greenhouse gas emissions would generate ancillary air quality benefits through reductions in sulfur dioxide, nitrogen oxides, and particulate matter emissions. In many large cities in developing countries the emissions of these air pollutants are a significant environmental health problem, and emissions reductions consistent with efforts to address climate change could assist in remedying this problem.

As noted earlier, trading, as a voluntary activity, benefits all parties involved. While developing countries may benefit from adopting a target and participating in trading, so would firms in developed countries.

ASSESSING THE COSTS AND BENEFITS OF REDUCING GREENHOUSE GAS EMISSIONS

Preliminary Assessment

The Administration employed a variety of tools to assess the various possible costs and non-climate benefits of our emissions reduction policy. Our overall conclusion is that the net costs of the Administration's policies to reduce emissions are likely to be relatively modest, assuming those reductions are undertaken in an efficient manner with effective international trading, the Clean Development Mechanism, meaningful developing country participation, and sound domestic policies. That potential small net premium, even excluding the benefits of mitigating climate change, purchases a partial insurance policy against a serious environmental threat. Further, although we think the economic benefits of mitigating climate change are subject to too many uncertainties to quantify, those benefits over time are likely to be real and large (see p. 69).

In reaching this conclusion, the Administration has drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum (Gaskins and Weyant 1993, Weyant 1997), the Intergovernmental Panel of Climate Change's review of the economic and social dimensions of climate change (Bruce et al. 1996), the work of the OECD on the economic dimensions and policy responses to global warming (OECD 1998), and the Administration's staff-level interagency analysis (Interagency Analytical Team 1997). In addition, the Administration used other tools, such as a meta-analysis (Repetto and Austin 1997), overviews of the domestic and international energy sectors (Energy Information Administration 1997a, d), simple statistics regarding energy efficiency, greenhouse gas emissions, and economic indicators from World Bank, International Energy Agency, and Energy Information Administration databases, and basic economic reasoning.

The conclusion that the impact of the Administration's policies to address the risks of climate change will be modest is not entirely dependent upon, but is fully consistent with, formal model results. The Administration continues to believe that there are limitations to relying on any single model to assess the economic impact of the Kyoto Protocol. However, model results can further inform and improve the understanding of the effects of climate change policy. To complement the economic analysis of the Administration's policy to address climate change, we have conducted an illustrative assessment with a modified version of the Second Generation Model. The results from the SGM substantiate the conclusion that the economic effects of an efficient, effective, and global policy to address the risks of climate change will be modest.

Difficulties of an Economic Analysis of Climate Change

The difficulties associated with economic analysis of climate change fall into three broad categories. First are the uncertainties that still remain over the operational considerations of the treaty, necessitating assumptions on which the analysis is predicated. Second are the inherent limitations of available models to analyze the costs of abating emissions. Third, it is extremely difficult to quantify the long-term economic benefits of climate change mitigation, although such benefits are the motivation for the Kyoto Protocol. Economists have a difficult time projecting the behavior of the economy over the next quarter or year, let alone over the next two decades. The scale of the forecasting exercise is therefore daunting, and any specific results should be treated with substantial caution.

Uncertainties in the International Effort to Combat Climate Change

The Kyoto Protocol provides the foundation for the international effort to address climate change. However, the Protocol is still a work-in-progress. Uncertainties about the ultimate characteristics of the international climate change policy regime provide challenges in conducting an economic assessment.

For example, some of the rules pertaining to the flexibility mechanisms in the Kyoto Protocol, such as emissions trading and carbon sinks, require further delineation. These issues and others, including the role of developing countries, will be addressed in future negotiations.

More importantly, the international community has not yet negotiated agreements to limit greenhouse gas emissions beyond the 2008 to 2012 window. The emissions targets established in Kyoto provide for the first of many necessary steps to address the risks of climate change. The first step is critical because it sends a signal to the private sector regarding the value of reducing greenhouse gas emissions and it begins the task of reducing emissions relative to the business as usual path. However, subsequent steps are also necessary to address climate change risks adequately. Lack of knowledge regarding what the subsequent steps will be complicates any analysis of climate change mitigation.

Inherent Limitations of Models

In addition to these uncertainties about the details of the international effort to address climate change, there are the inherent limitations of the models used to evaluate that effort. Even within a given model, answers depend critically on the precise nature of the question asked. For example, the costs of emissions reductions depend on the extent of global participation and international trading that a treaty is assumed to feature. But in addition to the dependence of the results from a given model on the precise assumptions, different models can give different answers even when all the assumptions are specified to be the same -- a concrete illustration of the range of uncertainty surrounding the predictions of any one individual model.

Benefits of Averting Climate Change

As discussed in the risks of climate change section, it is evident that the benefits of averting climate change are potentially very large. There are several difficulties associated with monetizing the benefits of averting the risks of climate change. First, there is the uncertainty relating to the specific effects of climate change (e.g., would the planet be 2 or 6 $^{\circ}$ F warmer in 2100, or some level within that range, without any measures to abate emissions). Second, the uncertainty over the extent that benefits should be discounted because they occur in the distant future presents challenges. Since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. Third, the benefits depend on global emissions paths after the 2008 to 2012 budget period specified in Kyoto. To calculate the benefits of averting climate change-induced damages, it is necessary to know the emissions path for many years beyond 2012. Thus while the benefits of getting started on the Kyoto path to reducing greenhouse gas emissions may be large over time, we cannot estimate these benefits without knowing where the path goes in the years after the Kyoto compliance period.

Illustrative Calculations: Methodology

Recognizing the difficulties inherent in an economic analysis, the Administration nonetheless undertook an examination of the economic impact on the U.S. economy of the Kyoto Protocol. Since no one model exists to handle all of the parameters of the Kyoto agreement, several tools had to be used to calculate the estimated costs of climate policy. First, the Administration constructed emissions baselines for all six types of greenhouse gases and 2010 business as usual levels for these gases for Annex I countries. These emissions estimates would serve as the basis for calculating the emissions reductions required to achieve the Kyoto targets. Second, we developed cost curves for reducing greenhouse gas emissions. For carbon dioxide, marginal abatement cost curves were derived from more than 60 model runs with the Second Generation Model. For other greenhouse gases, we used a bottom-up marginal abatement cost curve developed by the Interagency Analytical Team (1997). Third, we assessed several different trading scenarios based on the required emissions reductions and the constructed cost curves. Equalizing marginal costs across countries and regions generated a common permit price across the trading bloc. Fourth, we calculated the effects of the permit price on energy prices, energy consumption, GDP, investment, and consumption.

Construction of a 6 Gas Baseline and 2010 "Business as Usual" Baseline

To assess the potential economic impact of the Kyoto Protocol, it was first necessary to construct 1990/1995 baseline emissions and business as usual emissions paths that account for all six categories of greenhouse gases. While estimates of 1990 emissions and 2010 projected emissions for carbon dioxide are widely available for most Annex I countries and many large Non-Annex I countries, the Administration gathered data on the other greenhouse gases from more than 25 submitted National Communications to the Framework Convention on Climate Change, official reports of the Framework Convention, and Environmental Protection Agency and Department of Energy analyses. In some cases, we made extrapolations from one country to another based on common characteristics (e.g., GDP). These data provide the basis for our preliminary estimates until the parties to the Framework Convention provide more detailed information on historical and projected emissions of all six categories of greenhouse gases. With these baseline estimates, the Administration estimated the magnitude of the emissions reductions required of Annex I countries under the Protocol.

Carbon Dioxide Emissions

For projections of carbon dioxide, we used the business as usual projections in the Second Generation Model, with the exception of the United States, where we used the more recent Energy Information Administration (1997a) estimate of 2010 BAU for energy-based CO_2 and the Climate Action Report (1997) projection for non-energy-based CO_2. For the European Union, the Administration adjusted the Western Europe value in SGM to reflect the non-participation of Iceland, Norway, Switzerland, and Turkey in the E.U. bubble. Based on CO_2 emissions estimates from the Carbon Dioxide Information Analysis Center, we deducted 66.1 MMTCE from the Western Europe estimate to derive the E.U. 1990 baseline CO_2 emissions value. For 2010 BAU, 85 MMTCE were deducted from the Western Europe 2010 estimate.[12]

Emissions of Other Greenhouse Gases

For projections of the other five categories of greenhouse gases, we used information provided in the national communications to the Framework Convention on Climate Change. In some cases, 2010 emissions were extrapolated from projections of 2000 emissions levels. In addition, some projections in emissions were based on growth rates in comparable countries. For a country-by-country discussion of the emissions baselines derivations, refer to Appendix B.

Converting to Carbon Equivalence

In all cases where data are provided in tons of gas, or tons of carbon dioxide equivalent, the Administration converted the data to tons of carbon equivalent based on their 100-year time horizon global warming potential (Houghton et al. 1996; refer to Table 2). Some countries aggregated all HFCs into one value (and in some cases, all PFCs into one value). We constructed an HFC weight and a PFC weight based on specific HFC and PFC emissions in the United States in 1995. For HFCs, the following weight was used:

$$[2*GWP(HFC\text{-}134a) + GWP(HFC\text{-}23)]/3 = 1300$$

HFC-134a was 52% and HFC-23 was 21% of all U.S. HFC emissions in 1995 (Climate Action Report 1997). For PFCs, the following weight was used:

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[12] We assumed that these four non-E.U. European countries would experience the same emissions growth rate as the E.U. over the 1990-2010 period to calculate their 2010 emissions.

$$[2*GWP(CF_4) + GWP(C_6F_{14})]/3 = 1855$$

CF_4 was about 60% and PFC/PFPEs[13] were about 25% of all U.S. PFC emissions in 1995 (Climate Action Report 1997).

Carbon Sinks

The Kyoto Protocol specifies that removals of CO_2 by certain kinds of sinks count toward meeting emissions targets. Mechanisms are also provided for adding new categories of sinks. Very preliminary estimates suggest that incorporating the gains from carbon sinks throughout the world could substantially reduce the costs of meeting the Kyoto target, on top of the gains from trading among Annex I countries. Such gains could be substantial under business as usual and even larger after taking into account the additional effects of government policy. Government policy could, for example, provide an incentive to increase the activities qualifying as allowable sinks, like tree-planting. However, no model has yet tried to account for such additional effects. Because the quantitative uncertainty is so large, we do not yet have an estimate with which we are comfortable. But we expect that complete modeling of the Kyoto provision pertaining to sinks would have favorable effects on projected costs. For the analysis reported here, the Administration employed a conservative assumption that all countries' sinks equaled zero and that no country would implement policies to stimulate the creation of carbon sinks.

Kyoto Targets

The emissions targets for Annex I countries were from Annex B of the Kyoto Protocol. For Non-Annex I countries, the assumed emissions targets were equal to those countries' business as usual emissions levels in 2010.

Constructing Marginal Abatement Cost Functions

To construct marginal abatement cost functions for carbon dioxide, the Administration used model results from Battelle Laboratory's Second Generation Model (SGM). SGM is a computable general equilibrium model designed to provide

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[13] The Climate Action Report (1997) notes that "PFC/PFPEs are a proxy for many diverse PFCs and perfluoropolyethers (PFPEs), which are beginning to be used in solvent applications. Global warming potential and lifetime values are based upon C_6F_{14}" (p. 71).

estimates of the economic costs of actions to reduce carbon dioxide emissions.[14] SGM models the energy sector in greater detail than other sectors, so it can provide information on the trade-offs in the consumption of different fuels under a policy to reduce carbon dioxide emissions. It also serves the purpose of evaluating the effects of international emissions trading, because it includes twelve countries and regions (see Table 3). The capacity of the SGM model to take into account international trading is an obvious virtue of this model relative to the other two models used in the Interagency Analytical Team process, both of which only modeled the economic effects of emissions reductions in the United States. The SGM, like all models used to assess economic effects, has strengths and weaknesses. Therefore, the results from this analysis should be considered illustrative. However, the results of the Stanford EMF's investigation of the implications of international trading suggest that the conclusion that effective international trading can significantly reduce costs is robust (Weyant 1997).

Table 3. Countries/Regions in Second Generation Model

Annex I	**Non-Annex I**
United States	China
Western Europe	India
Former Soviet Union	Korea
Eastern Europe	Mexico
Japan	Rest of the World
Canada	
Australia	

Source: Second Generation Model

Abatement Cost Functions in Industrialized Countries

Drawing on results of more than 60 model runs from the SGM, the Administration developed country- and region-specific cost functions for carbon dioxide abatement by matching prices and emissions reductions in different model runs. For a given country or region, at a given emissions allowance price, the country/region reduces carbon emissions by a specified amount. Over a wide range of prices, the

[14] For more information about the Second Generation Model, refer to Edmonds et al. 1992.

relationship between the allowance price and emissions reductions can be traced out. This relationship depicts the approximate marginal abatement cost for the country or region. For the United States, we aggregated the cost functions for the non-carbon dioxide greenhouse gas emissions developed by the Interagency Analytical Team (1997) with the U.S. carbon dioxide cost function to generate a cost function for the entire basket of greenhouse gases. For all other countries and regions, we assumed the carbon dioxide cost function to hold for all six categories of greenhouse gases. Based on the pattern of U.S. abatement costs, this assumption for other countries would likely over-estimate the costs of abatement.

Abatement Cost Functions in Developing Countries

The marginal abatement cost functions for developing countries only include opportunities to reduce carbon dioxide released through energy consumption. Given that numerous options for abatement of other greenhouse gases and sequestration projects in these countries exist, these functions in fact over-estimate the costs of developing country participation.

Energy Efficiency Improvement

Energy efficiency improvements over time -- defined as the rate at which the total use of energy falls relative to GDP -- are attributable to three factors: changes in energy conservation due to price changes; the effects of non-price policy measures to improve energy efficiency (such as government support of R&D); and *autonomous* increases in energy efficiency. The first factor reflects the incentive provided by higher energy prices for firms and households to reduce energy consumption through efficiency measures and thereby make the economy as a whole more energy efficient. The second factor reflects the potential influence of a wide range of non-price public policies to improve the efficiency with which energy is used in the economy. For example, measures could be undertaken to speed the rate of diffusion and adoption of technologies which can simultaneously lower energy use and household and business energy bills. Finally, energy efficiency improvements occur over time which are independent of both prices and energy policies. For example, in the United States, the gradual transition from a manufacturing economy to a less energy-intensive service economy has improved the energy efficiency of the economy. The *autonomous energy efficiency improvement factor (AEEI)*[15] reflects only the pace of

[15] The Autonomous Energy Efficiency Improvement should be distinguished from the annual energy efficiency improvement used by some in the literature. The annual rate includes the autonomous component as well as price-induced and non-price (continued...)

efficiency improvements that are purely autonomous and thus independent of both energy prices and energy policies.

In modeling energy efficiency improvement, these three components are addressed in different ways. For the *autonomous* energy efficiency factor (AEEI), a plausible assumption is an improvement of about 1.0 percent per year. The developers of the Second Generation Model employ an AEEI of 0.96 percent per year as their default energy efficiency assumption. Similarly, the Energy Information Administration analysis (see Energy Information Administration 1997a) assumes a pace of energy efficiency improvement of 0.9 percent. In this analysis, we used the SGM default assumption concerning the autonomous energy efficiency parameter. For price-induced changes in energy efficiency, the model generates its own forecasts of changes in energy consumption that reflect the effects of greenhouse gas permit prices on energy prices.

Economists have traditionally had difficulty in modeling non-price policy-induced shifts in energy efficiency. For example, it is hard to assess the likely future pay-off from investments in energy R&D, although historical estimates of the rate of return to society from such investments are substantial. Similarly, the series of policy measures proposed by the Administration -- such as the Administration's electricity restructuring proposal, the Climate Change Technology Initiative, its voluntary sectoral initiatives, the federal sector's own energy efficiency program or other measures that could be adopted to spur the diffusion and adoption of existing technologies -- could substantially reduce the cost of mitigation and increase the amount of reductions achieved domestically. However, models like the Second Generation Model do not have the capacity to quantify these potential payoffs.

Some authorities in the field of energy policy, using an engineering approach rather than an economic paradigm, have sought to quantify the extent to which policy initiatives could spur more rapid improvements in energy efficiency. Experts at five national laboratories managed by the Department of Energy found that a third of the emissions reductions necessary to return to 1990 levels by 2010 could be achieved through the adoption of existing energy-efficiency technologies at no net resource cost. This translates into a non-price policy related efficiency contribution of 0.3% per year (Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies 1997). The National Academy of Sciences reached qualitatively similar conclusions in a 1992 report. As reflected in the Department of Energy study, if a higher rate of energy efficiency improvement were achieved, the United States could meet a correspondingly larger fraction of its commitment through domestic reductions potentially at lower permit prices.

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[15](...continued)
policy-induced components.

Trading Scenarios

Intergas Trading

We assumed that trading occurs across all gases based on 100-year global warming potential values.

Trading Blocs

The Administration assessed three different industrialized country trading blocs.

- Annex I implies trading among all Annex I countries.
- Umbrella without Eastern Europe refers to trading among a subset of Annex I countries, excluding participation by the European Union and Eastern European countries.
- Umbrella with Eastern Europe refers to trading among a subset of Annex I countries, excluding participation by the European Union.

In addition, we assessed two forms of developing country participation in conjunction with the industrial country trading blocs.

- Developing countries generate emissions credits through the Clean Development Mechanism and sell them internationally. The CDM is assumed to provide 20% of emissions reductions that a country would otherwise undertake if it agreed to a target at business as usual and participated in international trading.
- Key developing countries are assumed to adopt emissions growth targets equal to their 2010 business as usual emissions level and participate in international emissions trading.

Trading across Time

This analysis assessed the permit price in 2010, the midpoint of the first commitment period. Since SGM is a computable general equilibrium model, all outputs are predicated on the full use of the economy's resources, so the analysis implicitly assumes an averaging out of business cycles, weather induced energy use fluctuations, and other short-term phenomena. This smoothing out is consistent with the effect of the five-year averaging period between 2008 and 2012. The permit price estimates for 2010 therefore provide a reasonable representation of the average permit price over 2008-2012.

Banking

This analysis did not incorporate the banking provision in the Kyoto Protocol. To model banking behavior, it is necessary to know the emissions targets for subsequent commitment periods. Since these targets have not been established yet, any assumption about future emissions targets would be speculative.

Identifying market clearing prices for trading blocs

After developing the baselines and cost functions, we calculated the market clearing prices for the trading blocs. Market clearing prices were estimated by constructing functions for the marginal cost of abatement of greenhouse gas emissions in each trading bloc. Given the greenhouse gas emissions reductions required by the Kyoto agreement for the countries within the trading bloc, these functions allow for the identification of marginal cost of abatement, and the unique price for permits traded among the countries comprising the bloc.

Calculating the Effects on Energy Prices

Reducing greenhouse gas emissions, in particular carbon dioxide emissions, would, in effect, modestly raise energy prices. At the same time, these higher prices would have the effect of reducing energy consumption by a modest amount, as firms and households cut back on some low-value uses of energy. Tradable greenhouse gas permits would also cause some shift in the fuel mix, away from carbon-intensive fuels like coal, and toward carbon-lean and carbon-free fuels, like natural gas, nuclear, and hydropower. Households would hardly notice this fuel mix shift, however, as most of it would occur at power plants.

Summary of Assumptions of Illustrative Analysis

The following list summarizes the assumptions in the illustrative modeling analysis described in the preceding section on methodology.

- Efficient and effective domestic trading of emissions allowances.

- International trading of emissions allowances (within each of three possible blocs).
  - Efficient and effective Annex I trading.
  - Efficient and effective Umbrella trading.
  - Efficient and effective trading with developing countries that adopt emissions targets.

- Trading across all six categories of greenhouse gases.

- Autonomous energy efficiency improvement (AEEI) value of 0.96% per year.

- No banking of emissions allowances to second or later commitment periods.

- Emissions targets are expressed in terms of all six categories of greenhouse gases.

- Marginal abatement costs for carbon dioxide from SGM outputs.

- Marginal abatement costs for non-carbon dioxide greenhouse gases for U.S.

- Marginal abatement costs for non-carbon dioxide greenhouse gases for other countries assumed to be the same as the costs for carbon dioxide.

- No emissions mitigation through carbon sinks for any country included in the analysis (see p. 62).

- No emission reductions from the Administration's electricity restructuring proposal included in the analysis (see p. 64).

- No emissions reductions from the Climate Change Technology Initiative included in the analysis (see p. 64).

- No emissions reductions from industries' voluntary plans through the Administration's industry consultations included in the analysis (see p. 65).

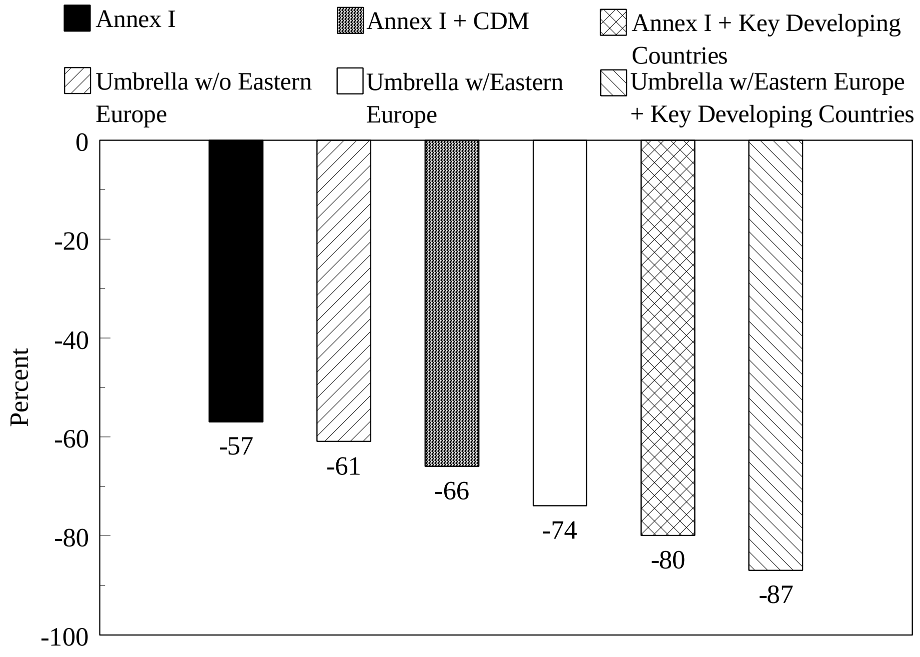
- No emissions reductions from the Federal government's energy efficiency initiative included in the analysis (see p. 66).

- No estimate of the benefits of addressing risks associated with climate change (see p. 69).

Economic Cost of the Administration's Policies to Reduce Greenhouse Gas Emissions in the Illustrative Analysis

The flexibility measures embodied in the Kyoto Protocol and the Administration's climate change approach could dramatically reduce the costs of complying with the Protocol (see Figure 19 and Table 4.) An effective international market for trading emissions permits among industrialized countries -- even without taking into account the added benefit of including key developing countries -- would potentially lower the resource cost to the United States of climate change policy by more than half relative to a scenario in which all abatement is performed domestically and would lower the price for emission permits (expressed as carbon equivalent) by nearly three

Figure 19. Percentage Reductions in Resource Costs Relative to "Domestic Only" Abatement Under Various Trading Scenarios



fourths.[16] If international trading took place only among "umbrella countries" (Annex I except for, in one scenario, the European Union, and, in another scenario, the European Union and Eastern Europe) resource costs could drop by 60-75% as compared to the domestic only cost, while permit prices could drop by 75-85% compared to a "domestic only" approach. Trading among industrialized countries alone could bring costs down into a relatively modest range.

An effective Clean Development Mechanism combined with industrialized country trading could reduce resource costs by two-thirds to four-fifths and could lower permit prices 79 - 88% compared to a domestic only approach. Finally, if some developing countries adopt growth emissions targets and participate in an effective trading system, the total resource cost to the United States could fall by 80 - 87% compared to a domestic only approach, while permit prices could sink by 88 - 93% compared to a domestic only effort.

Table 4. Permit Prices and Resource Costs Relative to "Domestic Only" Abatement of Various Trading Scenarios

Trading Scenario	Percent Reduction in Permit Price (relative to domestic only)	Percent Reduction in Resource Cost (relative to domestic only)
Annex I	72%	57%
Umbrella (with Eastern Europe)	85%	74%
Umbrella (without Eastern Europe)	75%	61%
Annex I + Key Developing Countries	88%	80%
Umbrella (with Eastern Europe) + Key Developing Countries	93%	87%
Umbrella (without Eastern Europe) + Key Developing Countries	91%	83%
Annex I + CDM	79%	66%
Umbrella (with Eastern Europe) + CDM	88%	80%
Umbrella (without Eastern Europe) + CDM	82%	71%

16 "Resource cost" refers to the direct cost to the U.S. economy of meeting its Kyoto target measured as the cost of emissions abated domestically plus the cost of purchases of international emissions allowances and emissions credits by U.S. firms. "Permit price" refers to the price paid for a permit to emit one metric ton of carbon equivalent. The permit price can be translated readily into an added increment for U.S. energy prices. See, for example, Table 6.

The Administration supports effective international trading and meaningful participation by key developing countries. An assessment using the SGM model that accounts for effective trading and developing country participation yields permit price estimates ranging between $14/ton and $23/ton, and resource costs between $7 billion and $12 billion/year (see Table 5). The range reflects uncertainty about the extent of Annex I participation in international trading.

Table 5. U.S. Permit Prices and Resource Costs Under the Administration's Policies

Trading Scenario	**Permit Price**	**Total Resource Cost**	**Share of 2010 GDP**
Umbrella with Eastern Europe + key developing country participation	$14/ton	$7 billion/year	0.07%
Annex I + key developing country participation	$23/ton	$12 billion/year	0.11%

The illustrative modeling analysis does not account for several key components of the Kyoto Protocol and the Administration's policies to reduce greenhouse gas emissions. These key issues include the benefits of reducing net emissions through carbon sinks, the Administration's electricity restructuring proposal, the Administration's Climate Change Technology Initiative, the Administration's sectoral consultations to encourage and support voluntary efforts by U.S. industry to undertake emissions reductions, including the provision of credit for early action, and the Administration's efforts to reduce federal energy use. Each of these factors has the potential to significantly increase the amount of reductions made domestically, while lowering the level of permit prices. The model estimates do incorporate the effects of higher energy prices on energy efficiency: results reflect annual rates of energy efficiency improvement of 1.10 - 1.21%, where 0.96% per year is the autonomous energy efficiency improvement and 0.14 - 0.25% is the price-induced energy efficiency improvement. However, any additional payoffs from the CCTI or electricity restructuring are not included in this range. The illustrative model also does not account for ancillary benefits of reducing greenhouse gas emissions, such as improved local air quality, nor does it account for the benefits of averting the risks of climate change (see pp. 66, 69). For a discussion of these cost mitigating factors, see page 62.

U.S. Energy Prices

Under the assumptions of the Administration's analysis, permit prices in the range of $14/ton to $23/ton translate into energy price increases at the household level between 3 and 5%. As Table 6 illustrates, the price increases for electricity and an array of fuels would be modest, and in several cases, the prices faced by consumers, even under the $23/ton permit price, would be lower in real terms than prices experienced today (see Appendix D for long-term energy price trends). By 2010, the increase in energy cost for the average household expected with permit prices between $14/ton and $23/ton would range between $70 and $110 annually, but this would be roughly offset by cost-savings associated with the Administration's electricity restructuring proposal.

Table 6. U.S. Energy Prices Under Permit Prices of $14/ton to $23/ton

Energy Source	**1996 Price**	**2010 BAU Price**	**2010, $14/ton**	**2010, $23/ton**
Electricity	6.9¢/Kwh	5.9¢/Kwh	6.1¢/Kwh	6.2¢/Kwh
Gasoline	$1.225/gallon	$1.259/gallon	$1.293/gallon	$1.314/gallon
Fuel Oil	$1.087/gallon	$1.092/gallon	$1.140/gallon	$1.170/gallon
Natural Gas	$4.25/mcf	$3.80/mcf	$4.00/mcf	$4.13/mcf

All data are in 1996 dollars. 1996 and 2010 BAU prices are from Energy Information Administration 1997a.

The average price of electricity is projected to fall between now and 2010 as a result of competition at the wholesale level, expected declines in coal prices, anticipated efficiency improvements, and falling capital expenditures (Energy Information Administration 1997a). Under business as usual, the average price of electricity in 2010 is projected to be 5.9¢ -- 1¢ below the average price in 1995. Permit prices of $14/ton to $23/ton would yield average electricity prices about 3 to 5% above this projected price of 5.9¢ (see Figure 20). In addition, the Administration's electricity restructuring proposal, by spurring competition at the retail level, is expected to cause electricity prices to fall an additional 10% on average. The electricity restructuring proposal with permit prices of $14/ton to $23/ton would yield electricity prices well below the business as usual projection for 2010 (see Figure 21). Refer to Appendix C for a discussion of the potential cost-savings associated with the Administration's electricity restructuring proposal.

Figure 20. Average U.S. Electricity Prices Under $14/ton to $23/ton Permit Prices, Excluding the Cost-Savings Associated with Electricity Restructuring

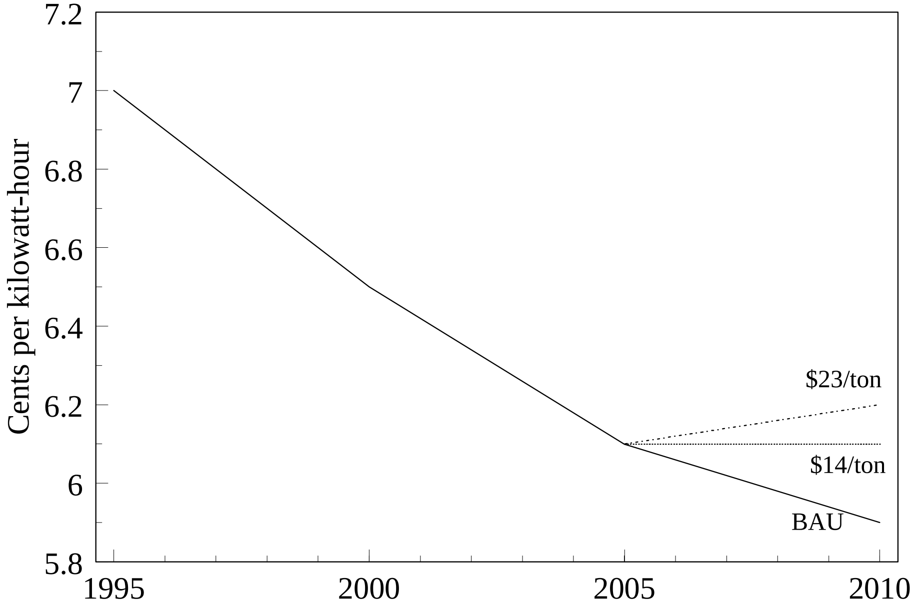
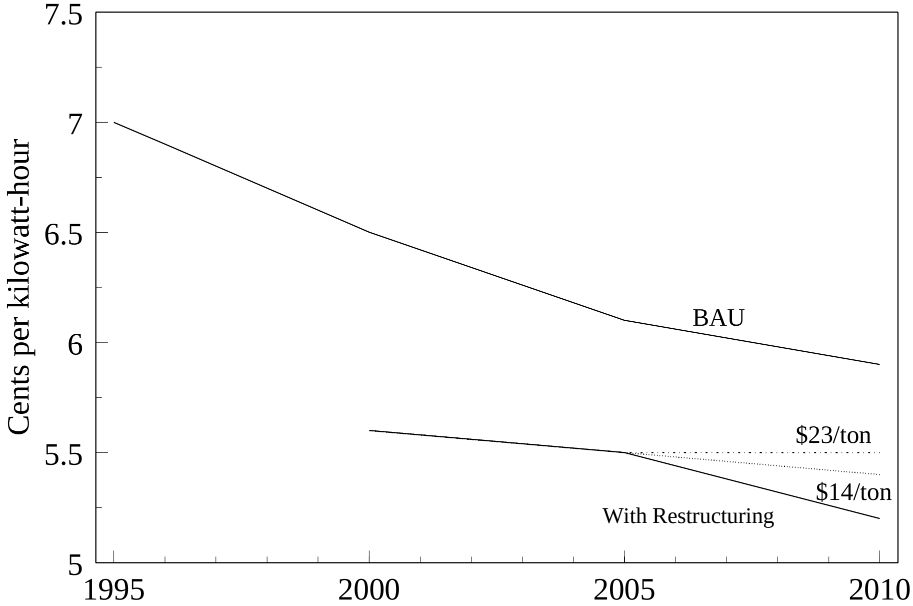
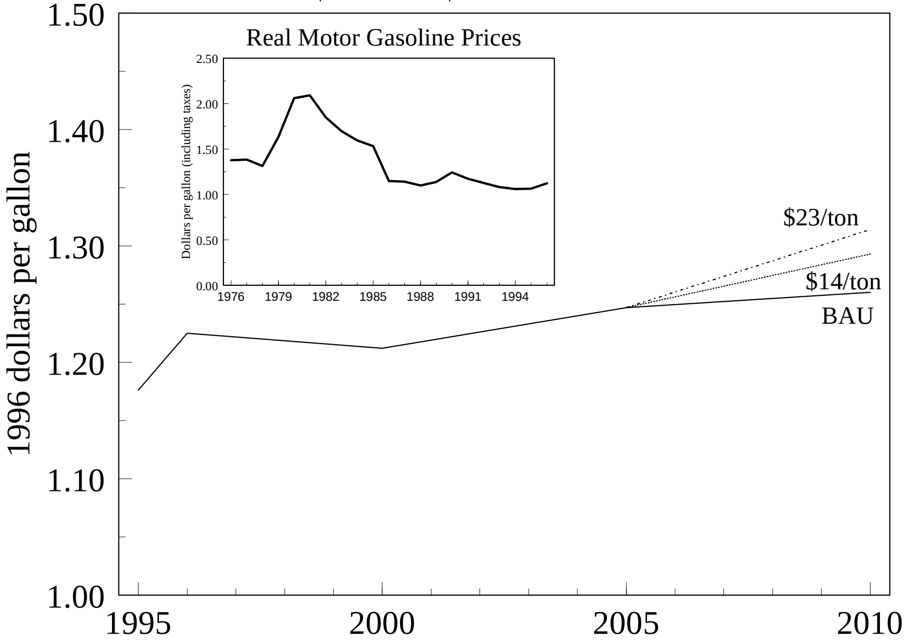


Figure 21. Average U.S. Electricity Prices Under $14/ton to $23/ton Permit Prices, Including the Cost-Savings Associated with Electricity Restructuring



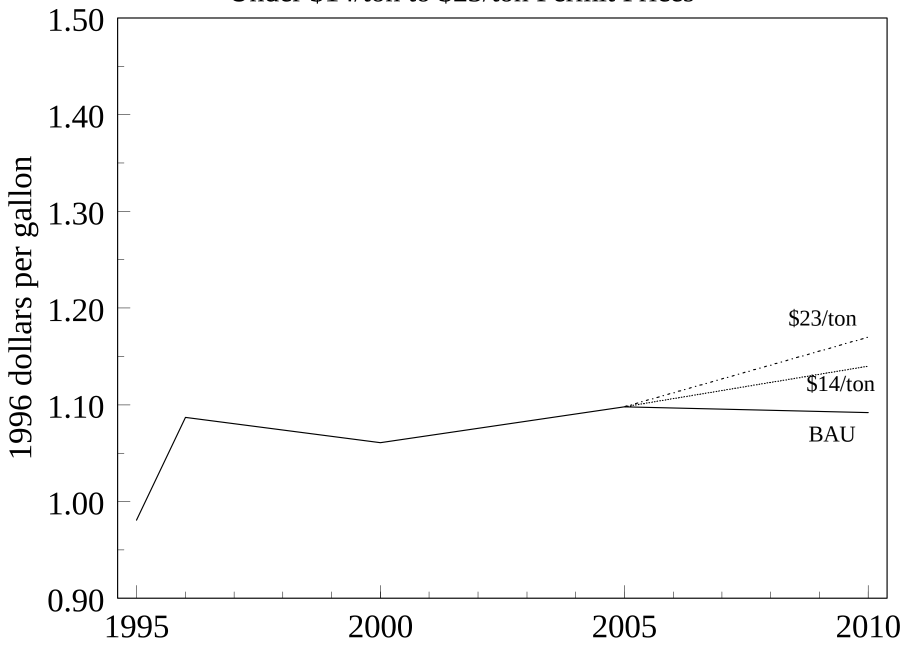
Permit prices of $14/ton to $23/ton also would be expected to increase gasoline prices by 3 to 4%, or 4 to 6¢ per gallon, relative to BAU projections for 2010 (see Figure 22). This increase, which would occur over the next decade, is smaller than the increase in gasoline prices over 1995-1996. Further, this change in gasoline price is small compared to historical changes in gas prices (see inserted figure). Over the past two decades, the average *annual* absolute change in the price of gasoline was 7.5%, about double the projected increase in gasoline prices over 12 years under the assumptions set out here.

Figure 22. Average U.S. Gasoline Prices
Under $14/ton to $23/ton Permit Prices



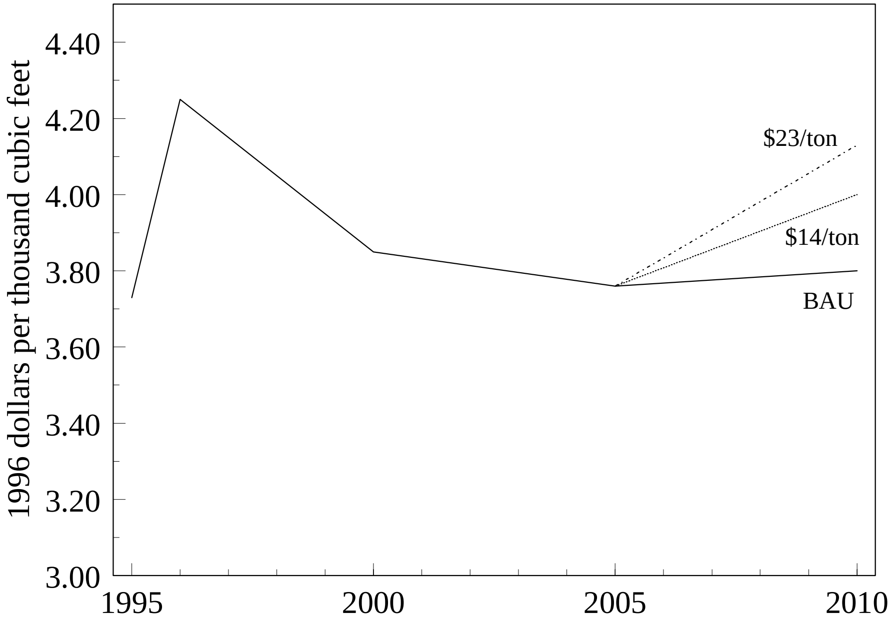
Permit prices of $14/ton to $23/ton could increase fuel oil prices by 5 to 8¢/gallon above their projected price in 2010 (see Figure 23). However, as in the case of gasoline, this increase is smaller, for example, than the jump in fuel oil prices experienced over 1995-1996.

Figure 23. Average U.S. Fuel Oil Prices
Under $14/ton to $23/ton Permit Prices



Between now and 2010, delivered natural gas prices are projected to fall because of anticipated efficiency improvements and an increasingly competitive market (Energy Information Administration 1997a). While greenhouse gas permit prices of $14/ton to $23/ton would likely result in modest increases in the price of natural gas relative to baseline projections, 2010 gas prices would still be below current prices (see Figure 24). Further, the price increases under these permit prices would be smaller than the price increase over 1995-1996.

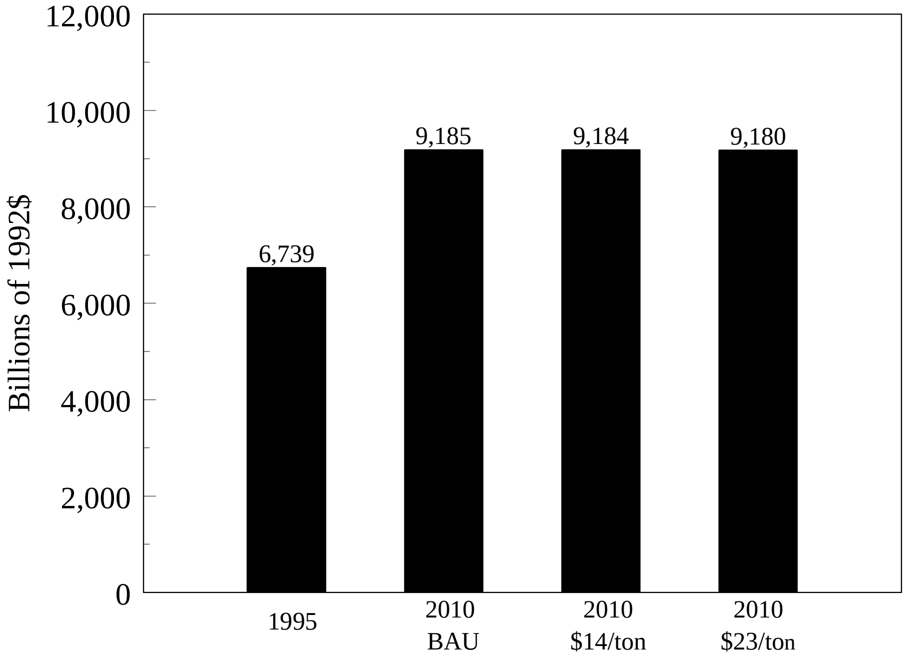
Figure 24. Average U.S. Natural Gas Prices
Under $14/ton to $23/ton Permit Prices



U.S. GDP, Investment, and Consumption

The Second Generation Model projects economic growth for the United States in its business as usual scenario through 2010 shown by the difference between the first two bars in Figure 25. Implementing climate policy through effective international trading in conjunction with meaningful developing country participation would have a negligible effect on economic output. A $14/ton permit price would result in a $1 billion (0.01 %) decline in GDP relative to business as usual. Under a $23/ton permit price, GDP would be $5 billion less in 2010 than it is projected to be otherwise.[17]

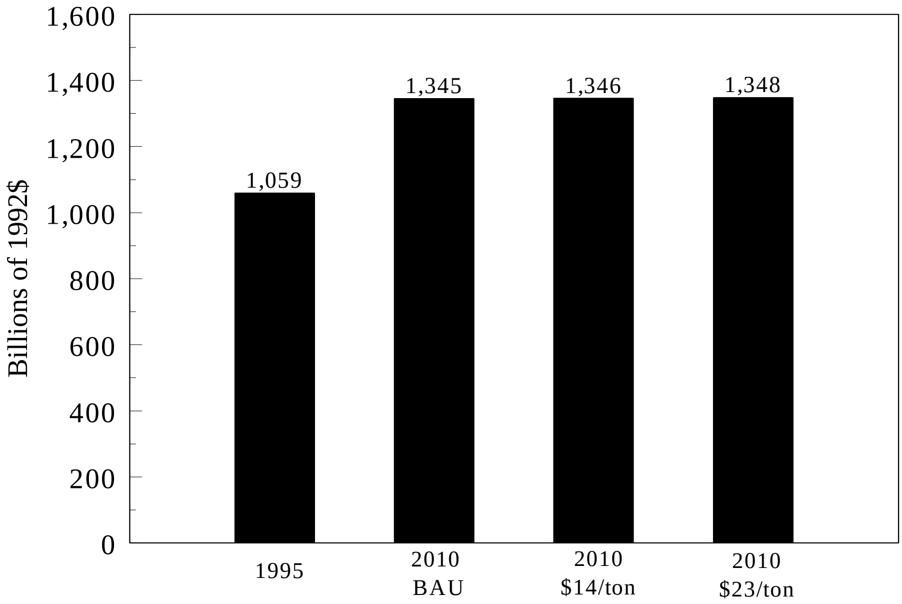
Figure 25. U.S. GDP Under $14/ton to $23/ton Permit Prices



[17] Note that the SGM GDP estimate does not reflect the effects of reducing non-carbon dioxide greenhouse gas emissions.

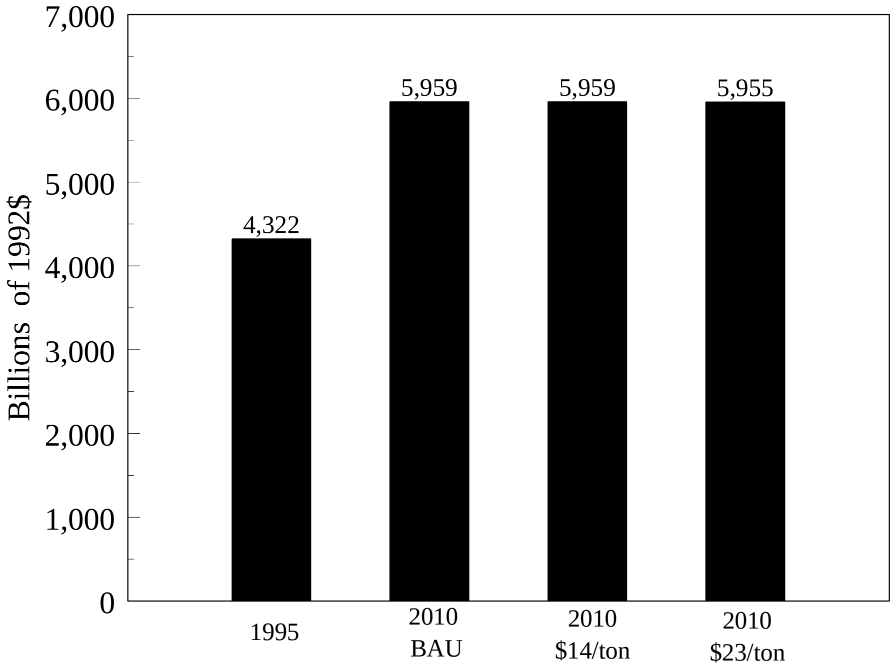
Permit prices of $14/ton to $23/ton imply a small increase in investment relative to business as usual (see Figure 26). Under a $14/ton scenario, investment would increase by $1 billion while a $23/ton permit price scenario entails a $3 billion increase in investment in 2010 relative to business as usual. This increase in investment reflects the adoption of energy efficient and carbon-lean technologies stimulated by the price of greenhouse gas permits.

Figure 26. U.S. Investment Under $14/ton to $23/ton Permit Prices



Permit prices of $14/ton to $23/ton would cause a slight shift from consumption to investment; however, this shift would be small. Under the $14/ton permit price scenario, the change in consumption would be insignificant relative to the business as usual baseline (see Figure 27). Under the $23/ton scenario, the shift would amount to a decline of about $4 billion in 2010.

Figure 27. U.S. Consumption Under $14/ton to $23/ton Permit Prices



Employment

The Second Generation Model is conditioned on the assumption that aggregate employment effects are negligible. Given the small projected energy price increases anticipated and the long lead time before any impact would occur, this assumption is appropriate. Although there may be job gains in some sectors and job losses in others, the analysis of the Kyoto Protocol with effective international trading and developing country participation suggests that there will not be a significant aggregate employment effect under permit prices of $14/ton to $23/ton. Some job loss could occur in energy-intensive sectors, although given the small predicted change in energy prices, impacts in most such sectors are apt to be modest. Further, new jobs will be created in other sectors -- such as in environmental protection technologies, energy production, and energy efficient technologies. Many of these are likely to be high-tech jobs that pay high wages. Nonetheless, as the President said in his October 1997 speech, where dislocations do occur as a result of policies to reduce greenhouse gas emissions, assistance should be provided to affected workers.

Additional Cost Mitigating Factors

Potential Benefits of Carbon Sinks

Various forestry and soil activities sequester carbon dioxide and thereby offset some emissions associated with industrial activity. Trees, other vegetation, and organic matter in soils take up carbon dioxide through photosynthesis and transform the carbon dioxide and store it in vegetative tissue. These carbon sinks can serve as opportunities to mitigate the emissions of carbon dioxide from fossil fuel combustion. For example, the Climate Action Report (1997) reported that gross anthropogenic greenhouse gas emissions in the United States in 1990 were 1,583 MMTCE. However, by including certain carbon sinks,[18] *net* greenhouse gas emissions totaled 1,458 MMTCE, or 8% lower.

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[18] Note that carbon sinks, as defined in the Climate Action Report, are different from the set of forestry activities included in the sinks definition in Article 3.3 of the Kyoto Protocol. While the estimate of sequestration from the Climate Action Report indicates that the United States has been a net sink of carbon, it should not be construed to represent the U.S. carbon sink potential under the Kyoto Protocol. Moreover, the Climate Action Report estimate of carbon sequestration excluded below-ground sinks, such as soil sinks.

The Kyoto Protocol includes opportunities to reduce net emissions through carbon sinks. Certain forestry activities -- afforestation and reforestation net of deforestation -- will be used by countries with emissions targets to meet their commitments (Kyoto Protocol, Article 3.3). The Kyoto agreement does not include carbon sinks in calculating the emissions baseline, but does allow for countries to achieve their targets by accounting for sequestration during the commitment period by these forestry activities that occur between 1990 and 2012. For countries such as the United States, where acres of tree-planting exceed acres of tree-cutting annually, this provision illustrates another opportunity where the United States can reduce net emissions at low cost. In addition, the Protocol provides the option to include additional categories of carbon sinks, like agricultural soils and other land-use change and forestry activities, based on additional technical work and negotiations (Kyoto Protocol, Article 3.4). With these carbon sinks, the United States could more easily meet its target even without additional policies to specifically encourage sink activity. However, given the ongoing negotiations to develop rules regarding carbon sinks, the Administration employed the very conservative assumption that business as usual sink activity generates no net sequestration.

Complementing the opportunities to reduce net emissions domestically through existing forestry activities, several economic analyses indicate that policies could stimulate the creation of additional carbon sinks at low costs. Stavins (1996) derived a marginal cost curve for carbon sequestration for the United States based on his analysis of land use decisions between 1935 and 1984 for a set of counties in Mississippi, Arkansas, and Louisiana. He found that more than 150 MMTCE could be sequestered at $25/ton. Adams et al. (1993) assessed several different scenarios of tree planting on agricultural land and found that about 250 MMTCE could be sequestered at approximately $25/ton.[19] Studies based on engineering/costing models indicate that even more carbon could be sequestered at low costs (Moulton and Richards 1990). While the Administration's illustrative modeling analysis did not incorporate carbon sinks, these studies clearly illustrate the potential for carbon sequestration efforts to play a significant role in meeting our emissions target. These studies provide some evidence that carbon sinks in the United States and other countries could significantly reduce the international emissions trading price and, consequently, the costs of achieving the environmental objective.

[19] Adams et al. (1993) provide their estimate in short tons, and for purposes of comparison, we have converted this estimate to metric tons.

Potential Emissions Reductions through the Administration's Electricity Restructuring Proposal

The Administration's Comprehensive Electricity Competition Plan (CECP) is estimated to reduce greenhouse gas emissions by about 25 to 40 million metric tons of carbon equivalent per year by 2010. Although competition will lower prices, which will tend to increase consumption, it will also provide a direct profit incentive for generators to produce more electricity with less fuel and improve energy efficiency as competitive sellers seek to maximize the value of their product offerings to buyers by bundling electricity with energy efficiency and management services. In the 2010 timeframe, the net result of retail competition in the absence of additional specific provisions to encourage renewables or subsidize investments in energy efficiency is expected to be nil or a small reduction in emissions.

Specific CECP provisions that will yield additional emission reductions include a renewable portfolio standard, a public benefits fund that will support renewable energy and energy efficiency investments, "green" labeling to help consumers who value clean energy choose it, and a net metering provision encouraging the installation of small renewable systems.

Potential Emissions Reductions through the Administration's Climate Change Technology Initiative

The President's Fiscal Year 1999 budget includes the Climate Change Technology Initiative (CCTI), a $6.3 billion package of tax cuts and R&D investments intended to spur the discovery and adoption of new technologies. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the deployment of those that exist already. Many of the components of the CCTI reflect recommendations made in a recent report by the President's Committee of Advisors on Science and Technology (PCAST 1997).[20] PCAST found that "the inadequacy of current energy R&D is especially acute in relation to the challenge of responding prudently and cost-effectively to the risk of global climatic change from society's greenhouse gas emissions.... Much of the new R&D needed to respond to this challenge would also be responsive to the other challenges" (PCAST 1997, p. i). The report concluded that investments in energy R&D would generate economic and environmental benefits, especially in the long run.

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[20] The President's Committee of Advisors on Science and Technology was established in 1993 to advise the President on matters involving science and technology. PCAST consists of distinguished representatives from industry, academia, research institutions, and other non-governmental organizations.

Building on PCAST's recommendations, the proposed CCTI package contains $3.6 billion over the next five years in tax cuts for energy-efficient purchases and renewable energy, including tax credits of $3,000 to $4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to $2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a credit up to $2,000 for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains $2.7 billion over the next five years in additional research and development investments -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is $277 million, up from $227 million appropriated in FY98. If supported by the Congress, this effort could further improve energy efficiency and lower the cost of meeting our Kyoto target.

The Administration has not included quantitative estimates of emissions reductions associated with the Climate Change Technology Initiative in the modeling analysis. This reflects the uncertainty in calculating the payoffs from funding research and development. A fully funded CCTI would provide for additional U.S. emissions reductions and result in lower permit prices than there otherwise would be.

Potential Emissions Reductions through the Administration's Industry Consultations

Under the Administration's 1993 Climate Change Action Plan, many businesses and institutions are taking voluntary steps to improve their energy efficiency and reduce greenhouse gas emissions. According to the Climate Action Report (1997) the wide array of voluntary actions in that Plan are expected to reduce emissions by 76 MMTCE in the year 2000 and 169 MMTCE in 2010. Annual energy savings are projected to grow to $50 billion (1995 dollars) in the year 2010.

In October 1997, President Clinton called for sectoral consultations which will build on the voluntary efforts undertaken pursuant to the Climate Change Action Plan. One partnership already announced, the Partnership for Advanced Technology in Housing (PATH), sets goals for voluntary improvements in home energy use that would result in an estimated 24 MMTCE in reductions in 2010 while saving consumers $11 billion in home energy expenditures. The Administration will be seeking voluntary agreements with major energy-intensive industries and energy providers to yield further emissions reductions.

As the sectoral consultations are still at an early stage, it would be premature and difficult to incorporate emissions reductions from consultations into the illustrative modeling analysis. Based on the effectiveness of these approaches in the past, these consultations could produce a significant amount of cost-effective action in the coming decade.

Federal Energy Plan

In October, 1997, the President called for a series of steps to reduce energy use in Federal buildings, transportation fleets, and other equipment purchases, and to promote the use of renewable energy sources. As the nation's largest single energy user, the federal government spends nearly $8 billion each year for power to operate facilities, vehicles and industrial equipment, and over 90% of this energy derives from fossil fuels. Long-term savings in cost and energy use can be secured by making sure that purchases for federal facilities, transportation, and systems operations emphasize energy efficiency and that energy-intensive equipment be retrofitted wherever feasible. In addition, the federal government can expand the procurement of renewable and less carbon-intensive fuels.

Ancillary Benefits of Greenhouse Gas Emissions Reductions in the United States

Reductions in fossil fuel combustion typically lead to reductions in conventional air pollutants. These include sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter and volatile organic compounds. These reductions in emissions can have important implications for environmental quality and public health.

To estimate the ancillary benefits for the United States of the Kyoto Protocol, we employed the methods that were used for the Regulatory Impact Analysis (RIA) that the Environmental Protection Agency published in July 1997 for the revised national ambient air quality standards (NAAQS) for particulate matter and ozone. First, the DRI model was used to simulate the changes in fossil fuel combustion by region and economic sector that the Kyoto Protocol would bring about.[21] These changes in fuel

[21] DRI/McGraw-Hill U.S. Energy Model.

consumption were then used by Pechan Associates, an EPA contractor, to estimate changes in emissions of local air pollutants.[22]

Identification of the baseline from which to estimate emission reductions attributable to a carbon control strategy is complicated by the gradual transition to full attainment of the new NAAQS. In particular, states and emission sources could respond to a carbon control strategy by either replacing or maintaining NAAQS-related emission controls. Because of this uncertainty, ancillary benefits are treated as a range.

If ancillary benefits of carbon mitigation make the NAAQS-related emissions controls unnecessary, substantial costs for controlling pollution will be avoided. Reasonable estimates of the cost-savings per ton are approximately $1,620 for NO_x and $700 for SO_2, based on current information about the specific technologies likely to be avoided at utilities and large industrial sources. (These estimates are derived from the estimates of the incremental costs of tighter regional caps on NO_x and SO_2 emissions that were developed for the NAAQS RIA.) Given these unit values, the value of these cost-savings for sulfur dioxide is about $360 to $600 million per year, and for NO_x is about $370 to $610 million per year. Adding these together gives cost savings of about $0.74 to $1.2 billion per year.

If carbon mitigation partially supplements, rather than displaces, NAAQS-related controls, valuing the ancillary health and welfare benefits requires (1) an estimate of the changes in air quality, and (2) an estimate of the value in dollars of such changes. For this analysis we employed the methodologies and tools used for the NAAQS RIA of July 1997. However, we note that in this area, as others, there is substantial uncertainty surrounding the appropriate methodology. The academic literature is in flux and provides a number of possible approaches.

Since the measure of air quality responsible for most of the quantifiable benefits is the abatement of fine particulate matter, we do not quantify changes related to ozone, and concentrate instead on fine particles ($PM_{2.5}$). Reducing $PM_{2.5}$ concentrations yields a wide variety of benefits. Our analysis indicates that the reductions in $PM_{2.5}$ attributable to carbon mitigation that corresponds to the $14/ton case would lead to between $1.1 billion and $5.7 billion in benefits annually. Similarly, the reductions in $PM_{2.5}$ attributable to carbon mitigation in the $23/ton case would lead to between $1.8 and $9.4 billion in benefits. Although these plausible ranges appear large, they are consistent with prior estimates, e.g., in the NAAQS RIA, and reflect a variety of uncertainties in the nature of the health effects.

In this scenario, there are additional ancillary benefits in the form of avoided NAAQS-related air pollutant control costs. Specifically, for the two pollutants

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[22] See E.H. Pechan and Associates 1997a, b.

governed by cap and trade programs (SO_2 and NO_x), avoided control costs total about $450 million in the $14/ton case and about $740 million in the $23/ton case. Total annual ancillary benefits for this valuation approach range from about $1.6 billion to $6.2 billion for the $14/ton case and from about $2.5 billion to $10.0 billion for the $23/ton case.

Thus as a conservative estimate, a quarter of the costs of the Kyoto agreement are offset by these ancillary benefits, although there is substantial uncertainty about these estimates.

It should be noted that the level of ancillary benefits from carbon mitigation increases with the extent of domestic mitigation and decreases to the extent that mitigation is based on purchasing international emissions allowances. In general the magnitude of these ancillary benefits depends on the type of regulation of air quality and emissions of local air pollutants, as well as baseline local air quality.

Greenhouse gas mitigation strategies will result in additional reductions of other air pollutant emissions, including several that have not been quantified (see Table 7). In particular, greenhouse gas mitigation strategies will result in additional reductions in heavy metals, acetaldehyde, formaldehyde, organic aromatics, polycyclic aromatic hydrocarbons (PAH), and chlorinated dioxins and furans. These substances are capable of producing a wide array of health and environmental effects, including some forms of cancer. Exposure to these substances at some concentrations can cause effects in addition to cancer; these may range from respiratory problems to reproductive and developmental effects. Further, although reductions in nitrogen and sulfur dioxide emissions were quantified in dollar terms, the estimated values exclude the mitigation of adverse impacts on agricultural and forestry yields, aquatic and terrestrial ecosystems, and recreational fishing.

Table 7. Unquantified Ancillary Emissions Benefits

Effect Category	**Effects**	**Other Possible Effects**
Human Health	Cancer Mortality Non-cancer Effects -neurological -respiratory -reproductive -hematopoietic -developmental -immunological -organ toxicity	
Ecological	Effects on: -wildlife -plants -ecosystem -biological diversity	Loss of habitat for endangered species
Welfare	Decreased recreation opportunities Decreased agricultural yield Decreased visibility	Loss of biological diversity Building deterioration

Benefits of Averting Climate Change

In conducting this analysis, the Administration has not attempted to quantify the benefits of mitigating the risks of climate change. While several economists have estimated the damages of global warming under a doubling of atmospheric concentration (Cline 1992; Fankhauser 1993; Nordhaus 1994), they all assumed an endpoint -- an atmospheric concentration, and subsequently, an increase in global temperature. However, the Kyoto Protocol only stipulates an emissions path through 2012. To calculate the benefits of averting climate change-induced damages, it is necessary to know the emissions path for many years beyond 2012. Thus while the benefits of getting started on the Kyoto path to reducing greenhouse gas emissions may be quite large over time, we cannot estimate these benefits without knowing where the path goes in the years after the Kyoto compliance period.

Cline (1992) assessed the economic damages from warming associated with two temperature increases: 2.5° C (4.5° F) and 10° C (18° F). He presented the former temperature change as the likely effect of a doubling of the atmospheric carbon dioxide concentration and the latter temperature change as the result of "very long term warming." Under the scenario where the temperature increases 4.5° F, Cline found that the annual damage to the United States would be about 1.1% of GDP, or about $89 billion in today's terms.[23] Cline's "very long term warming" scenario resulted in economic damages of about 6% of GDP.

Cline's estimates of annual economic damage of global warming take account of the following categories of impact: agriculture, forest loss, species loss, sea-level rise (including costs of constructing dikes and levees, wetlands loss, and drylands loss), electricity requirements, non-electric heating, human amenity, human life, human morbidity, migration, hurricanes, construction, leisure activities, water supply, urban infrastructure, and air pollution. Cline provides only qualitative assessments for several categories. In addition, he found that non-electric heating expenditures decline with global warming, so this is actually considered a benefit, not a cost, associated with warming.

The economic damage under a doubling of the atmospheric carbon dioxide concentration found by Cline is not significantly different in magnitude from the results of Nordhaus (1994) and Fankhauser (1993). Nordhaus estimated that a temperature increase of 5.4° F would result in annual costs of about 1% of GDP. Fankhauser found that under the same 5.4° F temperature increase the annual costs of warming would be about 1.3% of GDP for the United States, and 1.5% of GDP worldwide. However, the similarity among the aggregated estimates of these three researchers masks both the differences in their methodologies and the true uncertainty associated with long-term forecasts of the damages from given increases in global warming. Different researchers account for different categories of damages, and even within the same category, they may estimate different effects. More importantly, the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will become apparent only with future experience.

International Impacts Associated with Reducing Greenhouse Gas Emissions

Just as in the United States, all Annex I countries would benefit significantly from effective implementation of the Kyoto Protocol's flexibility mechanisms. Further, Non-Annex I countries would accrue three kinds of benefits: 1) under international trade with binding targets slightly below business as usual and the CDM, they will enjoy economic gain from trade in emissions allowances; 2) reductions in carbon

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[23] Cline's original estimate is quoted in 1990 dollars. The figure given above translates the Cline estimate into 1997 terms by scaling it to 1997 GDP.

emissions will reduce emissions of local air pollutants; and 3) contributing to lower global greenhouse gas emissions would further reduce the risks of climate change, to which they are, in many cases, the most vulnerable and the least able to adapt.

- **Economic benefits:** With growth targets, developing countries could enjoy substantial net gains through the international sale of emission reductions achieved at lower cost than the world price. Such participation by developing countries in international emissions allowance markets would lower the costs to industrial countries, including the United States, of meeting their Kyoto targets. In particular, costs would be lower than with trading among only Annex I countries. On a project-by-project basis, the Clean Development Mechanism would also result in net gains to developing countries and cost-savings to industrial countries. Given the anticipated difference in scale, a system including effective trading of developing countries' emissions would yield greater gains to developing countries and greater cost-savings to industrial countries than the Clean Development Mechanism.

- **Environmental benefits:** Developing country growth targets would lower global greenhouse gas emissions relative to a world with only Annex I targets. To the extent that these lower global emissions further reduce the risks of climate change, the more vulnerable developing countries would benefit. Further, reducing carbon dioxide emissions generates ancillary air quality benefits by reducing emissions of particulate matter, sulfur dioxide, and nitrogen oxides. By adopting a growth target and engaging in trading, developing countries could achieve environmental benefits not achievable by pursuing CDM alone.

Effects of Climate Change Policy on U.S. Competitiveness

Some have expressed concern that the Kyoto Protocol might adversely affect the competitive position of American industry. In general, structural changes in the economy have the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. For example, premium gasoline cost $1.28 per gallon in the United States in 1996, but only 8 cents per gallon in Venezuela. Similarly, gas prices were $3.71 per gallon in Switzerland and $4.41 per gallon in France (Bureau of the Census 1997). Electricity prices also vary significantly: in the U.S., for industry, they were 5 cents per kilowatt hour in 1995, a fraction of prices in Switzerland of 13 cents per kilowatt hour (OECD/IEA 1996). Yet U.S. industry did not move en masse to Venezuela, nor did Swiss industry move to the United States. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings, sectors which, by their very nature, are severely limited in their ability to relocate to other countries.

Evaluating how the Kyoto Protocol could affect competitiveness of a few specific manufacturing industries -- especially those that are energy-intensive, such as aluminum and chemicals -- is complex. However, the modest energy price effects associated with permit prices of $14/ton to $23/ton would likely have little impact on competitiveness.

Further, there is no reason to expect that mitigating climate change would necessarily have a negative effect on the trade balance. Indeed, the efforts to reduce greenhouse gas emissions would likely decrease oil exports to the United States, benefitting the trade balance. In short, we believe that the reason we need developing country participation is primarily because the problem is global and cost-effective solutions are essential, rather than to avoid adverse effects on competitiveness.

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APPENDICES

Appendix A

Annex I and Non-Annex I Countries

Appendix B

Construction of Non-Carbon Dioxide Emissions Baselines

Appendix C

Potential Electricity Restructuring Cost-Savings

Appendix D

Historical Trends in U.S. Energy Prices

Appendix E

Country-Specific Energy and Emissions Data

APPENDIX A: ANNEX I AND NON-ANNEX I COUNTRIES

The 1992 Framework Convention on Climate Change stipulated that, among other provisions, a non-binding emissions reduction goal for the industrialized countries of the world. These countries, including most developed countries and the economies in transition of the former Soviet bloc, are identified in the treaty as members of "Annex I". Countries not included in this list are identified as "Non-Annex I". Non-Annex I is composed primarily of developing countries, but also includes the newly industrialized countries of Asia, and two OECD members (Korea and Mexico). In general, Annex I has often been used to refer to industrial countries and Non-Annex I has been used to refer to developing countries.

Under the Kyoto Protocol, the industrialized, or developed countries, that agreed to binding emissions targets are identified as Annex B countries. The list of Annex B countries is virtually identical to the list of Annex I countries (see below).

Annex I Countries under Framework Convention

Australia
Austria
Belarus
Belgium
Bulgaria
Canada
Czechoslovakia
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Latvia
Lithuania
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Romania
Russian Federation
Spain
Sweden
Switzerland
Turkey
Ukraine
United Kingdom
United States

Annex B Countries under Kyoto Protocol

Australia
Austria
Belgium
Bulgaria
Canada
Croatia
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Latvia
Liechtenstein
Lithuania
Luxembourg
Monaco
Netherlands
New Zealand
Norway
Poland
Portugal
Romania
Russian Federation
Slovakia
Slovenia
Spain
Sweden
Switzerland
Ukraine
United Kingdom
United States

APPENDIX B: CONSTRUCTION OF NON-CARBON DIOXIDE EMISSIONS BASELINES

Emissions of greenhouse gases for countries were drawn from the countries' national communications to the Framework Convention on Climate Change. For some countries' emissions of greenhouse gases in some years, estimates of emissions were not provided. Details of the derivation of these emissions are provided below.

- Australia: Non-CO_2 greenhouse gases comprise 33% of all greenhouse gas emissions in 1990. These are assumed to be 25% of all greenhouse gas emissions in 2010 based on the trends projected in the United States and the European Union. The 1990/95 baseline excludes SF_6 and HFCs.

- Austria: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2000 level using the projected average annual growth rate over the 1990-2000 period. For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Belgium: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Canada: For non-CO_2 greenhouse gases, Canada is assumed to have the same non-CO_2 emissions/total greenhouse gas emissions ratio as the United States (0.17 in 1990/95 and 0.13 in 2010). Total greenhouse gas emissions are then calculated based on historical and projected CO_2 emissions.

- Denmark: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2005 level using the projected average annual growth rate over the 2000-2005 period. For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Eastern Europe: For non-CO_2 greenhouse gases, Eastern European countries are assumed to have the same non-CO_2 emissions/total greenhouse gas emissions ratio as the Former Soviet Union (0.25 in 1990/95 and 0.19 in 2010). Total greenhouse gas emissions are then calculated based on historical and projected carbon dioxide emissions.

- Finland: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Former Soviet Union: Non-CO_2 greenhouse gases comprise 25% of all greenhouse gas emissions in 1990. These are assumed to be 19% of all greenhouse gas emissions in 2010 based on the trends projected in the United States and the European Union. The 1990/95 baseline excludes SF_6, PFCs, and HFCs.

- France: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Germany: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2005 level using the projected average annual growth rate over the 1990-2005 period. For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Greece: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP times the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Ireland: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Italy: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Japan: Non-CO_2 greenhouse gases comprise 4% of all greenhouse gas emissions in 1990. These are assumed to be 3% of all greenhouse gas emissions in 2010 based on the trends projected in the United States and the European Union. The 1990/95 baseline excludes SF_6, PFCs, and HFCs.

- Luxembourg: For methane and nitrous oxide, 2010 emissions are based on a linear extrapolation from the projected 2000 level using the projected average annual growth rate over the 1990-2000 period. For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Portugal: For the three categories of synthetic gases, estimated emissions for 1995 and 2010 are based on multiplying 1995 GDP by the emissions/GDP(1995) average ratios derived from the Netherlands, Sweden, and the United Kingdom.

- Spain: At the time this analysis was conducted, the United Nations had not posted a national communication for Spain on the FCCC webpage. Estimates of the methane and nitrous oxide emissions are based on the average methane/GDP(1995) and nitrous oxide/GDP(1995) ratios for the other 14 E.U. countries multiplied by Spain's 1995 GDP. Similar calculations were done for the three categories of synthetic gases, but only based on the average of emissions from the Netherlands, Sweden, and the United Kingdom.

APPENDIX C: POTENTIAL ELECTRICITY RESTRUCTURING COST-SAVINGS

The Administration's electricity restructuring proposal provides potential cost-savings in four areas: cost reduction (including fuel procurement, non-fuel operation and maintenance [O&M] expenses, and administrative and general [A&G] expenses), dispatch efficiency, improved capital utilization, and savings in capital additions. These four categories of savings are likely to reach or exceed $20 billion annually. Table C1 summarizes these potential savings.

Table C1. Summary of Restructuring Cost-Savings Potential

Source of Savings	Potential Annual Cost-Savings (billions of 1996 dollars)
Cost Reduction (Fuel, non-fuel O&M, A&G)	$24.6
Dispatch Efficiency	$0.6
Improved Capital Utilization	$0.8 to $2.6
Reduced Capital Additions	$0.3 to $3.8
TOTAL	$26.3 to $31.6

Several sources of important additional savings are not considered in this analysis.

- First, as pricing becomes more efficient, load shape adjustments from consumers on the demand side of the meter can reduce the need to add expensive new capacity that would otherwise be necessary to meet peak demands of only a few hours duration per year (e.g., on the hottest summer days). A recent study of the New York State power pool suggests that savings in that one area alone could reach $660 million annually by 2010.

- Second, our cost analysis assumes that regulators and firms would not repeat past mistakes with respect to capacity planning, choice of technology, or project management that have raised the cost of power to consumers. While regulators have undoubtedly learned from past events, future regulation is unlikely to be perfect.

- Finally, experience in other sectors suggests that competition will lead to the creation of new product combinations with greater economic value to consumers. Our estimates do not reflect this benefit at all.

Fuel Costs, Non-Fuel Operation and Maintenance (O&M) Costs, and Administrative and General (A&G) Costs

Fuel Costs, Non-Fuel O&M Costs, and A&G Costs, which together accounted for roughly $94 billion in reported utility costs in 1995, largely reflect the current operations of electric utilities.[1]

Information reported in standard industry filings suggests a wide range of cost experience across reporting units and companies. These data can provide insight into opportunities for cost reduction. Our approach here is to estimate the value of bringing the cost performance of the entire industry up to the standard already demonstrated by top industry performers -- represented in this paper as the average of the top quartile of reported performance.

Some of the differences in cost experience clearly reflect circumstances that will not change under competition. For example, coal prices differ according to the distance from low-cost coal supplies; heat rates reflect the vintage, type, scale, and operating rate of plants and pollution control requirements; and distribution costs are systematically related to the density of customers on a system. To account for such factors, we stratified the reported data along key dimensions prior to developing the quartile analysis. Stratification narrows the range of cost variation, but significant differences remain, as reported in Table C2.

Table C2. Cost-Reduction Opportunities

Category	Potential Annual Cost-Savings (billions of 1996 dollars)
Fuel Acquisition	$6.7
Heat Rates	$0.9
Non-fuel Operation and Maintenance	$11.0
Administrative and General	$6.0
TOTAL	$24.6

The reported total of $24.6 billion in cost-saving potential could either underestimate or overestimate actual cost reduction opportunities. On the underestimation side, top quartile performance under regulation may understate achievable efficiencies under competition as even the best current performers re-engineer and rethink their activities. Moreover, the lack of data for existing non-utility generators, which are

[1] A portion of A&G costs also reflect historical operations to the extent that pension liabilities have not been funded on a current basis.

widely believed to be among the most cost-effective operators, could lead to some underestimation of even the current state-of-the-art efficiencies. On the overestimation side, the stratification underlying the quartiles reported in Table C2 for fuel and O&M costs may fail to account for all sources of irreducible cost differences. Moreover, the portion of the variation in cost across plants that reflects contract cycles for fuel and other inputs could be expected to narrow over time independent of the advent of competition.

Dispatch Efficiencies

Competition likely will result in improved dispatch efficiencies. The advent of competition will shift the market from a "shared savings" paradigm to one in which the party that identifies a cost-effective trade can reap the benefits, providing dispatch efficiencies beyond those that might result from wholesale competition alone. Analyses using the Policy Office Electricity Modeling System (POEMS) suggest that dispatch efficiencies resulting from retail competition can reduce aggregate system fuel costs by approximately $600 million relative to a scenario reflecting a continued cost-of-service regime.

More Efficient Utilization of Capital

The generation, transmission, and distribution of electricity are among the most capital-intensive activities in the United States. Yet, the relatively inflexible price signals provided to consumers under traditional cost-of-service regulation have resulted in relatively poor utilization of our substantial investment in electricity-related capital. Retail competition will allow electricity markets to emulate the experience of airlines and communications providers in implementing load-sensitive pricing regimes,[2] allowing the additional use of electricity in price sensitive applications during off-peak and off-season periods.

Ideally, the gains from more efficient capital utilization would be calculated separately for each load segment in each season. Although data on the segment-specific demand responses to price variation are not available, we can use the impacts of competition on average prices to develop a rough estimate of capital utilization cost-savings. Model results and recent experience with restructuring at the state level suggest that average delivered prices in a restructured industry will be 6 to 9 mills (9 to 13 percent) lower than prices projected under continued cost-of-service regulation, depending upon what provisions are made for stranded cost recovery. Using an

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[2] An example of such a pricing regime can be found in the telecommunications industry where some firms offer lower prices during off-peak times, such as 5 cents per minute calls on Sundays.

estimate of -0.1 to -0.2 for the price elasticity,[3] the 9 to 13 percent price drop translates into an increase of between 0.9 and 2.6 percent in electricity sales.

The net welfare benefit from these extra sales includes two components. First, there is additional "consumer surplus," which reflects the extent to which the value of the extra electricity to buyers exceeds its price. Second, since extra sales under load-sensitive market pricing do not increase transmission or distribution system costs or stranded costs, any transmission, distribution, or stranded cost charges on these sales are also a net welfare gain. In 1995, the national average for transmission and distribution was 2.38¢/Kwh. For a level of baseline demand of 3.25 trillion kilowatt hours, the estimated net welfare gain from more intensive capital utilization is estimated to fall between $820 million and $2.6 billion.

It is important to note again that the estimates in this section focus narrowly on the more efficient use of the baseline capital stock. These estimates do not account for the substantial cost-savings associated with more nimble pricing in curtailing peaks that often necessitate the addition of expensive new capacity.

Reduced Capital Costs at Existing Plants

Capital additions at existing plants are another area where available data suggest a considerable range of experience across utilities. However, the analysis of such additions can be quite complex. First, a considerable portion of the observed variation in the cost of capital additions per unit of capacity can result from environmental or nuclear regulatory decisions affecting specific units that would not be sensitive to the shift to a more competitive regime. Second, capital additions occur at irregularly spaced intervals, and many plants will have no significant capital additions in a particular year.

To address the issue of irregularly spaced capital additions, we focused on average capital additions over a decade rather than additions in a single year. Over the 1985 to 1995 period, reported capital additions at existing power plants averaged approximately $6.3 billion per year, with average additions of $3.1 billion at nuclear plants, $2.6 billion at coal-fired plants, and $0.6 billion at oil and gas steam plants.

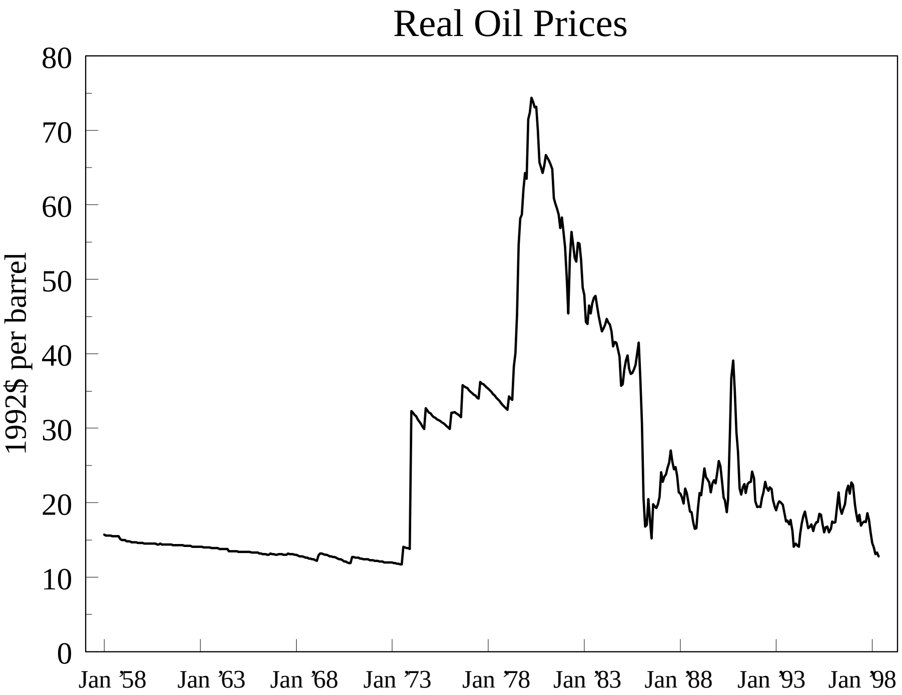
For present purposes, the most interesting comparisons can be made within the set of coal plants commissioned after 1965 that were operating without scrubbers or NO_x controls at the end of the sample period, since capital additions at these plants would not reflect the costs of repowering, emissions control requirements, or nuclear regulation. Assuming that the average of the top quartile of reporting units reflects

[3] This represents the percentage change in demand resulting from a 1% increase in price.

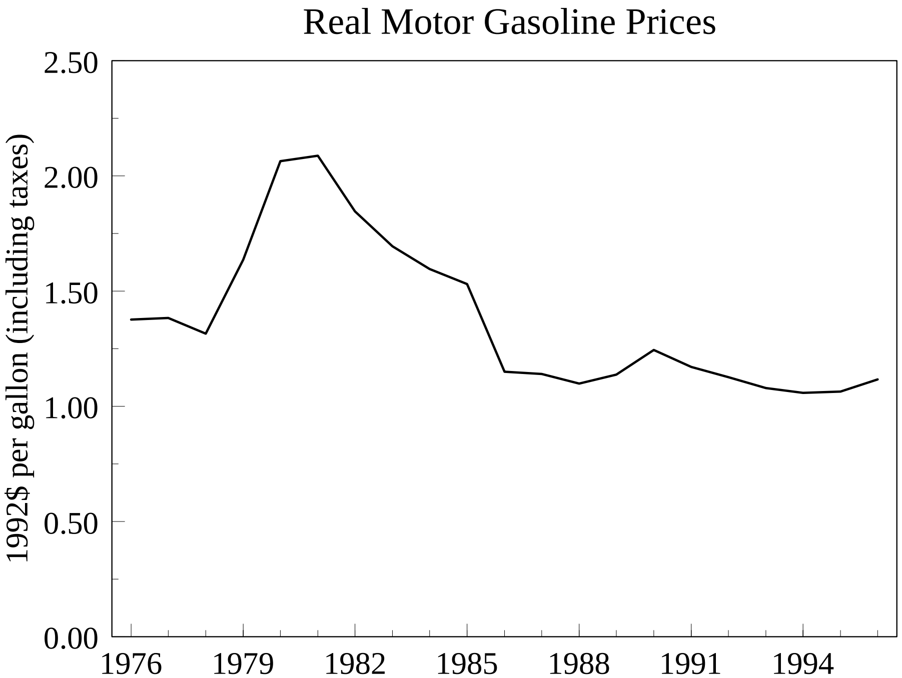
the standard of performance likely to be typical in competitive markets, annual cost-savings opportunities relative to actual reported costs for capacity additions within this relatively homogeneous subgroup of coal plants are estimated to be $274 million out of $468 million. The application of cartel analysis to the capital additions data for the stratified sample of all plants of all fuel types suggests an overall potential savings of $3.8 billion, but this is likely to be a significant overestimate for reasons outlined above. The real potential for cost-savings in capital additions likely lies in the lower portion of the range of $0.3 to $3.8 billion.

APPENDIX D. HISTORICAL TRENDS IN U.S. ENERGY PRICES

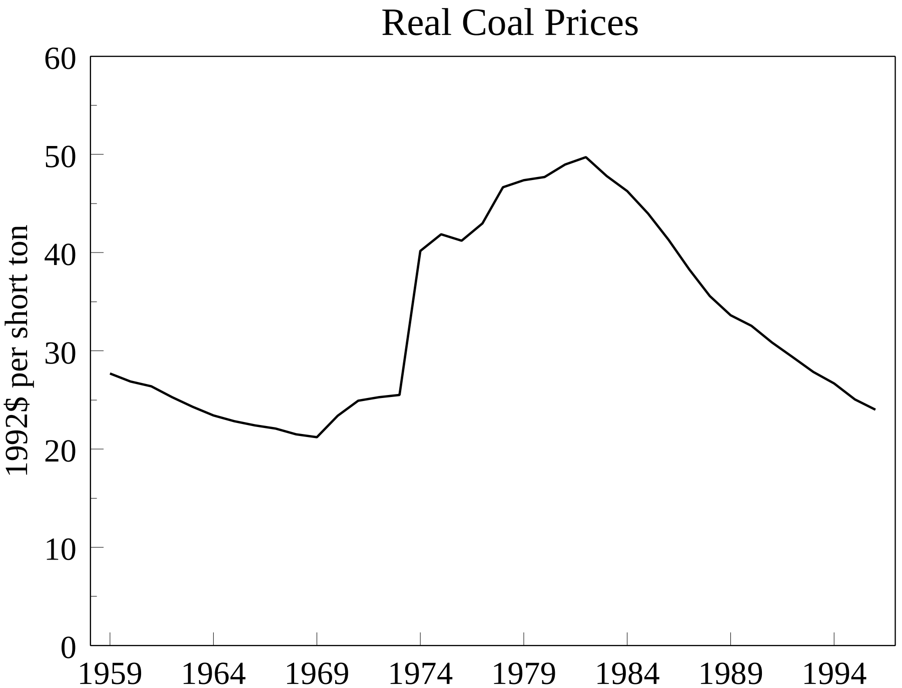
Predicted changes in real energy prices in the illustrative $14/ton and $23/ton permit price scenarios are smaller than the variations observed historically.



Source: Dow Jones Company.

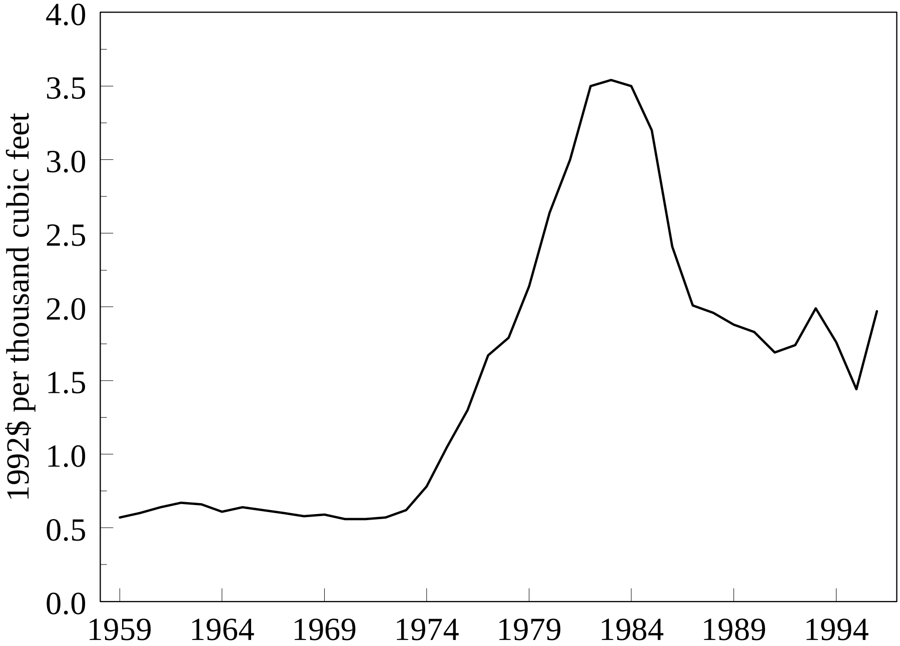


Source: Energy Information Administration 1997c.



Source: Energy Information Administration 1997c.

Real Natural Gas Prices

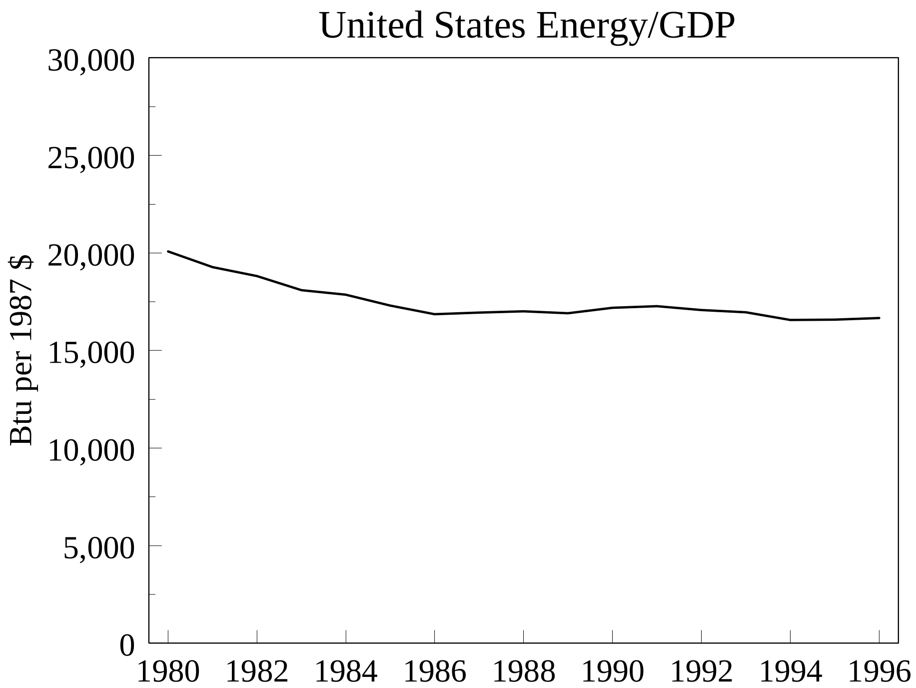


Source: Energy Information Administration 1997c.

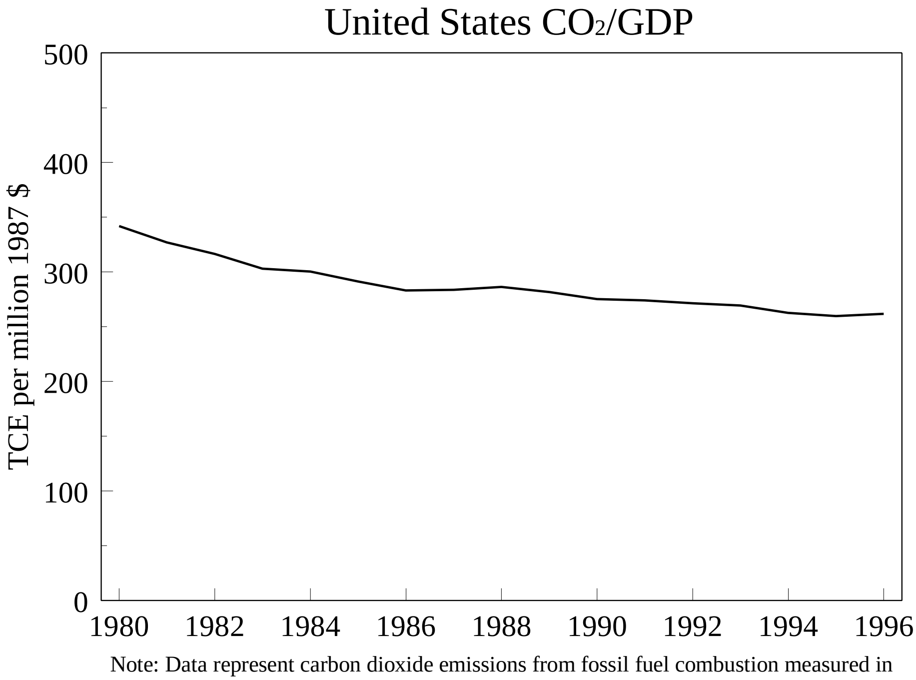
APPENDIX E: COUNTRY-SPECIFIC ENERGY AND EMISSIONS DATA

United States
Australia
Canada
China
European Union
India
Japan
Mexico

United States



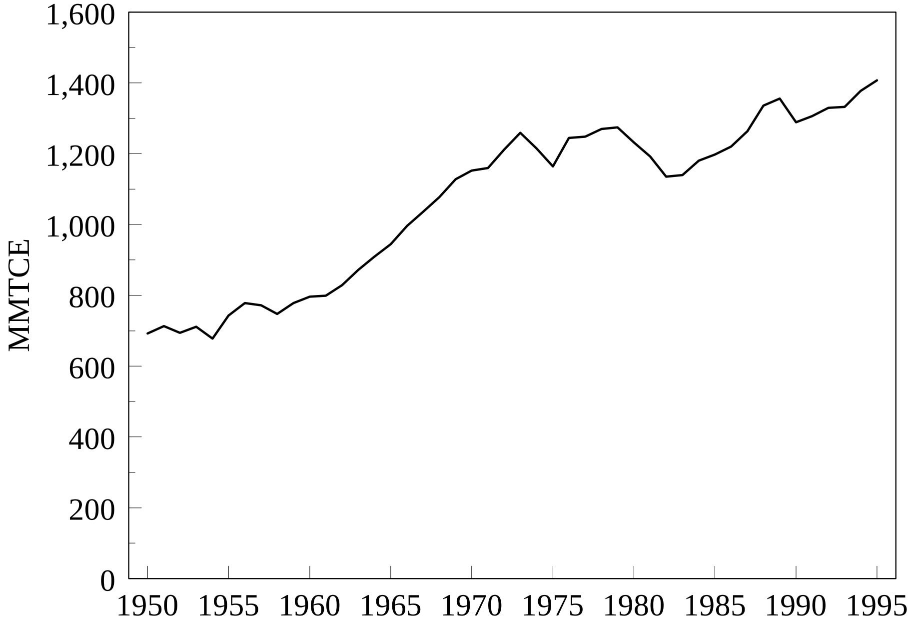
Source: Energy Information Administration 1997c.



Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

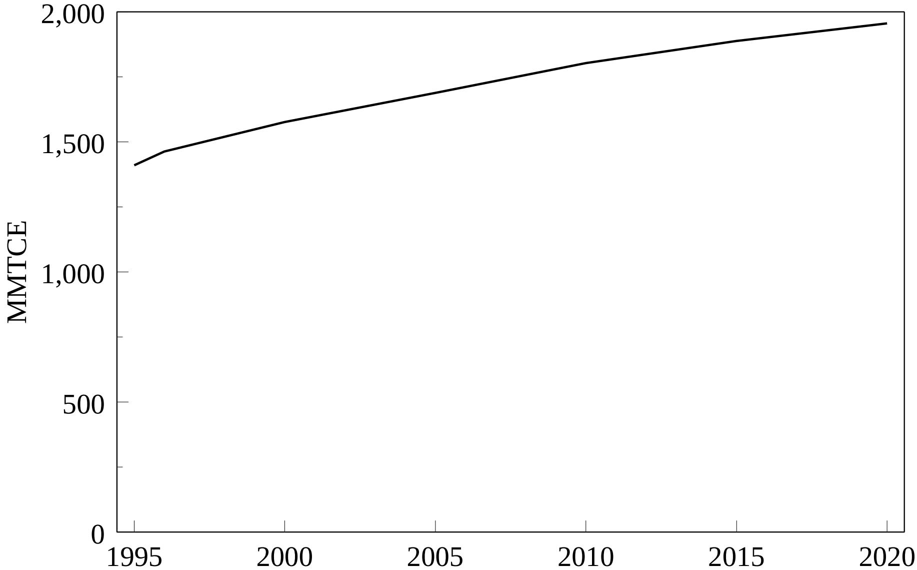
Source: Energy Information Administration 1997c.

U.S. Carbon Dioxide Emissions



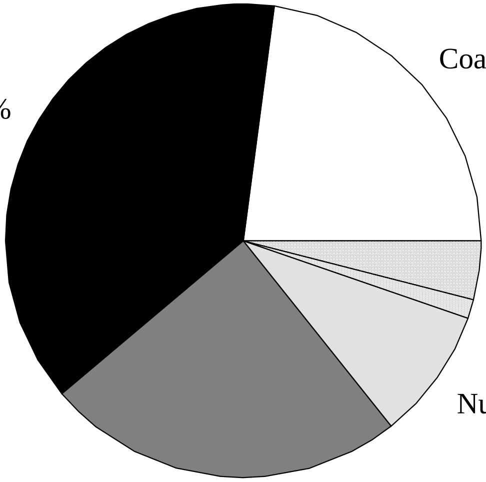
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

Projected U.S. Carbon Dioxide Emissions without New Abatement Measures



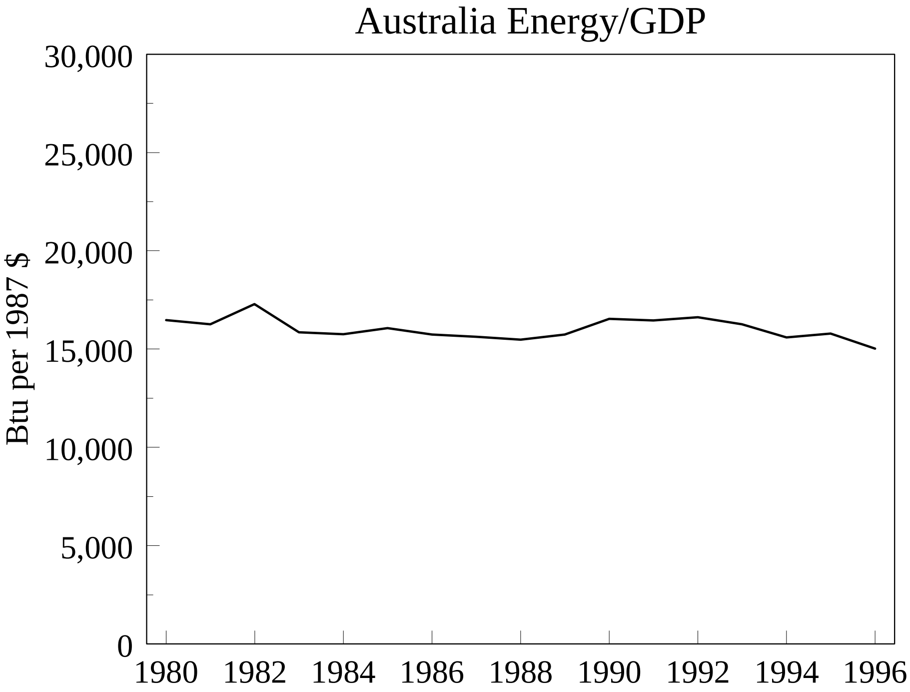
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

U.S. Total Primary Energy Supply Shares, 1995

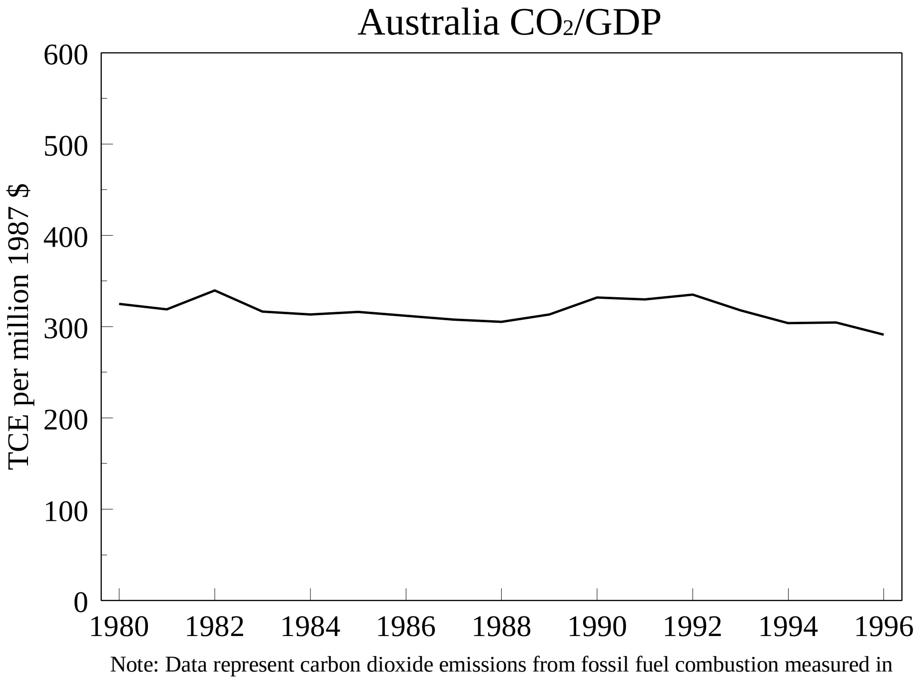


Source: International Energy Agency 1996.

Australia

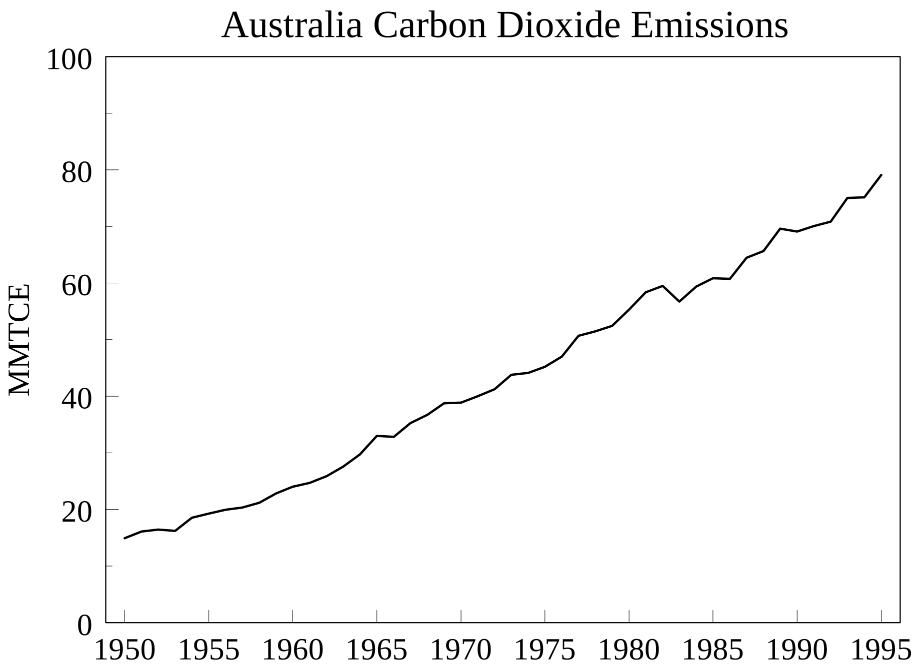


Source: Energy Information Administration 1997c.

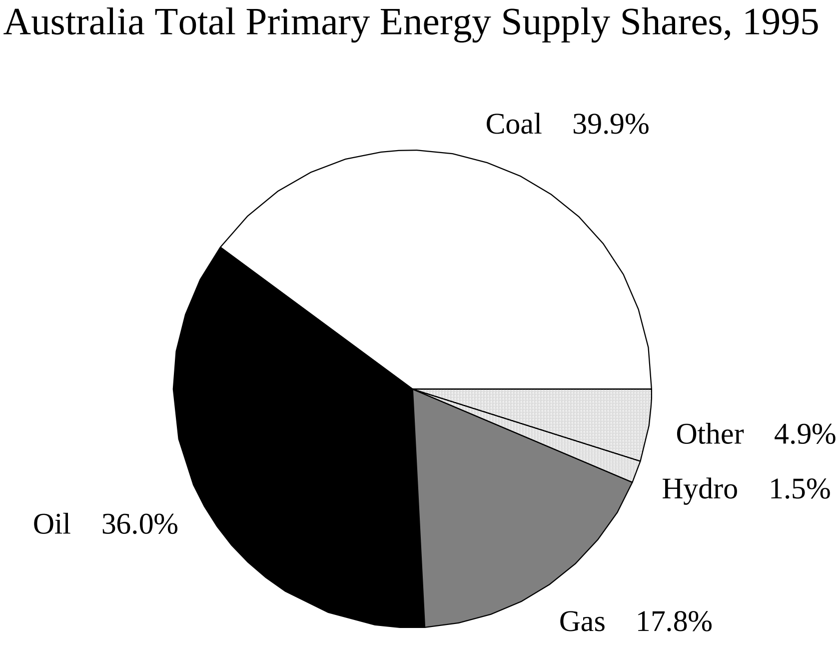


Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

Source: Energy Information Administration 1997c.

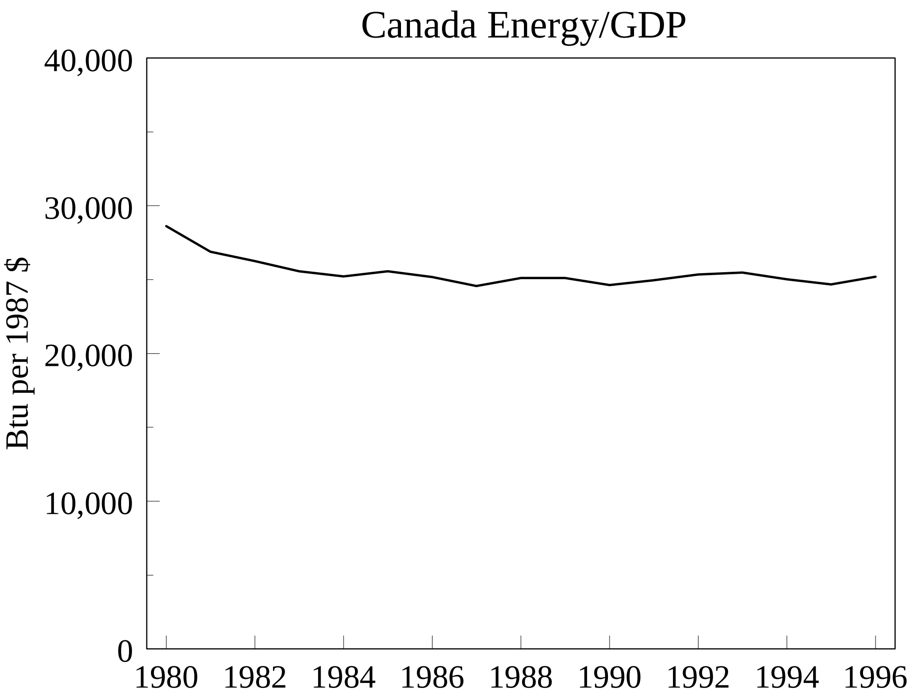


Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

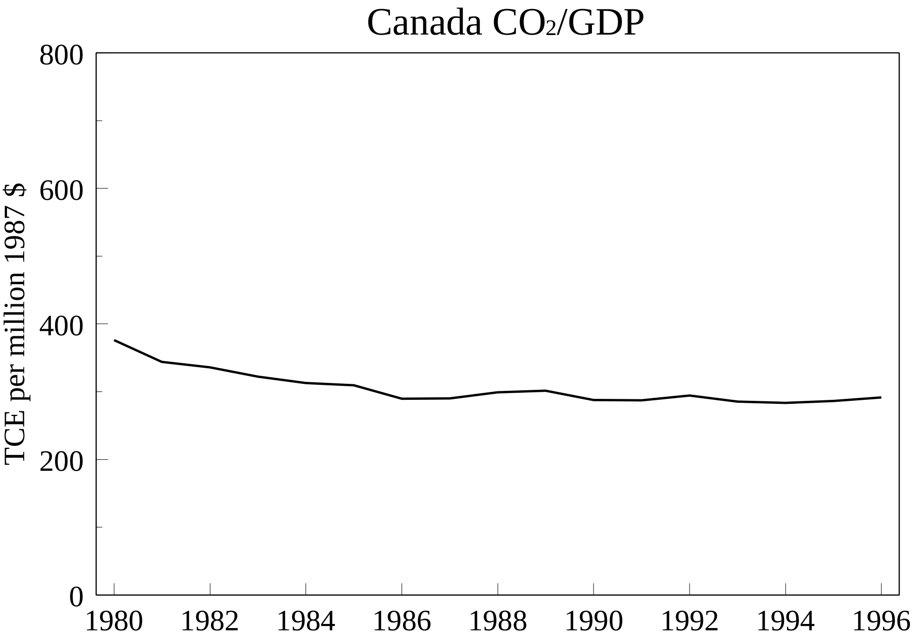


Source: International Energy Agency 1996.

Canada

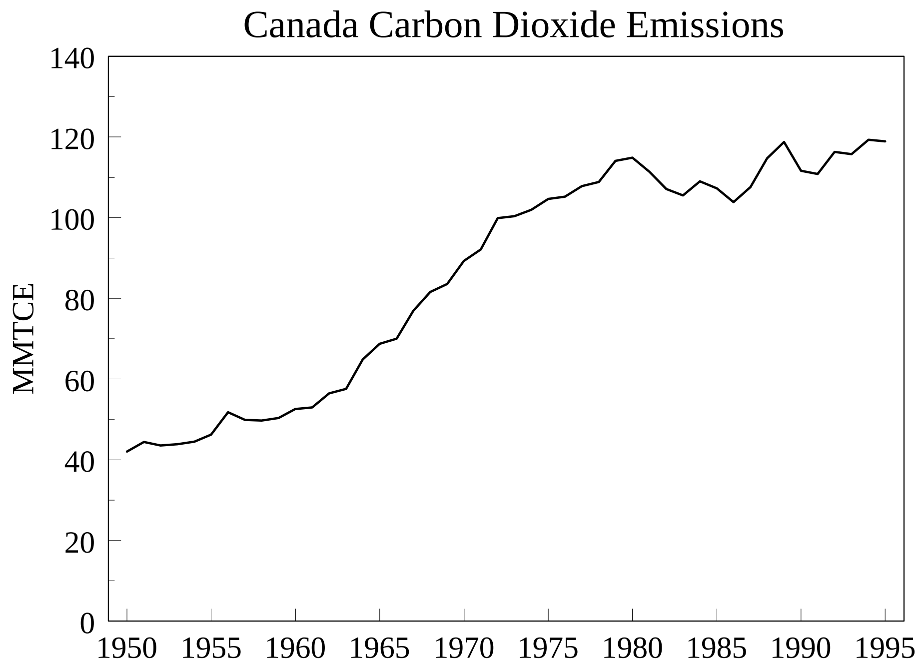


Source: Energy Information Administration 1997c.

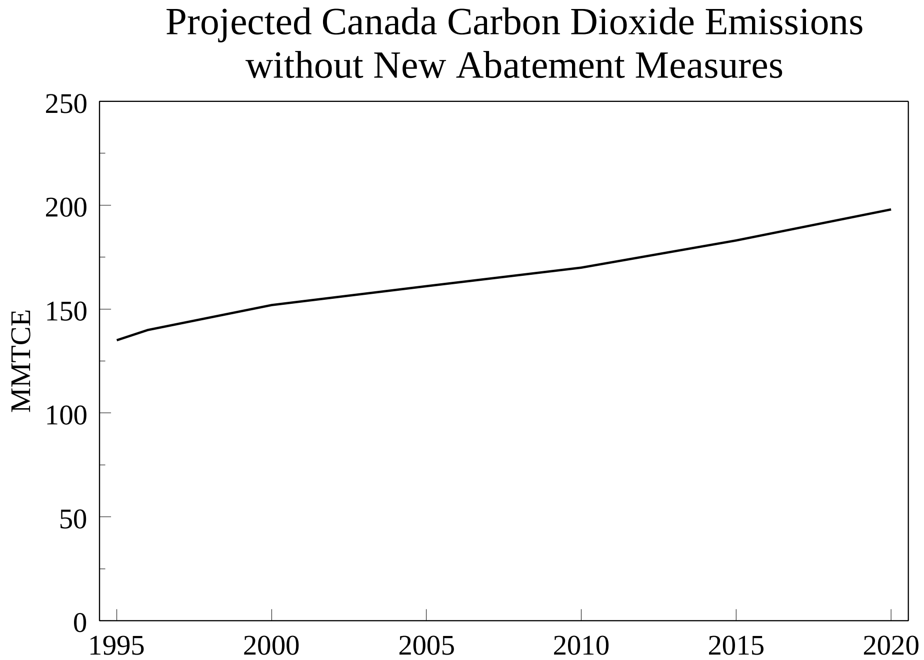


Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

Source: Energy Information Administration 1997c.

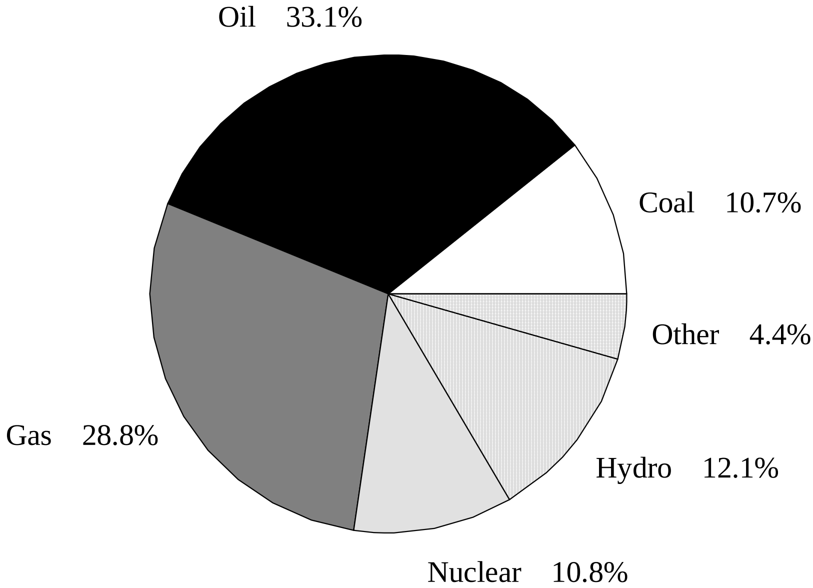


Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.



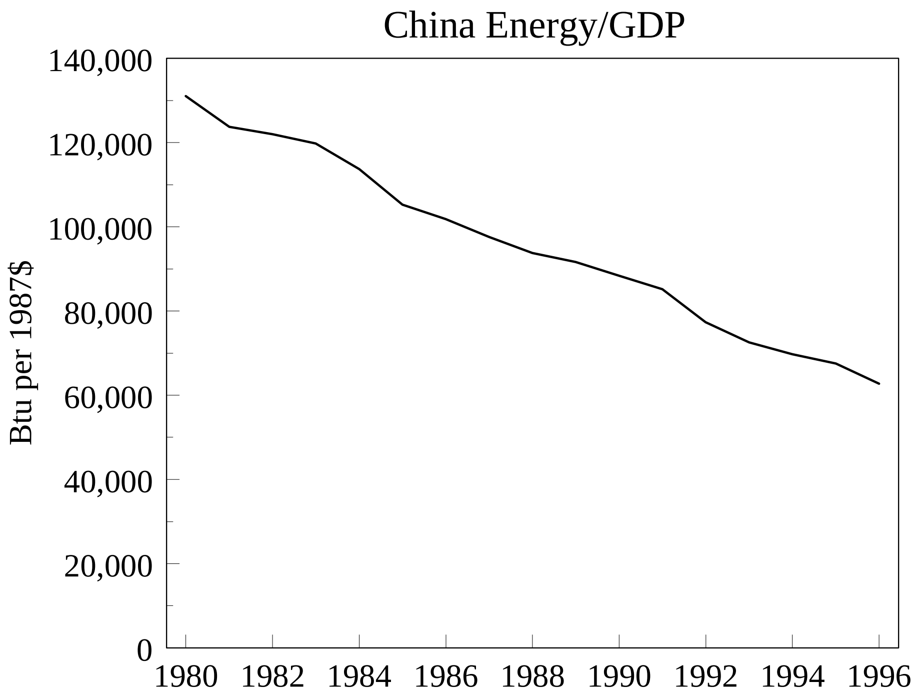
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

Canada Total Primary Energy Supply Shares, 1995

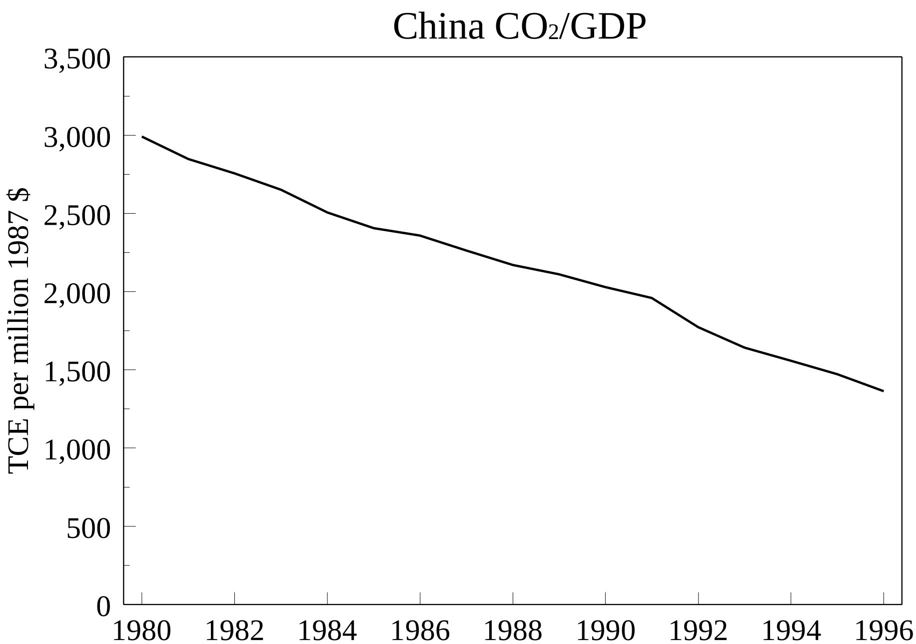


Source: International Energy Agency 1996.

China



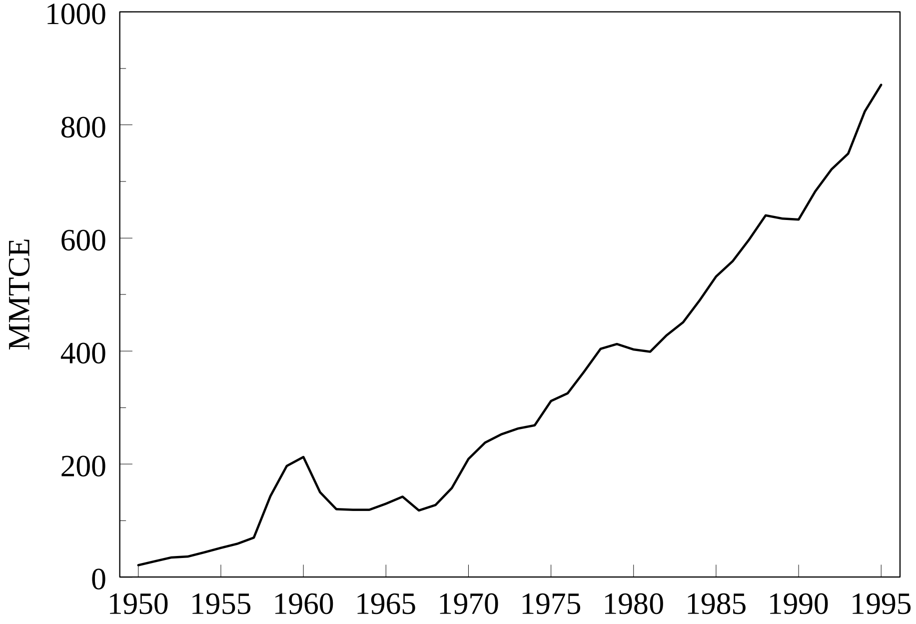
Source: Energy Information Administration 1997c.



Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

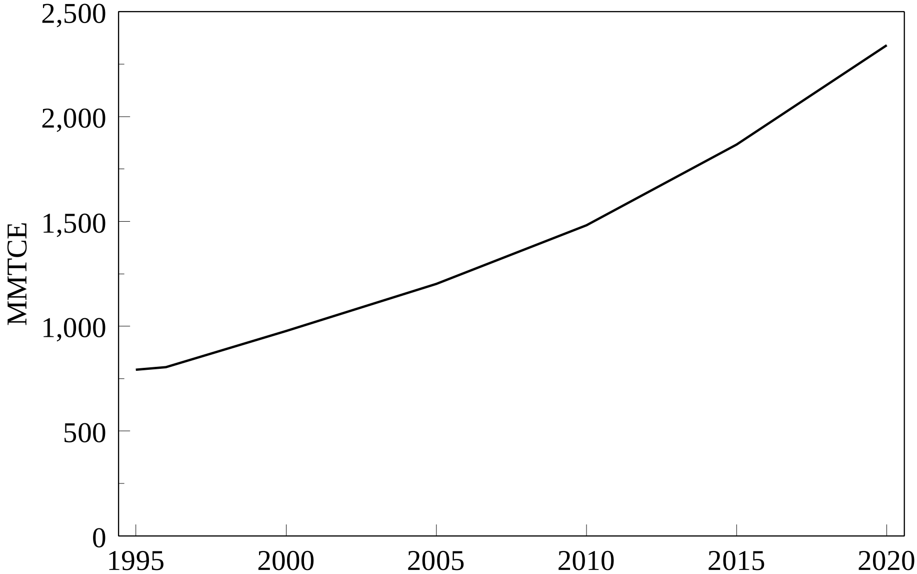
Source: Energy Information Administration 1997c.

China Carbon Dioxide Emissions



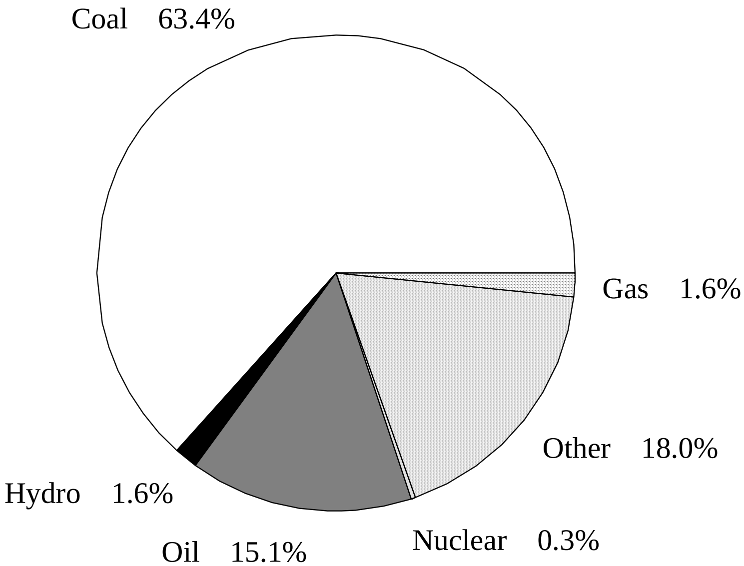
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

Projected China Carbon Dioxide Emissions without New Abatement Measures



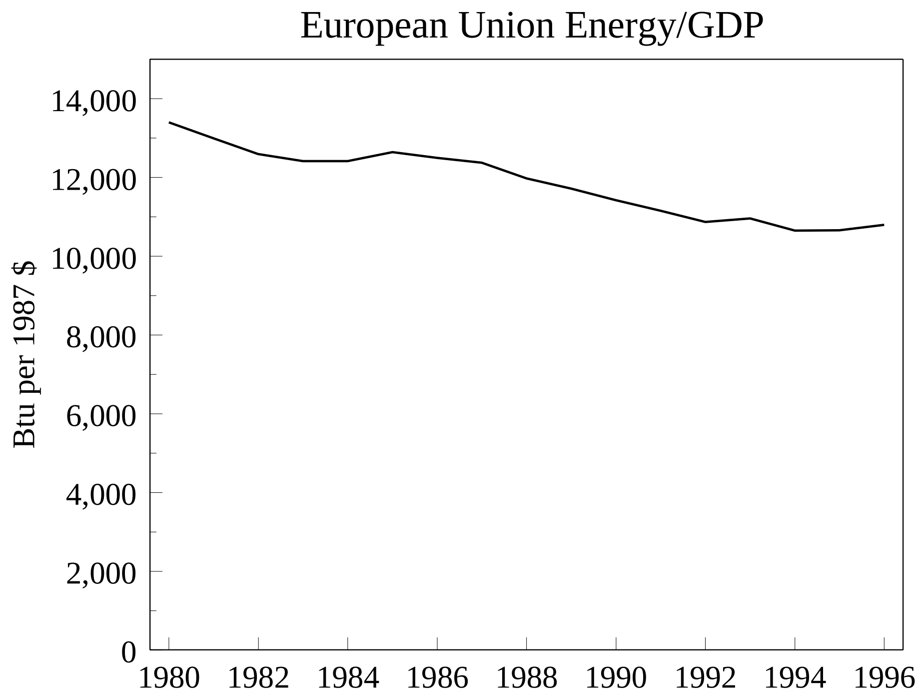
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

China Total Primary Energy Supply Shares, 1995

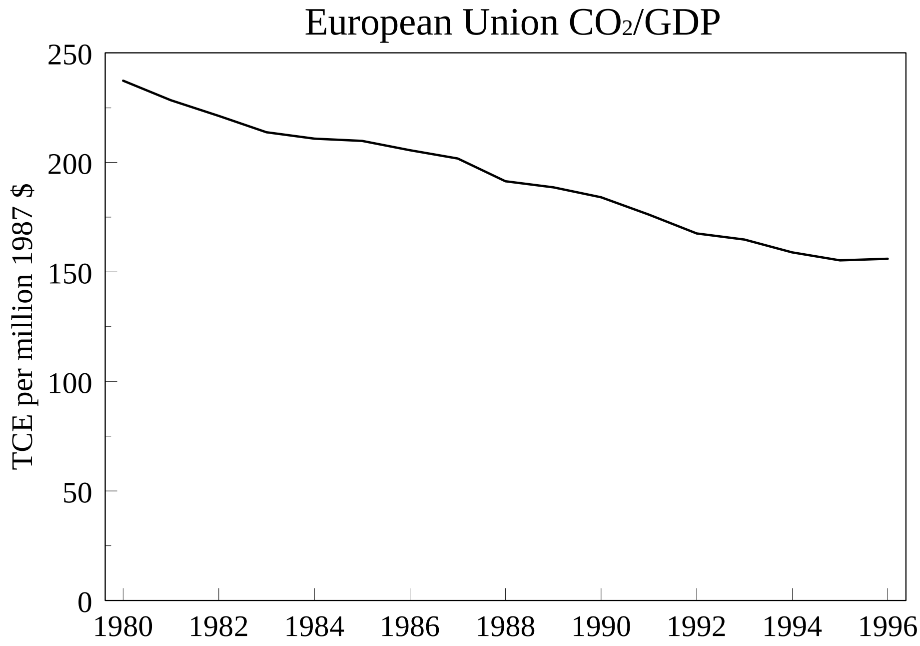


Source: International Energy Agency 1996.

European Union



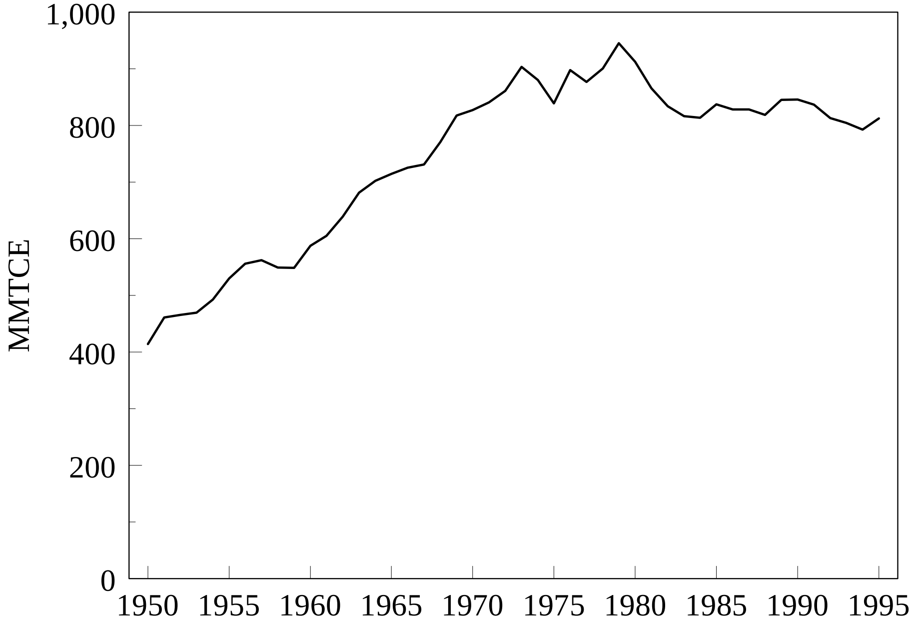
Source: Energy Information Administration 1997c.



Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

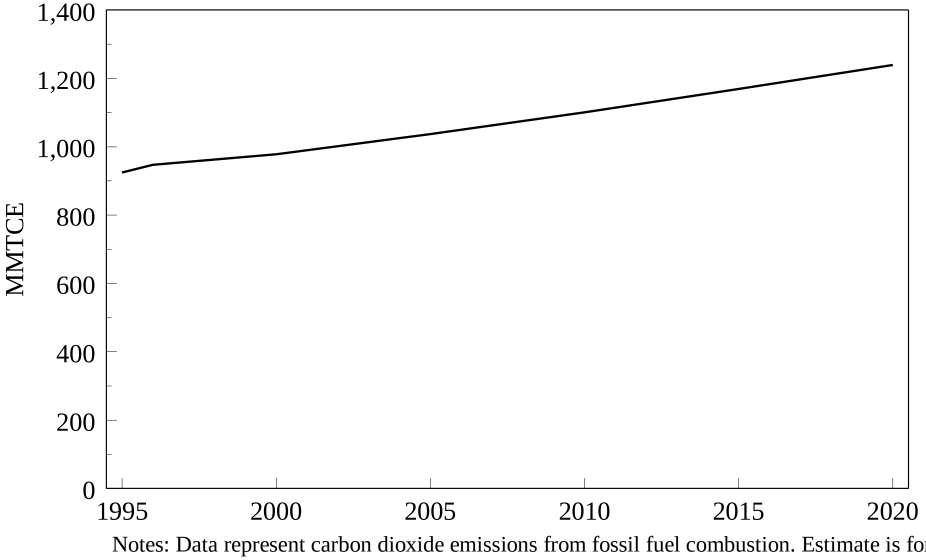
Source: Energy Information Administration 1997c.

E.U. Carbon Dioxide Emissions



Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

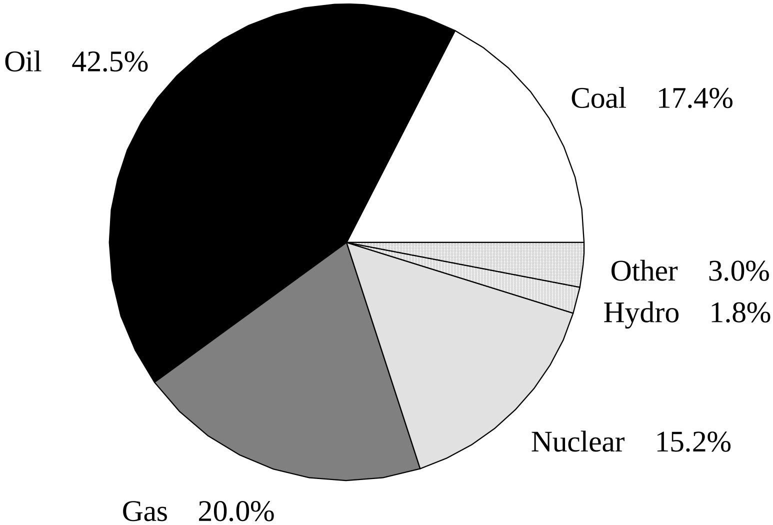
Projected E.U. Carbon Emissions without New Abatement Measures



Notes: Data represent carbon dioxide emissions from fossil fuel combustion. Estimate is for Western Europe. EIA defines Western Europe to include the E.U. and Iceland, Norway, Switzerland, and Turkey.

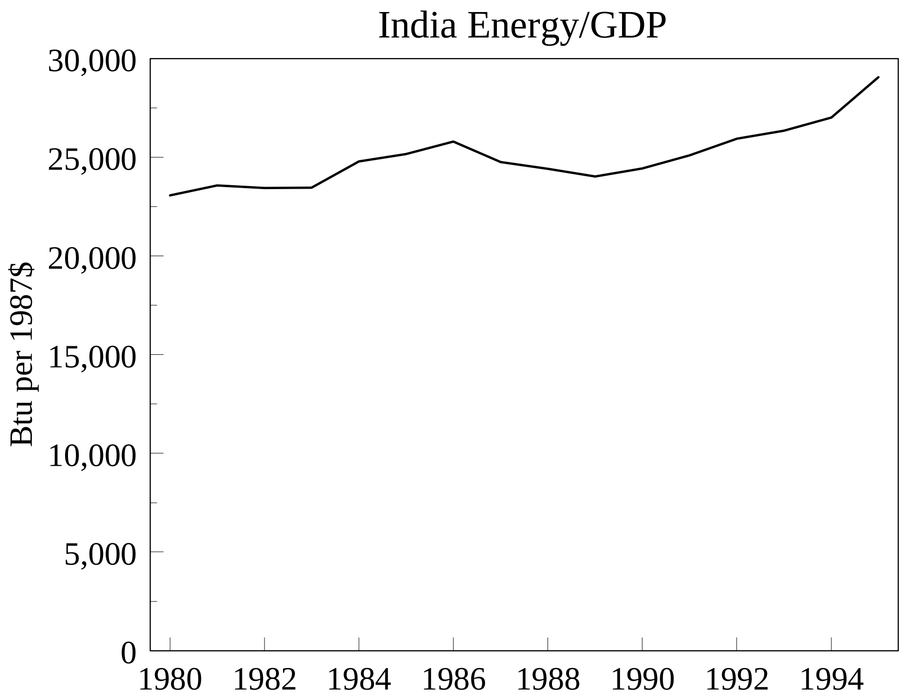
Source: Energy Information Administration 1998a.

E.U. Total Primary Energy Supply Shares, 1995

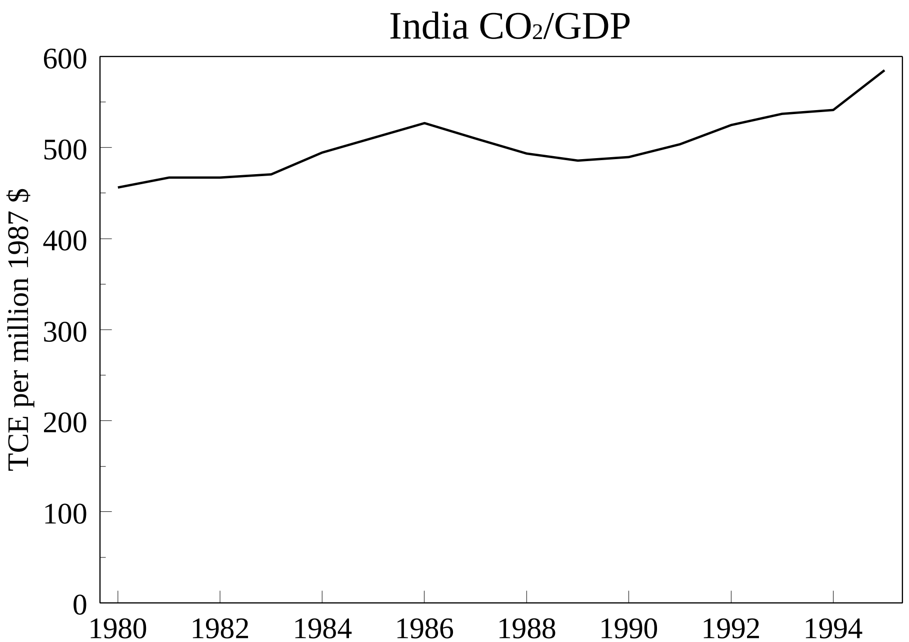


Source: International Energy Agency 1996.

India



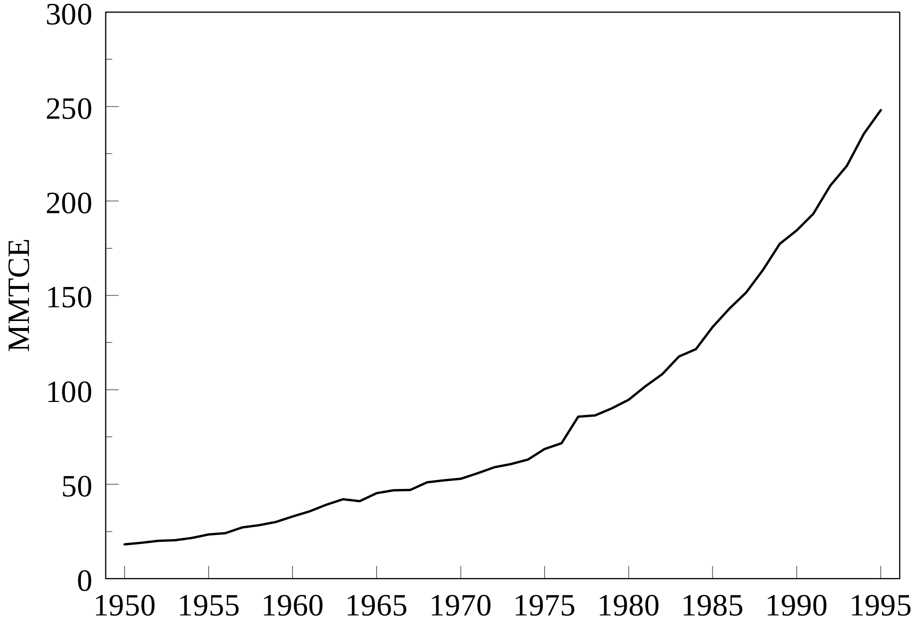
Source: Energy Information Administration 1997c.



Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

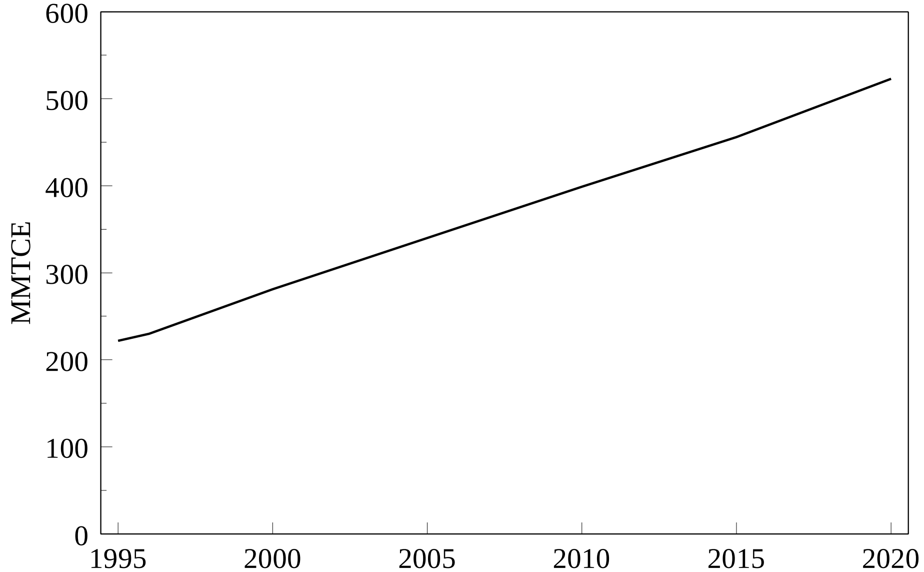
Source: Energy Information Administration 1997c.

India Carbon Dioxide Emissions



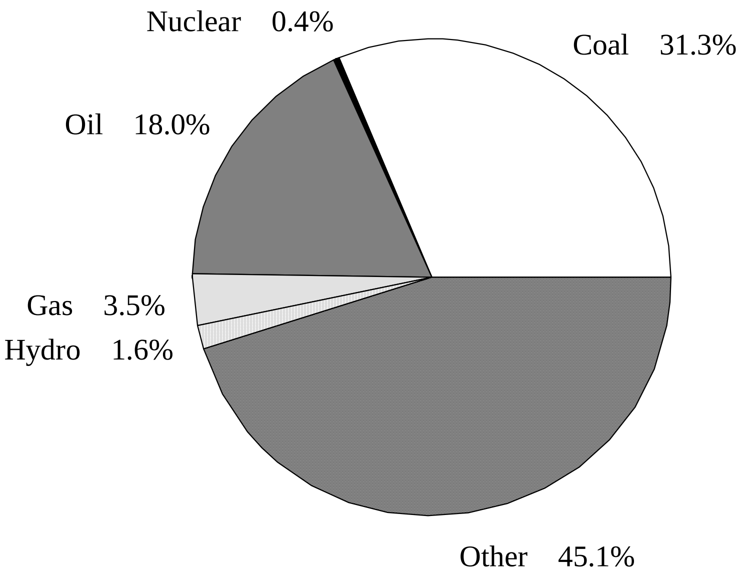
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

Projected India Carbon Dioxide Emissions without New Abatement Measures



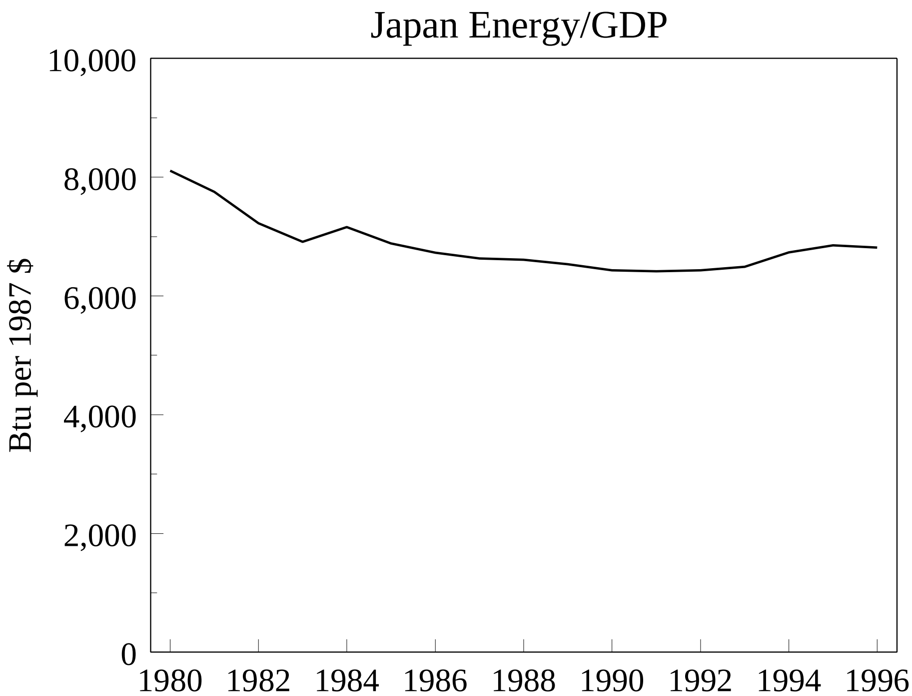
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

India Total Primary Energy Supply Shares, 1995

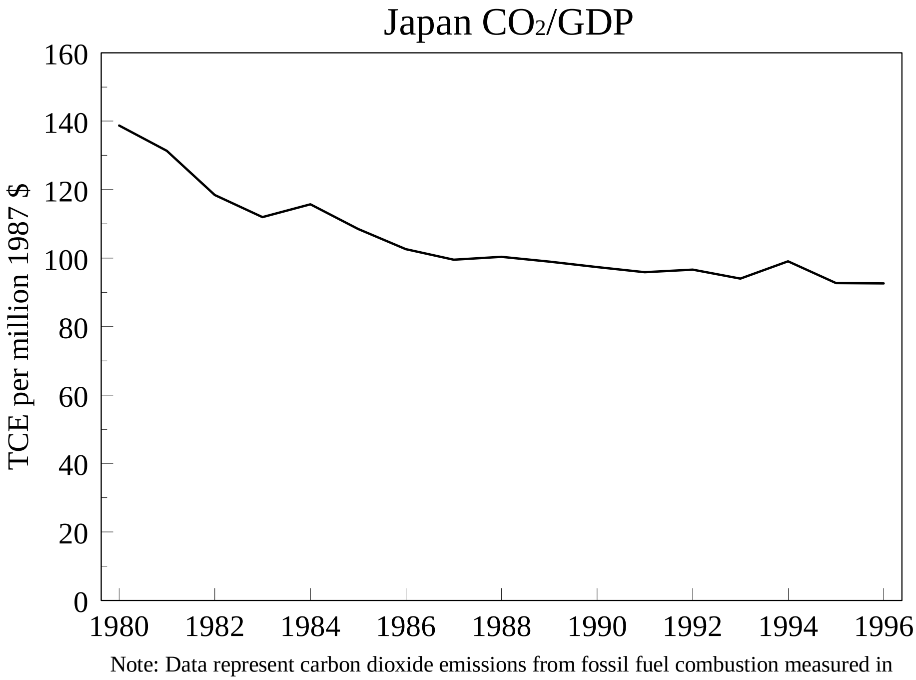


Source: International Energy Agency 1996.

Japan



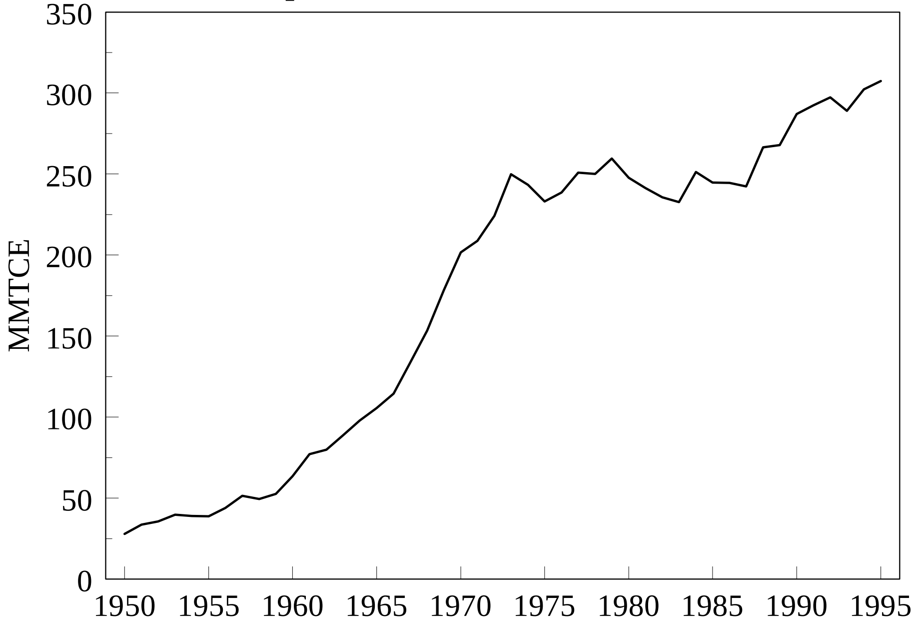
Source: Energy Information Administration 1997c.



Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

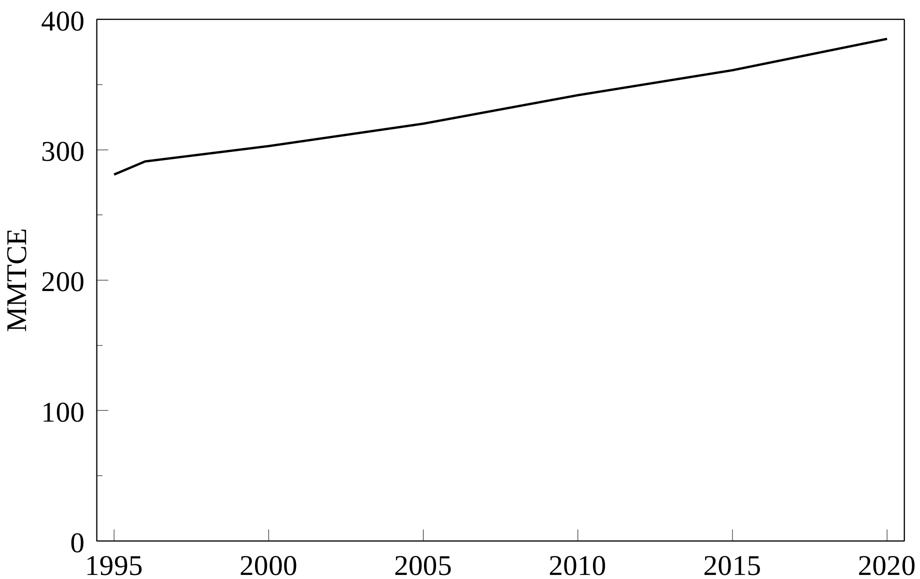
Source: Energy Information Administration 1997c.

Japan Carbon Dioxide Emissions



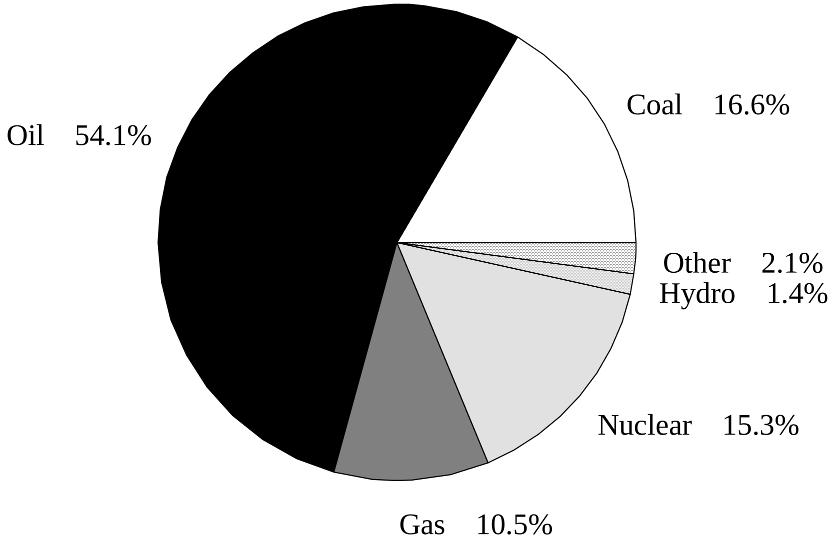
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

Projected Japan Carbon Emissions without New Abatement Measures



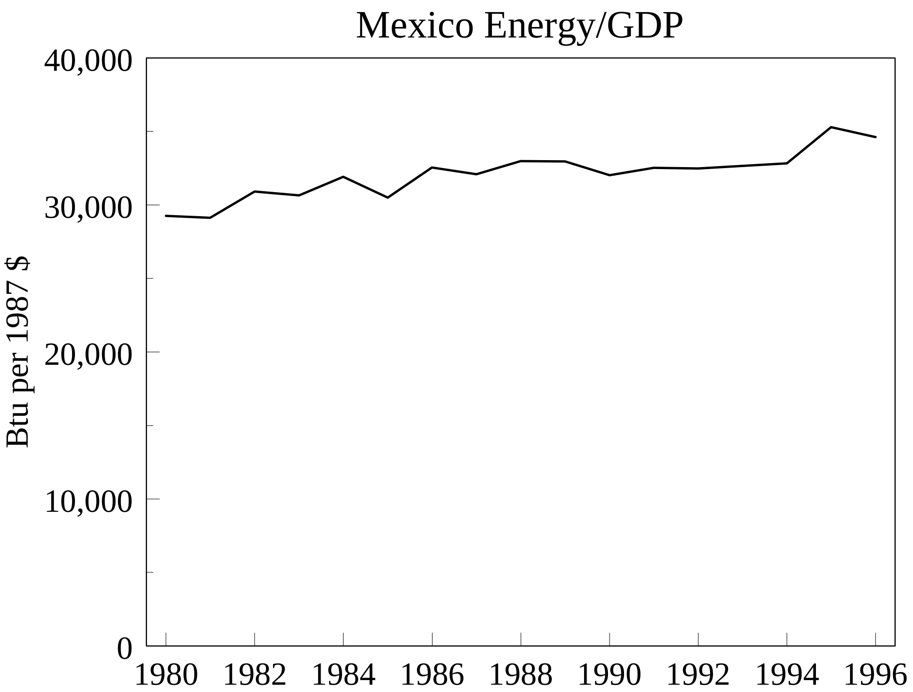
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

Japan Total Primary Energy Supply Shares, 1995

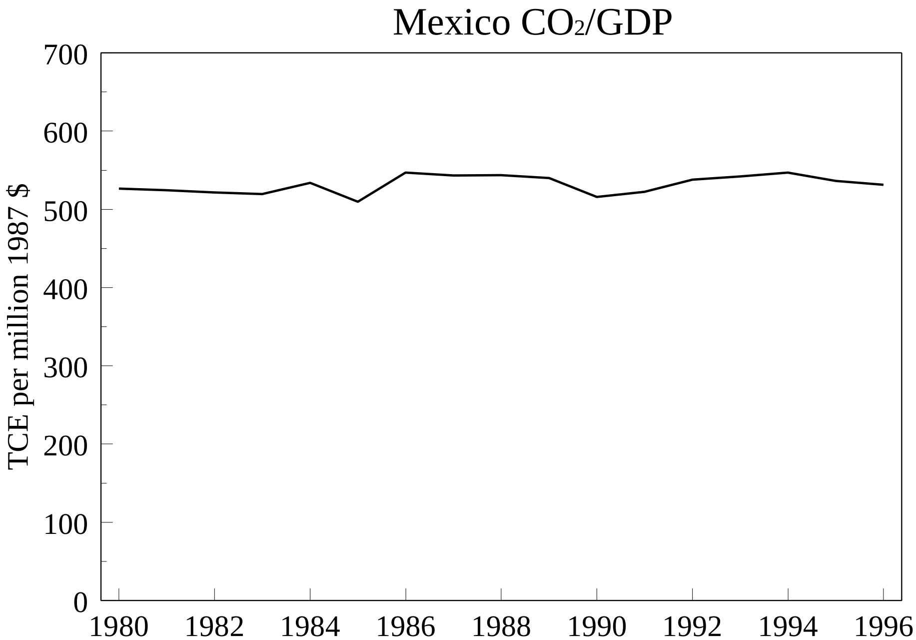


Source: International Energy Agency 1996.

Mexico



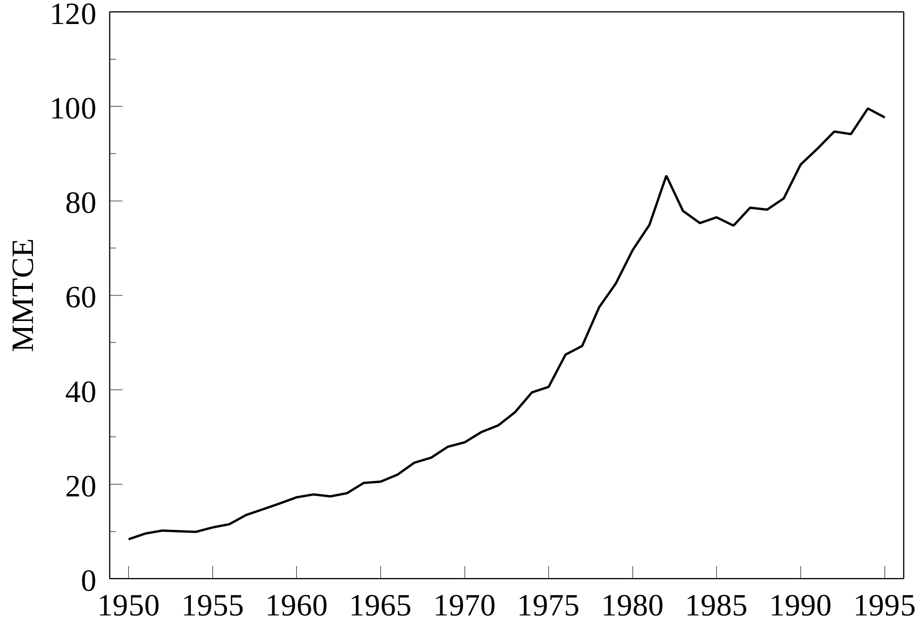
Source: Energy Information Administration 1997c.



Note: Data represent carbon dioxide emissions from fossil fuel combustion measured in carbon equivalent.

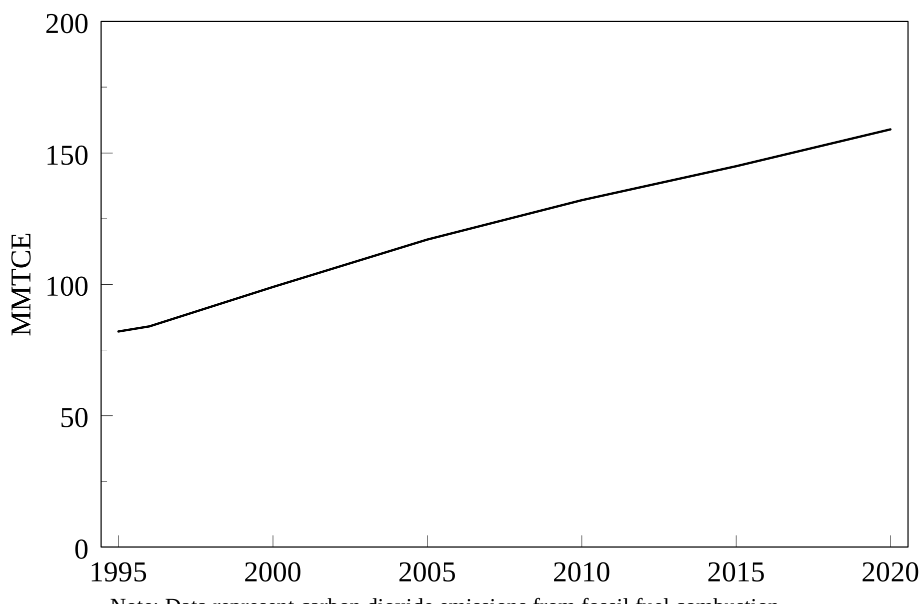
Source: Energy Information Administration 1997c.

Mexico Carbon Dioxide Emissions



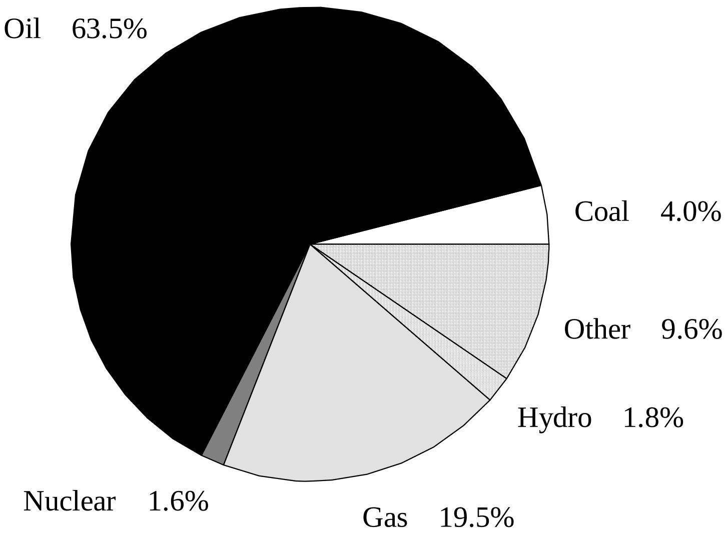
Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Marland and Boden 1998.

Projected Mexico Carbon Dioxide Emissions without New Abatement Measures



Note: Data represent carbon dioxide emissions from fossil fuel combustion.
Source: Energy Information Administration 1998a.

Mexico Total Primary Energy Supply Shares, 1995



Source: International Energy Agency 1996.