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The Economics of Greenhouse Gas Emissions Abatement in China

Over the past two decades, China has experienced an impressive rate of economic growth. Between 1978 and 1997, the size of the economy increased from the 16th largest to the 7th largest in the world, per capita incomes increased by nearly 400%, and energy consumption grew 112%. Like virtually all countries in the world, economic growth also resulted in the growth of greenhouse gas emissions, especially carbon dioxide.

Emissions of greenhouse gases from all countries pose a risk to the global climate. International efforts to address these risks in Rio in 1992 and Kyoto in 1997 recognize the need to abate greenhouse gas emissions while sustaining economic development. Specifically, the Kyoto Protocol calls for the design of markets that will facilitate the transfer of capital and technology to the countries where emissions can be abated at least cost. A country that can abate greenhouse gas emissions at lower cost than others has the opportunity to attract investment for climate-friendly technology that abates emissions and can then sell emissions credits or allowances to higher cost countries. Effectively, Kyoto provides the potential for low-cost abating countries to create an export industry – whose export products are emissions abatement – that could be financed through foreign direct investment.

What is the potential for a fast-growing economy such as China's to create and benefit from such export industries? The economic literature indicates that China has the opportunity to abate more greenhouse gas emissions at a lower cost than any other country. Selling these abated emissions through the Kyoto mechanisms could attract billions of dollars of investment per year that would finance some technology leap-frogging in the energy generation and industrial production sectors. In addition, abating carbon dioxide, for example by improving combustion efficiency of coal power plants, would reduce emissions of local air pollutants that carry significant economic costs through lost worker days, additional health care expenses, and premature mortality. The potential is clearly available for China to be better off economically through the development of an emissions abatement export industry.

This paper provides an overview of this potential drawing from economic research on China conducted by academic, industry, and government analysts from around the world. First, the paper presents a description of the trade-oriented mechanisms in the Kyoto Protocol that will promote capital and technology flows for emissions abatement. Second, it reviews the extensive literature on the potential economic gains associated with participation in the Kyoto mechanisms. Finally, it describes the potential improvement in public health associated with abating emissions of local air pollutants that usually accompany carbon dioxide abatement.

I. Opportunities to Participate in Kyoto Flexibility Mechanisms

The Kyoto Protocol establishes three mechanisms that, if designed and implemented efficiently, could provide the foundation for a global emissions market. Through international emissions trading (Article 17), joint implementation (Article 6), and the Clean Development Mechanism (Article 12), an emissions reduction would have economic value in the international emissions market.

Since greenhouse gas emissions have the same climatic consequences regardless of where they occur, the least-cost approach to addressing the risks of climate change would be to reduce emissions wherever such reductions are cheapest. This implies that emissions abatement has the economic property of a commodity, which facilitates the evolution of a market where entities that demand emissions abatement (e.g., those with high abatement costs) can funnel capital and/or technology to suppliers of abatement. In such a market, countries with low emissions abatement costs could take advantage of the opportunity to "produce" emissions abatement and to export these abated emissions, as certified emissions reductions or tradable allowances, at lower costs than other, higher-cost countries. Just as in the production of commodities, low-cost producers could attract foreign direct investment to finance their emissions abatement industry.

This potential evolution of an international emissions market reflects some of the experiences and lessons learned from the international trade in a variety of goods and services. The concept of gains from trade in emissions allowances is the same as it is for trade in goods and services. For example, Frankel (1999) notes that developing countries could "specialize in installing clean new-technology power-generation capacity, while industrialized countries specialize in producing the capital goods that go into those plants" (p. 4). Toman et al (1998) also note that "[t]hose countries which find themselves with lower abatement costs and more generous emission ceilings can generate a valuable commodity to export" (p. 3). Thus, developing countries would export emissions abatement, and use their export revenues to import, among other things, these new energy technologies.

The gains from trade in emissions allowances occur as a result of the large differences in marginal abatement costs across countries. Weyant and Hill (1999) note that "if the marginal cost in any country participating in a trading regime is higher than in any other participating country, it is advantageous to both countries for the higher cost country to buy emissions rights at a price that is between the two marginal costs" (p. xvii). However, before reviewing the estimated marginal costs across countries, it is important to understand how the Kyoto Mechanisms, specifically the Clean Development Mechanism and international emissions trading, could serve as the necessary foundation of an international emissions market.

A. The Clean Development Mechanism

The Clean Development Mechanism was incorporated in the Kyoto Protocol to 1) promote sustainable development; 2) contribute to the Framework Convention's climate objective; and 3) to assist Annex B parties in complying with their commitments (Toman et al 1998). The CDM allows for developed and developing countries to work together to design and implement projects in developing countries that abate greenhouse gas emissions. These projects must undergo a review process to certify that the emissions reductions are below what would have been otherwise. In addition, a portion of the proceeds from the project must be used for an adaptation fund for low-income countries especially vulnerable to climate change and for administrative costs of the CDM. Under the Buenos Aires Plan of Action, the rules for the Clean Development Mechanism are scheduled to be developed by the sixth Conference of the Parties.

In addition to firms in developed and developing countries working together to design and implement specific projects, some have suggested that governments could cooperate to design project "fast-track" processes (Chayes 1998). To reduce some of the transaction costs associated with participating in the CDM, two countries could design a fast-track process that makes the project approval process more transparent to the private sector and simplifies the rules for approval.

[Brazilian example?]

However, even these efforts to promote sustainable development by increasing the number of CDM projects probably would not compare to the likely volume of capital and technology flows expected for a country with an emissions target that is participating actively in international emissions trading. The CDM carries with it several transaction costs, such as project approval and certification, the adaptation charge, and a charge to cover administrative expenses that reduce the potential cost-effectiveness of this approach relative to a less-burdened trading system. It should also be noted that non-Annex I countries that adopt emissions targets could be able to participate as a host to CDM projects until the beginning of the commitment period, at which time, it would participate in international trading.

B. International Emissions Trading

Articles 3 and 17 of the Kyoto Protocol allow countries with binding targets to lower the cost of meeting their targets by participating in international emissions trading. These binding targets take the form of an "assigned amount" – the number of metric tons of greenhouse gases (counted in carbon dioxide equivalent) that may be emitted by sources within the country during the five-year commitment period running from 2008 through 2012. In emissions trading, one country transfers part of its assigned amount to another. This transfer of assigned amount lowers the number of tons of greenhouse gases that the first country may emit between 2008 and 2012, and raises the number of tons that the second country may emit by an equal amount. It is useful to think of each one-ton unit of assigned amount as a tradable allowance for one ton of emissions that may be transferred between countries.

Because the cost of controlling greenhouse gases differs by many times from country to country, emissions trading will allow substantial gains from trade in meeting the Kyoto targets. Countries that have relatively inexpensive ways to control greenhouse gases have incentives to reduce emissions by more than their targets require, because they can sell tradable allowances that they will not need to others. Countries facing the most expensive control measures have incentives to buy less costly allowances from others, and thereby increase the amount they may emit. Since greenhouse gases are global pollutants, the environmental impact of reducing them is the same no matter where the reductions take place. The same overall reduction is achieved, total costs are reduced, and both buyers and sellers gain from the savings allowed by trading.

A country that wants to increase the number of tons of greenhouse gases that it is allowed to emit would seek out other countries that are willing to sell some of their tradable allowances. Buying and selling countries could arrange their transactions directly or use brokers or exchanges. Because of the voluntary nature of trading, a selling country would engage in a trading transaction only if it makes that country better off.

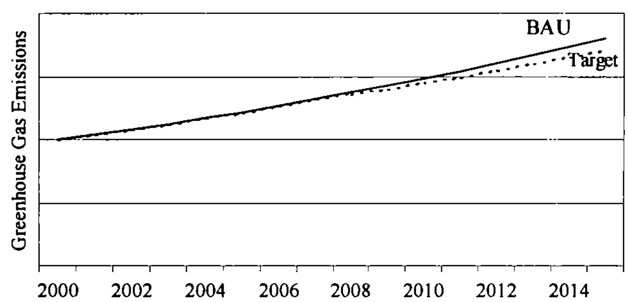
In addition to trading at the governmental level, some countries (including the United States) plan to use both domestic and international emissions trading at the company level as part of their program to meet their Kyoto commitments. Companies and other legal entities subject to these domestic trading programs (integrated with the international trading system) would have strong incentives to look constantly for innovative ways to abate their greenhouse gas emissions. Those who found inexpensive opportunities to abate their emissions could sell the allowances they do not need to other companies or countries who face higher costs. Further, some companies that have climate-friendly technology may find it cost-effective to transfer this technology to facilities in a low-cost abatement country in return for tradable allowances. These tangible rewards for innovation should provide the incentive for research and development and subsequent technological breakthroughs (Petsonk et al 1998).

As stated above, the Kyoto Protocol stipulates that countries must have an emissions target to engage in international emissions trading. Since the Kyoto Conference, several non-Annex I countries have expressed an interest in emissions targets. Consistent with the Framework Convention on Climate Change, targets for non-Annex I countries should help promote their sustainable development. To do so, such targets should accommodate emissions growth. Unlike Annex B targets, which were set below most countries' current emissions levels, such a target for non-Annex I countries would be set above current emissions levels. To contribute to the international effort to address climate change risks, it would also be desirable for such targets to result in real abatement in emissions below levels that would otherwise occur during the commitment period – that is, below the projected business as usual (BAU) emissions level. This kind of target, often referred to as an emissions growth target, would provide for continued economic development but with a lower emissions growth rate.

If developing countries were to agree to binding limits, even if they involved only small cuts below BAU in the first budget period, then such targets, with trading, would imply gains for their economies and gains for the environment. Figure 1 provides an illustration of an emissions growth target. Such a target could be expressed as some percentage of a base year, in a similar fashion to Annex B targets, but with a different base year and a percentage greater than 100% to account for emissions growth.

The term "business as usual emissions level" as used in this paper is synonymous with the term "reference emissions level."

Figure 1. Illustration of a Developing Country Growth Target



An emissions target could also take alternative forms. Some have expressed concerns about the uncertainty associated with BAU emissions projections (Baumert et al 1999). A country that takes on a commitment for the 2008-2012 period that is fixed *now*, faces the risk, for example, that its economy will grow more rapidly than expected, resulting in an inadvertently stringent target. Alternatively, a country's economy could grow less rapidly than expected, resulting in an inadvertently lax target. There are, however, ways of designing targets to reduce uncertainty and mitigate these risks. In particular, targets could be indexed to future values of economic and other, possibly demographic, variables.

A target could, for example, be indexed to a country's economic performance between now and the start of the 2008-2012 commitment period (Frankel 1999). This approach is used in the private sector, where contracts are frequently indexed. This approach is also used in the public sector (e.g., the U.S. government provides cost-of-living adjustments for social security recipients). A target could then be specified in a way that depends on the future values of economic variables, such as GDP. For example, Baumert et al (1999) have argued for a carbon-to-GDP intensity measure as an appropriate form of developing country commitment. Zhang (1999) also discussed a greenhouse gas emissions per unit GDP measure as the basis for a voluntary commitment by China around 2020.

Such targets would avoid the risk of inadvertent stringency associated with higher than projected economic growth between now and the beginning of the commitment period in 2008. Non-Annex I countries would face only the much smaller risk that emissions would be higher than expected, *given* the economic conditions realized in 2007. Similarly, such targets would also avoid the risk of inadvertent laxness associated with lower than expected economic growth between now and the start of the commitment period.

An indexed emissions growth target set slightly below the 2010 business as usual emissions level could result in economic gains from trade for all trading participants. Further, participation in international emissions trading could attract investment capital and facilitate the transfer of technology to a greater extent than would be anticipated under the CDM, and the investment in clean-energy technologies would help address the local air pollution problems. Finally, the indexed nature of the target would reduce the risk that a target could be too stringent or too lax due to unanticipated economic performance between now and the commitment period.

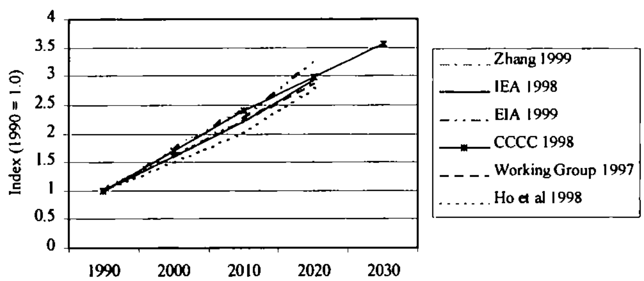
II. Economic Gains from the Clean Development Mechanism and Emissions Trading

A variety of economic models have been developed throughout the world that can evaluate the potential economic gains from trade in emissions allowances. These economic tools effectively model trade in emissions as if they were any other internationally tradable commodity where both production costs and demand vary across countries. However, before reviewing the summary of model results for China, it may be useful to consider some relevant statistics regarding China's projected energy trends. These data will facilitate an understanding of and provide some context for the model results presented below.

A. Illustrative Energy and Economic Statistics

China's economy is expected to continue growing at a strong pace. The International Energy Agency (1998) projects China's economy will grow 5.5% for the 1995-2020 period, while IEA projects OECD countries' GDP to grow on average about 2% over this time period. The higher economic growth rate will likely result in a higher emissions growth rate. However, projected emissions in China are estimated to grow at a slower rate than GDP growth, consistent with the declining energy-to-GDP ratio trend of the past twenty years (IEA 1998, CCCC 1998).

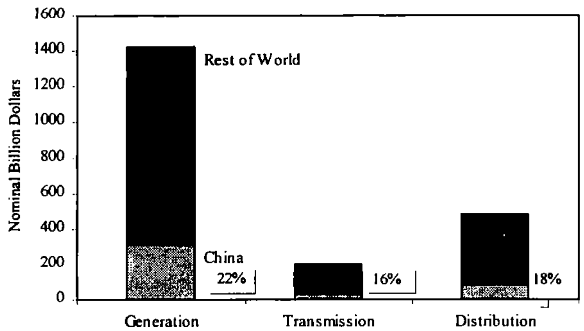
Figure 2. Growth in Carbon Dioxide Emissions, 1990 to 2030 Projected under Business As Usual



Emissions growth rates through 2010 across six different business as usual projections appear to be fairly similar (figure 2). The differences in projections also appear to be influenced by different economic growth rate assumptions. Indeed, energy-to-GDP projections by many of these analysts follow very similar trends of continued improvement. These forecasts illustrate that the recent decoupling of carbon emissions and economic growth will likely continue into the future.

Because of the higher growth rate, China has more opportunities than many OECD countries 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.

Figure 3. Cumulative Projected Worldwide Electric Power Investments by Region, 1995-2010



Source: Energy Information Administration 1998

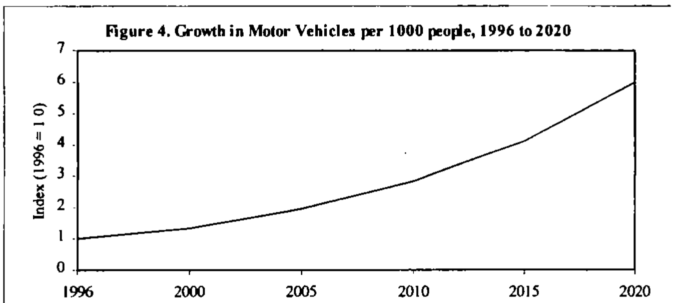
The faster economic growth expected in China implies a higher rate of investment than most OECD countries. For example, investments in electric power generation in China are projected to comprise nearly ¼ of total world generation investment between 1995 and 2010 (figure 3). Many of these Chinese investment projects are likely to increase total generation, while a larger share of OECD investments will likely replace existing power plants. Current Chinese coal plants are about 25 to 33% less efficient than developed countries' coal plants (Fang et al 1998). Investing in power technologies with comparable efficiencies to developed countries' plants could significantly reduce Chinese emissions per unit of electricity generated. Further, one out of every six dollars expected to be invested in transmission systems around the world will be spent in China through 2010. Improving transmission efficiency in China – where transmission losses are twice those found in developed countries and can range up to 30% (Ni and Nien 1998) – through these investments can further reduce emissions per unit of energy consumed.

Differences in energy efficiency between China and developed countries also exist in various industrial sectors. Table 1 illustrates some of these differences in industrial production activities. As these industrial sectors in China evolve, new investment could be leveraged by the value derived from generating emissions abatement to install more advanced, more energy-efficient production technologies.

Table 1. Comparison of Physical Energy Efficiency in Industrial Production between China and Western Countries

Production Activity	**China**	**Western Countries**
Industrial Boiler	55-60%	75-80%
Industrial Furnaces	20-30%	50-60%
Thermal Electrical Power	25-30%	35-40%
Steel Industry	1.0 tce/ton of output	0.7 tce/ton of output
Synthetic Ammonia	2.1 tce/ton of output	1.15 tce/ton of output
Cement	0.2 tce/ton of output	0.13 tce/ton of output

Source: Fang et al 1998, p. 125.



Source: Energy Information Administration 1999

As per capita incomes continue to rise in China, the number of motor vehicles per capita is projected to increase much faster (figure 4). Between 1996 and 2010, motor vehicles per capita is projected to triple, and then double again by 2020 (EIA 1999). Since Chinese fuel intensity in highway transport is 25% higher than in developed countries, and domestic-made vehicles consume 30-40% more fuel than comparable import vehicles (Lin and Polenske 1998), this growth in vehicle usage could significantly increase emissions. However, this differential in fuel economy also illustrates another potential opportunity to improve energy efficiency as the transportation sector continues to expand.

B. Clean Development Mechanism

The Clean Development Mechanism can serve as a vehicle for transferring technology from developed countries to developing countries. In addition, CDM projects can provide investment opportunities for clean energy technologies developed within developing countries. CDM projects will attract investment from firms in developed countries if they generate a sufficient economic return, which includes the value of the certified emissions reductions. The technologies to be diffused through the CDM most likely will be focused in the energy sector.

China has many options for improving efficiency in the energy sector with the continued use of coal. For example, Atmospheric Fluidized Bed Technology achieves thermal efficiency rates of 34-37% by combusting a circulating mixture of coal and gas. If an AFBT plant of X MW displaced a X MW Y coal-fired plant that was part of China's base load, then X MMTC per year could be abated. Further, Integrated Gas Combustion Cycle (IGCC) is the state of the art in electricity generation from coal. IGCC employs coal gasification along with gas turbines to achieve efficiency rates of 38-45% with SO_2 removal technology in place (Fang 1998). Desulfurization efficiency can reach levels as high as 99%, and the technology can reduce levels of NO_x formation by 25% to 50% when compared to a traditional pulverized coal plant (Government of China 1996). An IGCC plant displacing the same Y coal-fired plant discussed above could abate X MMTC annually.

China has extensive potential for the development of wind power especially along the coastline and in the north. Large-scale wind projects could directly replace coal plants and can usually start generating electricity within a year of beginning construction. Two examples highlight the potential for wind power. One effort, begun in the 1980s to subsidize rural electrification in Inner Mongolia, has generated 140,000 small systems, employed 15,000 technicians, and fostered 42 Chinese enterprises engaged in wind power development. Another project imported medium scale turbines to create a wind farm in Dabancheng, Xinjiang. Overall, China has about 30 MW of grid-connected wind power in operation (Fang 1998).

[Natural gas example]

In addition to technology investment opportunities in the energy sector, several technologies in industrial sectors could also have potential under the CDM. For example, the direct reduction technique for iron smelting could decrease energy use per unit of output. This process uses gas or liquid fuel and non-coking coal as a reducer to smelt iron. It achieves energy savings of 40-50% over blast furnace methods and can reduce carbon dioxide emissions by 50-60% per ton of steel produced (Government of China 1996).

To evaluate the economic potential of the CDM, several Dutch analysts modified their WorldScan model to account for some of the characteristics of the CDM (Bollen et al 1999). While the analysts did not include an adaptation or administrative charge, or costs associated with project review and certification, they designed the model so that it would mimic the efforts of private firms to cost-effectively invest in large energy projects. Thus, they analyzed CDM projects only in the form of investments that alter the input intensities of existing production capacity or replace existing capital. With this assumption, and assuming no trading among Annex I countries (thereby assuming higher demand for CDM credits than under an Annex I trading assumption), Bollen et al found that China could profitably abate approximately 150 MMTC annually during the first commitment period through the CDM. The WorldScan model estimates that the price for the certified emission reduction would be $X/ton.

Since a project-oriented approach, like the CDM, may not deliver least-cost abatement first like a tradable permit or tax system, some have argued that the CDM will deliver fewer tons of emissions abatement at a given price of carbon than a trading system (MacCracken et al 1999). Indeed, because of the complexity of the CDM, Manne and Richels (1999) assumed that a developing country would be able to generate only 15% the emissions abatement through the CDM that it would by adopting an emissions target set at 2010 business as usual and engaging in international emissions trading using their MERGE3 model. With this model, Manne and Richels estimate that Annex I trading plus CDM participation by all developing countries would result in a price of carbon of $97 per ton. At this price, China would find it economic to abate 16 MMTC per year during the commitment period, generating revenues from the sale of certified emissions reductions of $1.5 billion annually.

C. International Emissions Trading

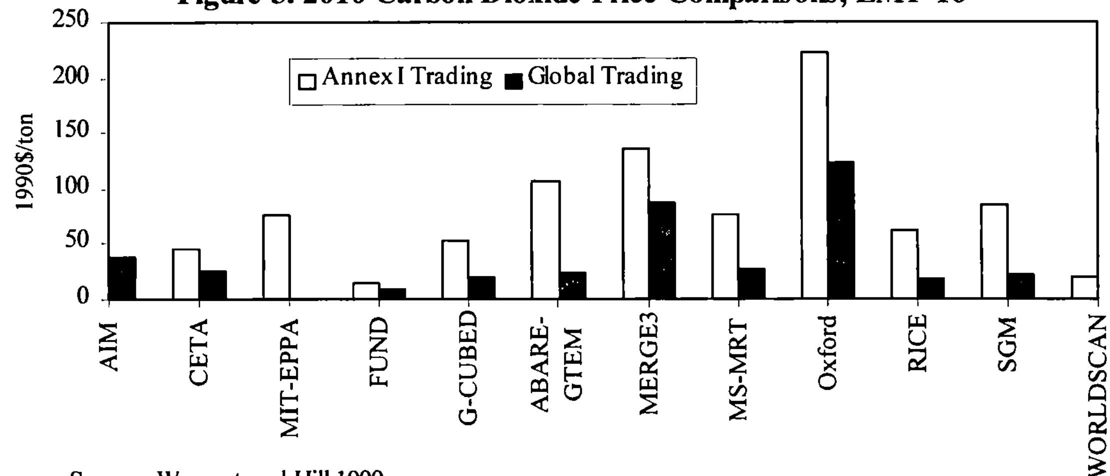
A variety of international energy-economic models have been used to evaluate the potential economic implications of the Kyoto Protocol. For example, the Stanford University Energy Modeling Forum coordinated a modeling comparison exercise involving 13 models developed by teams in Europe, the United States, Asia, and Australia. Further, the Organisation for Economic Cooperation and Development (OECD) hosted a workshop in 1998 where 9 modeling teams presented their assessments of the Kyoto Protocol.

These models assess the projected marginal cost of abating carbon dioxide across countries and then estimate the extent of buying and selling in an international emissions market until no further economic gains can be achieved through subsequent trades – i.e., they find the market clearing price for an emissions allowance. For estimating the marginal cost within a country, most of these models evaluate a country's potential emissions abatement by assuming that such abatement occurs at least-cost. This effectively represents the effects of a domestic tradable permit system or a domestic emissions tax. In the case of China, emissions abatement is assessed in these models assuming that the incentive to abate is provided through an instrument comparable to the U.S. sulfur dioxide trading system, but where carbon dioxide is traded, or some of China's pollution discharge fees (Panayotou 1998), but where carbon dioxide is taxed. Such a policy approach would provide the incentive to attract carbon-efficient technologies like those discussed in the CDM section above, but at a higher volume than would be expected under the CDM. These models provide estimates of marginal cost (e.g., price of one ton of carbon abatement), emissions abatement by country, capital transfers by country, and measures of total economic costs or benefits.

All estimates of carbon prices are in 1998 U.S. dollars per ton of carbon equivalent, unless specified otherwise.

In scenarios involving non-Annex I countries, these models assume that developing countries adopt emissions targets set at 2010 business as usual emissions levels and participate in international trading. Figure 5 presents results from 12 models that participated in the Stanford University Energy Modeling Forum Kyoto Protocol exercise (EMF-16).

Figure 5. 2010 Carbon Dioxide Price Comparisons, EMF-16

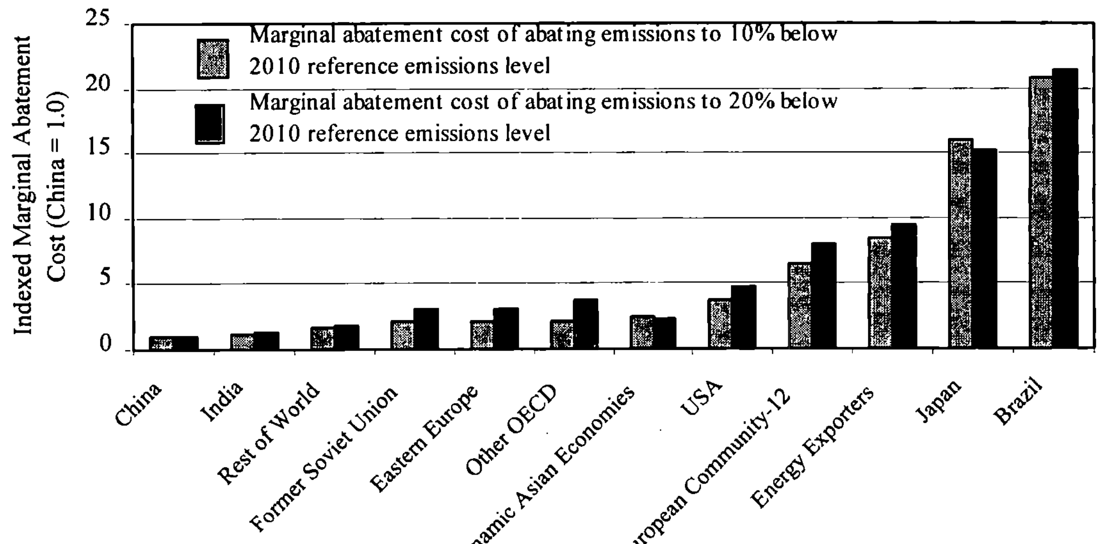


Source: Weyant and Hill 1999

While the price of a ton of carbon may vary across models, several common lessons can be drawn from these results. First, gains from trade, especially in expanding trading from Annex I countries to all countries, can be substantial. All the models found that marginal and total costs fell going from Annex I to global trading, because developing countries can undertake low-cost emissions abatement and sell their emissions abatement to OECD countries. Second, higher rates of economic growth in OECD countries increase demand for emissions allowances, while higher rates of economic growth in developing countries create more opportunities to substitute carbon-lean technology, and thus increase supply of low-cost emissions abatement. Third, countries with larger coal shares of total energy have more opportunities to abate emissions through energy efficiency and fuel switching than countries with smaller coal shares.

These model results provide illustrations of the possible characteristics of an international emissions market. What kind of role can China play in this emissions market? Analyses based on the EPPA model developed by researchers at the Massachusetts Institute of Technology indicate that China has the lowest marginal abatement cost of any country or region in the world (figure 6). To abate emissions to 10% below 2010 projected business as usual levels, Japan realizes marginal costs 16 times greater than China. The European Community would experience marginal costs more than 6 times greater than China, while the United States would witness marginal costs nearly 4 times greater. The relative differences in marginal costs increase as countries move from abatement of 10% below 2010 BAU to 20% below 2010 BAU. Further, no developing or transition economy countries have marginal costs lower than China's marginal cost. Thus, in this international emissions market, China would be the lowest-cost producer of emissions abatement.

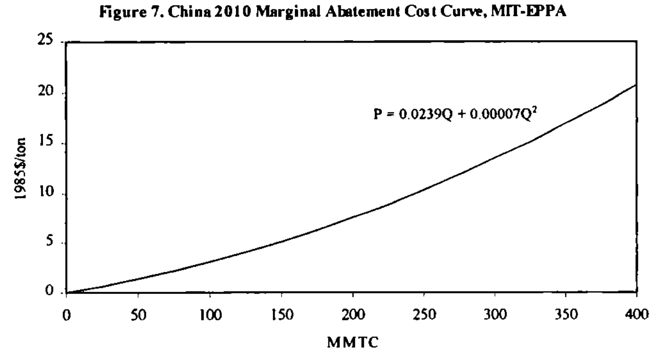
Figure 6. 2010 Marginal Abatement Costs Across Countries in MIT-EPPA Model



In addition to having the lowest abatement cost to achieve a percentage abatement below 2010 business as usual, as the largest non-Annex I economy, these modeling results illustrate the potential for China to be the largest producer of emissions abatement. Several of the EMF-16 modeling analyses also confirm the potential for China to produce the largest quantity of emissions abatement.

For example, Ellerman et al (1998) have estimated the marginal abatement cost curve for China with the MIT-EPPA model presented above (figure 7). With this marginal abatement cost curve, or emissions abatement supply curve, one can estimate the number of tons abated in 2010 at a given price of carbon. In

Figure 7. China 2010 Marginal Abatement Cost Curve, MIT-EPPA



Source Ellerman et al 1998

their assessment of global trading, they found that the market price for a ton of carbon would be $23.80 (1985$). At this price, China would find it economic to abate 436 MMTC in 2010. This estimate of emissions abatement is larger in absolute terms than the some other estimates (e.g., MacCracken et al 1999), but because Ellerman et al project a higher emissions growth rate for China, the projected abatement as a percentage of BAU is rather similar between these two models. If China had a target set at 2010 BAU, Ellerman et al estimate that it could sell $10.4 billion per year in emissions allowances which would generate gains from trade of $6.2 billion per year on average during the first commitment period.

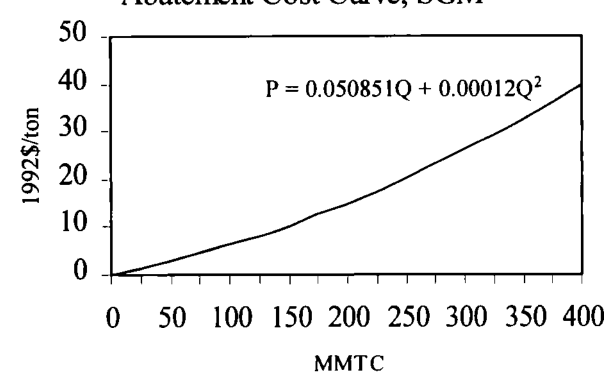


Figure 8. China 2010 Marginal Abatement Cost Curve, SGM

MacCracken et al (1999) employed the Second Generation Model (SGM) to evaluate the international emissions market assuming global participation. The SGM includes a China module, developed in coordination with Chinese energy-economic experts. The marginal abatement cost curve for China has then been estimated with SGM model outputs (figure 8).

They found that under global participation in the international emissions market, the price for a ton of carbon would be $26/ton (1992$), and China would find it profitable to abate 341 MMTC in 2010. With a target assumed to be set at 2010 business as usual, these 341 MMTC of abatement would be exported, generating revenue equal to 0.3% of GDP.

Van der Mensbrugghe (1998) conducted several analyses of the Kyoto Protocol with the OECD's GREEN model. GREEN also includes a distinct China module. Van der Mensbrugghe found that under global trading, the international market price for a ton of carbon would be $19/ton (1985$). At this price, China would find it profitable to abate 228 MMTC. China would be able to sell $4.3 billion in allowances under a 2010 BAU target. In this analysis, Van der Mensbrugghe assumed that China provided the incentive for in-country abatement through a carbon tax, revenues of which would comprise 1.4% of GDP. Moreover, by participating in the international emissions market, he found that China's GDP would increase 0.4% above 2010 BAU.

In addition to the CDM analysis noted above, Manne and Richels (1999) evaluated two other international emissions market scenarios involving China. The researchers found that under global trading, the international market price for a ton of carbon would be $67/ton (19XX$). At this price, China would find it profitable to abate 109 MMTC annually during the first commitment period. China would be able to sell $7.3 billion in allowances under a 2010 BAU target. Further, assuming that Annex I countries and China participate in a trading system, the carbon price is estimated to be $80 per ton. China would find it economic to abate 131 MMTC at this price generating sales revenues of $10.5 billion annually.

In addition to the international economic models used in the EMF-16 exercise, some China specific assessments of abatement potential have been conducted. While these studies cannot explicitly illustrate the potential role of China in an international emissions market, they have the benefit of evaluating the Chinese economy in greater detail, and can provide additional insights about the abatement potential in China.

For example, Garbaccio et al (1999) completed a recent evaluation of a carbon tax on the Chinese economy. Such a tax could mirror other emissions and pollutant charges in China. Garbaccio et al designed a 29-sector computable general equilibrium model based on China's 1992 input-output (I-O) tables. They estimated three streams of carbon taxes necessary to abate emissions 5%, 10%, and 15% below business as usual over a 40-year period. Revenues from the carbon tax were recycled to the economy by proportional reductions in labor and capital taxes, although given the higher rates of taxation on capital than labor, this recycling promotes higher rates of investment. While GDP falls below projected business as usual in the first year of these three simulations, the investment induced by revenue recycling results in GDP growth above BAU after the first year in all scenarios. In this model, China's emissions could be abated by

15% below business as usual at a cost less than $10 per ton, which is well below the estimated Annex I trading carbon prices in the EMF-16 model results. This analysis indicates that China can substantially reduce its greenhouse gas emissions while maintaining or even increasing its rate of economic growth. Participating in emissions trading and exporting emissions allowances would further increase economic benefits and bring in additional capital that could also contribute to economic growth.

While not an explicit modeling exercise, the China Climate Change Country Study (CCCC 1998) did evaluate several scenarios for emissions mitigation. The authors found that in its "policy" case, emissions could be abated over the next 3 decades such that 2030 "policy" emissions were 30% below 2030 business as usual emissions levels. Without accounting for any potential gains from exporting this emissions abatement, the authors found that this mitigation would not reduce economic output from the projected level.

Table 2 summarizes the key findings in the economic-energy modeling literature on the potential economic gains for China in participating in international emissions trading. These results assume that China has an emissions target for the first commitment period set at 2010 business as usual.

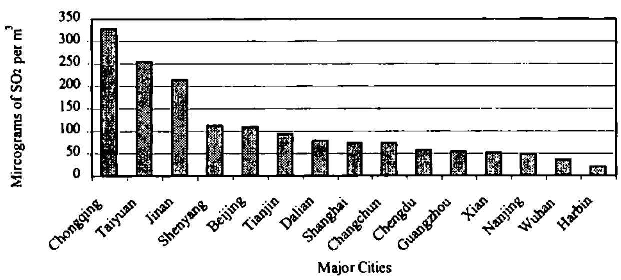
Table 2. Potential Economic Effects of Chinese Participation in International Emissions Trading

Model	**Price of Carbon**	**Emissions Abatement (% below BAU)**	**Value of Sales of Emissions Allowances 2008-2012**
EPPA (Ellerman et al)	$24/ton (85$)	24%	$10.4 billion/year
SGM (MacCracken et al)	$26/ton (92$)	24%	$8.9 billion/year
GREEN (van der Mensbrugghe)	$19/ton (85$)	15%	$4.3 billion/year
MERGE3 (Manne and Richels)	$67/ton (xx$)	8%	$7.3 billion/year

III. Local Air Quality Benefits from Abating Greenhouse Gas Emissions

The same combustion processes that emit carbon dioxide and other greenhouse gases also generate numerous local air pollutants like sulfur dioxide and particulate matter. In its Report on the State of the Environment in China, the State Environmental Protection Administration noted that "atmospheric pollution results mainly from coal-burning" (SEPA 1998, p. 8). This is true for both global and local pollutants. By reducing carbon emissions through the use of coal substitutes and the adoption of more efficient coal combustion methods, China can simultaneously abate greenhouse gases and improve local air quality.

Figure 9. 1994 Daily Average SO_2 Emissions



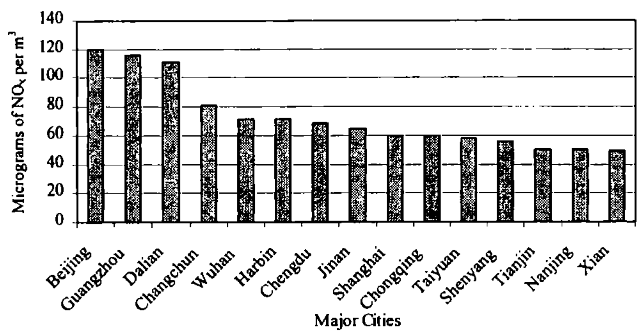
WHO Recommended Level is 50 micrograms per cubic meter

A. Local Air Quality

Local air quality is the most immediate environmental threat facing China. As figures 9 and 10 show a number of China's cities regularly encounter more than 2 to 3 times the World Health Organization's recommendations for levels of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2).

In recent years, the level of pollutants has stabilized due primarily to two countervailing effects (Florig 1997). First, more efficient power generation technology and the use of pollution control devices have reduced emissions from industrial sites. Second, household pollution, primarily a result of cooking and heating with coal, increased substantially, leaving the total pollution levels constant. Estimates from the World Bank (1997), however, show particulate emissions increasing 39% and household smoke increasing 90% between 1995 and 2020.

Figure 10. 1994 Daily Average NO_x Emissions



WHO Recommended Level for NO_2 is 40 micrograms per cubic meter

B. Costs of Local Air Pollution

A number of studies have analyzed the relationship between current high levels of local air pollutants and health problems. Xu Zhaoyi and associates at the Liaoning Public Health and Anti-Epidemic Station estimated that indoor and outdoor pollution cause 60% of urban chronic obstructive pulmonary disease cases (Florig 1997). Research by Xu Xiping at the Harvard School of Public Health and his colleagues found that a one-percent increase in SO_2 and total suspended particulates (TSP) levels increased the number of non-surgical visits by 20% and 17%, respectively (Xu et al 1995a; Xu et al 1995b). Xu Zhaoyi and Xu Xiping have also estimated the effects of pollution on mortality rates in Shenyang and Beijing respectively (Xu 1998). In Beijing, a doubling of SO_2 levels increased the mortality rate by 11% while in

Shenyang, mortality increased by 2% for each 100 g/m^3 of SO_2 and by 1% for each 100 g/m^3 for TSP. The World Bank (1997) estimates that the economic costs from lost work hours, hospital and emergency room visits, and chronic bronchitis at $20 billion per year in China.

Researchers have also documented the effects of pollution on children. Liu Yulin of the Institute of Pediatrics in Beijing found that children's chances of contracting pneumonia doubled if they lived in a home with coal stoves or adults who smoked. He Qingci of the Wuhan Environmental Protection Institute showed that children from Wuhan's urban areas had lung capacities 5% smaller than children from the suburbs where outdoor TSP levels are 50% lower (110 g/m^3 vs. 251 g/m^3). Finally, Xu Zhaoyi found "up to four times more rhinitis, pharyngitis, and tonsillitis [inflammation of the nasal mucous membrane, pharynx, and tonsils, respectively] among children living in areas of heavier outdoor pollution" (Florig 1997).

While these estimates demand consideration, they should be used with caution. This area of epidemiology has a relatively short history compared with other disciplines. As a result, many of the studies ignore the effects of pollution levels over time and may not adequately control for the presence of covariates that could magnify or diminish the estimated effects of pollution levels on public health. This criticism withstanding, the Working Group on Public Health and Fossil-Fuel Combustion (1997) estimates the number of potential lives that could be saved from particulate matter (PM) alone through a 10% reduction from business as usual over the 2000 to 2020 period. The authors project that 1.5 million premature deaths could be avoided in Centrally Planned Asia. Since the study assumes an immediate reduction in the mortality rate after a reduction in PM concentrations, the actual number of premature deaths avoided may extend beyond 2020. Additionally, the study does not account for other causes of death, which brings into question the actual number of life-years these statistical lives represent. By assuming PM distributions similar to the United States, however, the authors underestimate the number of deaths because of China's higher use of coal and residential reliance on coal and biomass stoves.

In addition to public health effects, local air pollution adversely impacts agricultural and silvicultural production activities. The World Bank (1997) estimates that the share of farming and forestry output damaged by sulfur deposition is more than 5% of total economic output in these industries in several provinces. This damage affects commodities representing a value of more than $4 billion annually in the Chinese economy.

C. Options for Carbon Dioxide Abatement and Local Air Quality Improvement

The future increases in pollution levels reflect the growth of numerous small pollution sources, including new power plants, household heating sources, and automobiles. China has set a goal

Centrally Planned Asia includes China, Laos, North Korea, and Vietnam.

of 95% electrification by the year 2000, and to that end, electricity capacity has increased by 200% between 1980 and 1994. Because Chinese generators tend to be small, to run for long life spans, and to have low efficiency levels, significant potential exists both to improve ambient air quality and to generate credits for carbon abatement under an emissions target. Even relatively simple policies such as washing and screening coal could both improve air quality and generate more efficient power, reducing levels of carbon emissions (Murray and Rogers 1998).

Similarly, to reduce congestion on public transportation and to improve commercial service, China has begun encouraging the use of automobiles. Between 1983 and 1990, the automobile stock increased from 1.8 million to 8.2 million and road transportation volume increased at an average annual rate of 13.5% for both passengers and freight while rail volume only increased 7.7% and 5.6% for passengers and freight, respectively (Lin and Polenske 1998). China's emissions standards and automotive technology are similar to those of the west in the 1970's; compared to foreign vehicles, Chinese vehicles emit "2.5 to 7.5 times more hydrocarbons, 2 to 7 time more nitrous oxides, and 6 to 12 times more carbon monoxide" (World Resources Institute 1998). These trends also offer substantial opportunities for simultaneous reductions in local air pollutants and carbon dioxide emissions through improved highway infrastructure and the use of more recent automotive technology.

Finally, most Chinese residents rely on coal and biomass stoves for cooking and heating. These also constitute the main sources of indoor air pollution. If other energy options develop such as natural gas or electricity, then the adoption of gas furnaces or electric appliances would provide an obvious route to reducing pollution levels. Absent these developments, however, options still exist. China's cities, for example, are very dense. This may allow a more centralized control of pollution emissions through large scale heating systems that service multiple housing units (Fang et al 1998).

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Climate change

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Growth Targets for Carbon Emissions from Developing Countries

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Introduction and Summary of Findings

As part of the effort to address the problem of Global Climate Change, the United States has advocated "growth targets" for emissions of greenhouse gases (GHG) by developing countries. A few of these countries are considering the possibility of adopting such targets, and have solicited assistance in how to formulate them. This policy brief presents some basic principles for determining what would constitute appropriate growth targets and discusses several proposals.

- **Environmental benefits**
  - Growth targets even as high as "business as usual" can yield significant **reductions in global emissions** by forestalling the "leakage" that would otherwise occur.
  - Further, when permits are sold, reductions in carbon dioxide emissions generate **ancillary air quality benefits** in the developing countries through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions.
- Targets can result in **economic gains** from trade for all sides, if they are not too stringent.
  - **Economic benefits to developing countries:** With targets at busines as usual (BAU), developing countries would enjoy net gains of billions of dollars through the international sale of emission reductions achieved at costs below the world price.
  - **Cost savings to the U.S.:** Participation by developing countries in international permit markets would greatly lower the costs of meeting its Kyoto target, as analysis by the Council of Economic Advisers has shown. It is estimated that effective trading with developing countries would lower U.S. costs more than 80 percent (as compared to 57 percent savings from trading among Annex I countries alone).
- A "fair" allocation to expect of potential new participants might be a target that fits the apparent pattern agreed among industrialized countries at Kyoto in December 1997. This approach turns out to imply some degree of "progressivity" -- with richer countries asked to make bigger sacrifices than poor ones.
- Given uncertainty about the future, fixing the precise quantitative target now would create great risks regarding the ultimate stringency of the target. It would raise concerns that a target could turn out unexpectedly stringent, unintentionally constraining economic development, on the one hand, or that the target could turn out unexpectedly lax, resulting in "hot air," on the other hand. These risks could be reduced by an indexation approach.

Growth Targets for GHG Emissions from Developing Countries

Many difficulties plague the effort to implement the Kyoto Protocol tbat was negoitatied in November 1997, and the other steps that would be necessary to make a start at reducing global emissions of greenhouse gases with the aim of mitigating global climate change. There are wide chasms to be bridged: the chasm between some Senators and environmentally-concerned scientists and citizens regarding how genuine is the problem, the chasm between the extent of popular concern and the extent of popular willingness to bear even a small increase in energy prices to address the problem, and the chasm between US and European attitudes toward international trading of emission rights. Probably the most difficult chasm that needs to be bridged is between the United States and developing countries regarding the necessity of participation by the latter in any global plan to address global climate change.

The viewpoint from the North

We cannot solve the climate change problem without participation by developing countries. (Developing countries are here defined as those outside the 38 industrialized countries -- and transition countries -- known as Annex I or Annex B countries, that agreed to binding reductions on emissions of greenhouse gases at Kyoto.) Just for starters, the U.S. Senate strongly opposes any agreement that does not include the developing countries. The Byrd-Hagel resolution, which proclaimed LDC commitment to emission targets a pre-requisite for ratifying the Kyoto treaty, was passed by a vote of 95-0.

Senators use words like "competitiveness" and "fairness" to express why they insist on full developing country participation in any plans for emission reductions. Competitiveness is not well-defined in the lexicon of economists. Paul Krugman has explained to us why competitiveness is "a dangerous obsession." And "fairness" is much in the eye of the beholder -- witness the argument by developing countries that a fair distribution of emission rights would be an equal allocation on a per capita basis. It is crucial that developing countries participate. Indeed, the President has said that he will not submit the treaty for Senate ratification until there is commitment to meaningful participation by key developing countries in the first budget period (2008-2012). But I would phrase the reasons differently than does the Congress.

There are several reasons why meaningful participation from developing countries is essential.

- First, a global problem requires a global solution. The problem is inherently one on which an individual countries can make little progress on itsr own. It can be thought of as an "international externality," "the tragedy of the commons," "free-riding," or "global public goods." Whatever you call the problem, a solution requires that all countries agree to participate together.

- The effort to address climate change will not succeed without cooperation by the developing countries because their emissions are the fastest-growing, and will surpass those from the industrialized countries early in the century if everyone proceeds according to business as usual. The crossover is projected to occur by 2010, according to the International Energy Outlook 1999 released by the U.S. Energy Information Agency. China is expected to surpass the United States as the largest single emitter by around 2020. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not go far in averting from climate change.

- If developing countries do not participate in the international regime, their emissions could potentially increase by *more* than they are currently forecast to increase under their business-as-usual baselines. This is the problem of ***leakage***. [redacted] One mechanism for such an unintended consequence of the Kyoto agreement is the relocation of carbon-intensive industries from participating to non-participating countries. Another mechanism is via the oil market. As Annex I countries comply with their targets, their demand for oil will fall, causing the price of oil to fall on world markets, thereby encouraging non-participating countries to use more oil and emit more carbon than they otherwise would have. The result would be that every ton of emission reductions in the North would be partially offset by an increase in the South.[1] [redacted]

- Finally, participation by developing countries is crucial because it would permit relatively low-cost reductions in emissions there to be substituted in place of some high-cost reductions in the industrialized countries. Greenhouse gas emissions have the same basic impact on the climate regardless of where they occur. So reductions in developing countries have the same environmental benefit as reductions in industrialized countries, even though the reductions in developing countries are often much less costly. It thus makes sense, from both an environmental and an economic perspective, to incorporate emissions reductions in developing countries into the international system.

What about "competitiveness"? One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses "loss of competitiveness" to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated. The aggregate trade balance is determined by macroeconomic forces -- the difference between saving and investment[2] -- and not by our environmental policies.

If competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- it is easier to see the possibility of negative effects. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, we need to consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already differ significantly between the U.S. and countries such as Venezuela, and yet U.S. industry is not generally fleeing to Venezuela. Third, approximately two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings.

In short, I believe it more accurate to say that we need developing country participation for the reasons I outlined above -- projected emission paths, the global nature of the public good, leakage, and cost-minimization -- than to say that we need it to avoid adverse effects on competitiveness.

The viewpoint from the South

Developing countries make several arguments on the other side.

- First, their duty is to their citizens. Specifically,

(1a) Their priority must be raising their own economic standards of living.

(1b) This objective includes, in addition to raising market-measured incomes, also beginning to control local air and water pollution. Such pollution already is visible and is taking a large toll on health. Controlling local pollution therefore must take precedence over controlling greenhouse gases, which are not visible and which may not have serious health effects until a century into the future.

- Second, the developing countries should not be required to take any step that entails economic sacrifice until the industrialized countries have done so. There are two reasons for this:

(2a) the industrialized countries created the problem, and

(2b) they are richer and can more readily afford to make sacrifices.

It is hard to disagree with these arguments. But I do not believe that the Clinton Administration is asking poor countries to forego their economic development. "Meaningful participation during the period 2008-2012" need not entail economic sacrifice by developing countries. This argument is not based on diplomatic or political "happy talk", but on sound economic logic, as we shall see.

The gains from trade

I will concentrate on the possibility that developing country participation would take the form of commitment to a quantitative growth target, with international trading. If developing countries were to join the system of targets-with-trading, it would not only have environmental and economic advantages for the rest of the world; it would also have important environmental and economic advantages for the developing countries themselves. For the sake of concreteness, let us begin by considering a plan under which developing countries do no more than commit to their "business-as-usual" (BAU) emission paths in the 2008-2012 budget period and join the trading system.

The first thing to notice is that this system is not going to hurt the developing countries. They have the right in this budget period to emit whatever amount they would have emitted anyway. They need not undertake emission reductions unless a foreign government or foreign corporation offers to pay them enough to persuade them voluntarily to do so.

One anticipates that foreign governments and foreign corporations would indeed offer to pay participating countries enough in the budget period to persuade them voluntarily to reduce emissions below their BAU paths. The reason is that it could get expensive for the United States, Europe, and Japan to reduce emissions below 1990 levels over the next ten-to-fourteen years if the reductions are made only domestically, because this is a short span of time in which to achieve such a major structural change in the US economy. But the cost of reductions is far lower in developing countries. Thus governments and corporations in industrialized countries will be able to offer terms that make emission reductions economically attractive to developing countries. The economic theory behind the gains from trading emission rights is analogous to the economic theory behind the gains from trading commodities. By doing what they do most cheaply, both sides win. In Ricardo's classic trade example, Portugal specialized in producing wine and England in producing textiles. In the current context, developing countries specialize, for example, in installing clean new-technology power-generation capacity, while industrialized countries specialize in producing the capital goods that go into those plants.

Why is it so much cheaper to make reductions in developing countries than in rich countries? One major reason is that, in industrialized countries, one would have to scrap coal-fired power plants far in advance of their 40-year useful life, in order to replace them with natural gas facilities or other cleaner technologies. This would be very expensive to do, because it would mean wasting a huge existing capital stock. In rapidly-growing developing countries, on the other hand, it is more a matter of choosing to build cleaner power-generating plants to begin with, instead of building coal-fired plants. In general, when contemplating large increases in future demand for energy, it is good to be able to plan ahead. This includes learning from the mistakes of others that have gone before, and taking advantage of their technological advances.

The gains from trade can be made more concrete with some estimated magnitudes. The Council of Economic Advisers has estimated -- using the Second Generation Model (SGM) of

Battelle Labs -- [redacted][1]

An extreme example of how measures to reduce carbon emissions have low costs in developing countries is the case of subsidies to fossil fuels, especially coal, which is the most carbon-polluting form of fuel. Eliminating such subsidies would create substantial immediate benefits -- fiscal, economic, and environmental -- even before counting any benefits under a global climate change agreement. Coal supplies the majority of energy in China, for example.[2] A major reason for the heavy use of coal is that it has historically been heavily subsidized. Estimates are that coal subsidies outside the OECD totaled from $37 to $51 billion worth in 1991-92. Total fossil fuel subsidies have been much greater -- well over $200 billion in the early 1990s, though smaller now. A 1994 study estimated that removing them would reduce global emissions by 7%. A 1995 study estimated that energy subsidies currently act as a negative carbon tax of about $40 per ton, and that global CO_2 emissions would be reduced by 4 to 5 % if all energy subsidies were removed. Some countries have already reportedly reduced the dollar value of such subsidies substantially in recent years, such as China (and other Asian countries, Argentina, Brazil, South Africa, and some oil-producing countries). Non-OECD countries cut fossil fuel subsidies by half between 1990-91 and 1995-96. But more progress is needed. Subsidy cuts within a target-and-trade system would pay developing-country governments twice over -- once in the form of the money that is saved by eliminating wasteful expenditure, and then again in the form of the money that is paid by an Annex I country for the resulting emission reductions.]

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Summary of Benefits of Targets-and-trade

To summarize: [redacted] There are five reasons:

- [redacted]

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[1] Emissions abated would be roughly 19% of Mexico's BAU. India is estimated to abate about 18% of BAU. China abates about 20 % of BAU. The worldwide price of emission permits falls by half, relative to trading among Annex I countries alone The estimated gain in each case is the area under the marginal cost of abatement curve.

[2] 76% of commercial traded fuels, including nuclear and hydro. The figures are 57 % in India and 36% in Africa. Other statistics are given in a March 1997 World Bank study.

- [redacted]

- [redacted]

- [redacted]

- [redacted]

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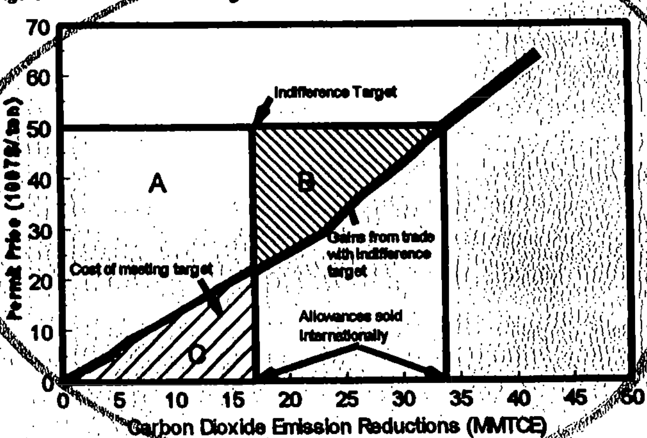
A Lower Bound Target: The "Indifference" Level

If developing countries were prepared to countenance emission targets, how should the level be determined? A reasonable number for the countries themselves to propose would be BAU targets. As noted, targets at that level have environmental and economic benefits for everyone involved. But the Annex I countries, and especially the environmentalists residing there, will respond by demanding targets that represent cuts in emissions, below the BAU path. Such a demand could also be viewed as reasonable, unless the proposed cuts were so large as to inflict economic damage. A lower bound to what could sensibly be proposed is what I will call the indifference level. Anything above BAU will not necessarily benefit Annex I countries, while anything below the indifference level will not necessarily benefit the others. Clearly the aim should be to fall somewhere in this range. For either side to propose a point outside the range would be equivalent to a rug-merchant in the bazaar asking a price higher than the customer can get the same rug for back home, or else equivlant to the customer asking a price lower than the cost to the merchant.

[redacted]

Figure 1. Illustrative 2010 Marginal Abatement Cost Curve and Indifference Target



Note: For simplicity, this indifference target is illustrated for a country whose participation in world permit markets does not affect world permit prices.

[redacted] Further reductions are cost-efficient as well. But the cost rises with the magnitude of the reduction, tracing out the upward sloping supply curve. If the equilibrium world price is $50 a ton, then it pays this country to reduce emissions by about 34 MMTCE and sell all of this at a profit. (The last metric ton costs as much to abate as the $50 that the permit fetches on the world market.) The windfall for a country with a target that does not build in reductions relative to BAU is the entire area in the upper triangle (A+B).

It may not be considered reasonable for all these gains to go to the developing country. A requirement that the country must reduce emissions a certain amount before beginning to earn money by selling permits would balance the gains from trade more evenly. [redacted] This is the indifference level.

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[3] This analysis presumes that non-Annex I countries abate their emissions cost-effectively, e.g., through a tradable permit system or a carbon tax.

[4] This hypothetical example assumes that the country in question does not reduce emissions in response to other policy initiatives. [If this country were to participate in an effectively-operating Clean Development Mechanism (CDM) under the case where it did not adopt a target, then its indifference target would not be at the level where net gains from trade are zero, but rather where expected net gains from trade would equal expected net gains from the CDM. The CDM option implies that the indifference target would

As a numerical example of the effects of increasing the stringency of an emissions growth target, consider results from some modeling scenarios of Annex I trading with China.[3] Table 2 illustrates the effects of Chinese emissions targets at various levels, assuming that China trades its permits with Annex I countries.[4]

Table 2. Effects of Various Chinese Emissions Targets with Annex I Trading

Emissions Target[1]	Permit Price (1997$/ ton)	Chinese Emissions Reductions (MMTC)	Chinese Emissions Sales (MMTC)[2]	Chinese Gains from Trade (billions 97$)	Increase in Total U.S. Cost Relative to China BAU Target
BAU	$26/ton	276	276	$3.6 b	not applicable
BAU - 1%	$26/ton	276	262	$3.2 b	~$0
BAU - 5%	$29/ton	304	235	$2.4 b	$1.3 billion
Indifference =BAU-13%	$36/ton	343	172	$0	$4.2 billion

[1] The SGM BAU is employed for China for the purposes of these calculations.
[2] Reductions in Chinese emissions less Chinese emissions sales yields net global reductions.

Imposing the "indifference" target on China would lead to the following results, given that its participation lowers world permit prices.[5]

- An indifference target for China results in it foregoing $3.6 billion relative to the gains it would obtain if it were to take a BAU target.

- An indifference target for China increases annual U.S. costs by $4.2 billion relative to a BAU target for China. (This increase is about 33% of estimated U.S. costs under global trading.)

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be less stringent. (On the other hand, including the ancillary air quality benefits associated with abating carbon dioxide, especially in countries with significant local air pollution problems, could imply that the indifference targets should be *more* stringent.)]

[5] The reason that Chinese participation lowers world permit prices is because BAU or near-BAU targets result in more permits available on the world market.

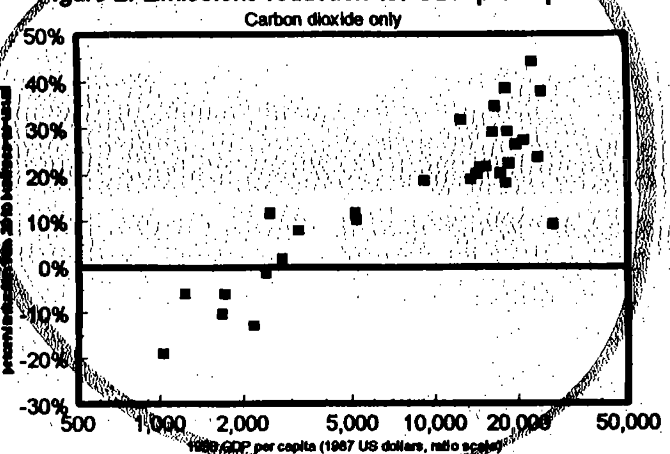
9 A

A "fair" allocation

If it is reasonable for poor countries to propose BAU targets as their opening bid, and also reasonable for rich countries to propose indifference targets as theirs, at what level would it be reasonable for a negotiated compromise to converge? While the emission targets in the Kyoto Protocol reflect the outcome of political negotiations, it is possible to discern systematic economic patterns in them. A fair target for developing countries might be one that fits whatever pattern tends to hold among existing targets. In particular, it turns out that this approach would allow some degree of progressivity, with richer countries making larger reductions than poor ones -- without going nearly so far as the massive redistribution of wealth that some poor-country representatives seem to ask for.

The Annex I targets (including the allocation within EU "bubble"), when presented in terms of reductions below 2010 BAU, follow a pattern of progressivity (see figure 2). This pattern holds for CO_2 as well as for all greenhouse gas emissions. For the 30 Annex I countries presented in this figure, the average reduction from BAU is 16.1%. For the lower half of Annex I countries by per capita income, the average reduction is 5.2% below BAU.

Figure 2. Emissions reduction vs. GDP per capita



Sources: The World Bank, U.S. Energy Information Administration, national communications to the UNFCCC

Statistical analyses can help us understand the progressivity of the targets. Data on four variables -- Annex I countries' per capita income, emissions growth projected between 1990 and 2010, coal as a share of total energy consumption, and a dummy variable representing whether a country is a transition economy -- can help explain the trend in emissions targets. The statistical analysis exhibits a pattern of progressivity among the existing targets: each 1% increase in per capita income implies a 0.11 to 0.17% greater sacrifice, expressed as emissions reductions from BAU. Levels of statistical significance are relatively high, suggesting that the results are meaningful. In absolute terms, an increase in income is associated with an increase in the level of the emission target. But the increase in income also implies an increase in the BAU level. The increase in BAU is *greater* than the increase in the target, implying that richer countries are making greater sacrifices. As an example, when the pattern is extrapolated to China the implied target is a 5 percent cut relative to BAU. This happens to lie inside the range spelled out in Table 2: both China and the rest of the world gain. It is not an unreasonable benchmark for other countries as well.

This statistical approach certainly has limitations, and the results reported here are preliminary. They are sensitive to decisions about the data used. Per capita income data can change depending on the year and exchange rate used to compare countries. Estimates of BAU emissions can vary too. But where the question of the distribution of targets seems inherently arbitrary, these results suggest an approach that incorporates the principle of progressivity while avoiding the impractical redistributive extremes proposed by some representatives of developing countries.

Uncertainty about target stringency, and a proposed solution

Some developing countries are worried that the uncertainty regarding projected economic performance is so great that they cannot risk adopting a binding emissions target for 2008 at this time. Even if a particular numerical target appears beneficial ex ante, it might turn out to be something different ex post. A response to this concern is that international agreements on these countries' targets should be structured to reduce the risk of being inadvertently stringent, and in particular to reduce the possibility of a target so stringent as to cause large economic losses to the developing countries or as to constrain economic development.

In addition to the concern expressed by some developing countries that adopting a binding target risks inadvertent stringency in the future, environmentalists have also expressed concern the symmetric concern on the other side, that a target may be too lax, creating "tropical hot air" and thus failing to result in environmental benefits in terms of actual emissions reductions relative to what would have happened in the absence of a treaty. Thus, it is desirable both to mitigate the risk of inadvertent stringency and also mitigate the risk of inadvertently laxity. The idea is to reduce the variability of the effective stringency of the target without loosening or tightening the intended target, i.e., to reduce the variance without changing the expected value.

The general notion is to agree today on a contract under which the numerical emission target is to depend in a specified way on future variables whose values are as yet undetermined. (The analogy is with a cost-of-living adjustment clause in a labor contract, that specifies a given increase in the wage for every cent increase in the Consumer Price Index -- thus reducing uncertainty over *real* wages.) Future economic growth rates are probably the biggest source of uncertainty. Forecasts of GDP among East Asian countries, for example, are already very different now from what they were in 1997, and will again look different in 2007. In what follows, we assume that a country's aggregate emissions are indexed to future income alone. Other possible proposals include other variables like population or temperature in the formula.[6]

The simple version of the indexation proposal is as follows: **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by 1%.**

There is also a more general case: **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by X%, where X is a number less than 1.** An advantage relative to the simpler version of the proposal is that countries that do well over the coming decade are asked to contribute a bit more than those that do not, while not being penalized unduly for their growth. The analogy is to a progressive income tax system.[7]

Worked-out Example for Argentina

Step 1 – setting expected target. BAU is for carbon emissions growth of 55% cumulatively from 1995 to 2010, or 3% per year (all data are from Argentine Government). Of this, 4.4% per year is GDP growth, -0.8% is decreasing energy/GDP, and -0.6% is decreasing emissions/energy. We could ask all LDCs to take targets that are expected to be 5% below BAU. For Argentina, the expected 2010 target would then be 50% above 1995 levels. An alternative, which might appeal to many countries, would be to let them pick their highest previous year, and set the target 50% above that.

Step 2 – [illegible]. The forecast is for 2007 GDP to be 57% above 1995 (1.044 to the 12th power). If 2007 GDP in fact turns out to be that level, then the target is as agreed. But for every 1% higher (or lower) that 2007 GDP comes in, the target for 2008-2012 will be X% higher (or lower).

The best way to phrase to the Argentines this contract is as follows: its target will be given by [1995 + 55% - 5% - X(4.4%)15] + [X(average realized growth)15]. This way of phrasing the proposal makes clear that it is a "growth target;" under indexation, the country can only win from growth.

For example, the implication of a tentative calculation would be to set X at .7. (This is calculated as a regression estimate of the average affect of growth on BAU, .9, minus an allowance for progressivity whereby richer countries are asked to make larger cuts, .2.)

Then, for concreteness, the Argentine target becomes:

[1995 + 50% - .7(4.4%)15] + [.7(average realized growth)15]

= 1995 level + 4% + .7(accumulated growth over next 15 years).

Notice that if growth comes in as expected (4.4%), then the target is 50% above 1995 levels, or 5% below BAU.

This example illustrates a possible approach to removing some of the economic uncertainty from the commitment of adopting a quantitative target. Another possible idea, suitable for any country willing to implement via a carbon tax or tradeable permit system would be an "escape clause" or "safety valve," which eases the quantitative limit when the price of carbon threatens to rise above a pre-agreed threshhold. Such approaches to the uncertainty problem would make it more likely that the target will turn out to fall in the range intended, where it brings benefits both environmental and economic, to developing countries and industrialized countries alike.

Endnotes

1. [redacted]

Table 1. Increase in Non-Annex I Emissions Under Annex I Trading

MERGE (Manne and Richels)	MRT (Charles River Assoc.s)	G^3 (Shackleton et al)
[redacted]	115 MMTCE	55 MMTCE

2. The only attempt to model the intertemporal dimensions of this problem with which I am familiar is by McKibben, Wilcoxen, and Shackleton, via the G-cubed model. But if one is truly interested in the trade balance, the proper analytical framework is probably the classic "transfer problem." It suggests that, in a world in which the United States would be buying permits from other countries, the effect on the US balance in goods and services would be positive. (The effect on broader measures of the balance of payments could well be negative.)

3. These analyses assume that no other non-Annex I countries participate in international emissions trading or the CDM. If other non-Annex I countries did participate in either flexibility mechanism, the world trading price could be lower, resulting in lower gains from trade and a less stringent indifference target for China.

4. A small reduction below BAU has no real effect on the Annex I trading price, and thus no economic effects on the U.S. However, as the target becomes more stringent the trading price increases, resulting in higher total costs of compliance for the U.S.

[redacted]

6. The rich countries are afraid of mentioning population, for fear of giving a platform to the utterly unrealistic proposal to give equal per capita emission rights to all countries. Nevertheless, some less extreme version of including a role for population seems fair. (One possibility is equal weight on three variables: shares of global population, shares of output, and shares of pre-Kyoto emission levels.) The argument for including the temperature over the coming decade is not that it will contain much scientific information regarding the true magnitude of the climate change problem -- weather fluctuations are far too noisy for that -- but rather that it will contain information regarding the political willingness of people to pay the costs of more stringent targets.

7. There exists an alternative proposal that I would reject: The target ratio of emissions/GDP that is set for the budget period does not depend only on the country's own past emissions rate, but also on a common standard established for all countries. This approach has two serious drawbacks:

(i) Because emissions/GDP varies widely across countries, a request that countries agree to a common standard would imply far greater sacrifice for some than for others (relative to their current positions, or to BAU). The United States wouldn't hear of this approach in setting the US target at Kyoto, and neither will many others who would be disadvantaged.

(ii) A comparison of GDPs across countries can easily vary by 100% or more, depending on whether market exchange rates are used or a "PPP basis" (Purchasing Power Parity), what year is chosen, and how PPP or the exchange rate is measured; the implied large year-to-year swings in targets (tons of GHG emissions) would be unworkable. The approach I favor does not have this problem, because measurement problems in yearly growth rates for a given country amount to a couple of percentage points at most.

8. A more accurate forecast might use different coefficients for different kinds of countries. An alternative that is more practical politically would be to let X be negotiated separately for each country.

Growth Targets for GHG Emissions from Developing Countries:

Introduction and Summary of Findings

The United States has advocated emissions growth targets for non-Annex I countries. As these countries consider the possibility of adopting such targets, several have solicited assistance from the United States. The tasks of providing technical assistance to these countries and working with the international community to develop an understanding of what constitutes "appropriate non-Annex I targets" require a further refinement of the US position on developing country growth targets. This paper presents some basic principles for growth targets and discusses several proposals.

Principles **Recognizing the interests of developing countries, the United States interest, and the economic and environmental impacts of emissions targets, there are three basic guiding principles for emissions growth targets:**

- **Targets should result in environmental benefits;**
- **Targets should be consistent with continued economic development; and**
- **Targets should be of a form that allows developing countries to participate in international emissions trading, to reduce the economic costs of attaining given targets.**

Findings While there is a general consensus on these basic principles, a further elaboration on some of the key issues involving these principles can help facilitate the effort toward a position on the form, magnitude, and timing of a developing country growth target. In reviewing existing data, ongoing research, and in conducting our own analyses, we have found that:

- Growth targets even as high as BAU can yield significant reductions in global emissions by forestalling the leakage that would otherwise occur.
- Targets can result in economic gains from trade for all sides, if they are not too stringent.
- A "fair" allocation to expect of potential new participants might be a target that fits the apparent pattern among Annex B countries. This approach turns out to imply some degree of "progressivity" -- with richer countries asked to make bigger sacrifices than poor ones.
- Given uncertainty about the future, to fix the precise quantitative target now would create great risks regarding the ultimate stringency of the target; it would raise concerns that a target unintentionally constrains economic development, on the one hand, or that the target could result in hot air, on the other hand. These risks would be reduced by indexation approaches.
- Approaches to index targets to income growth between now and the commitment period have some advantages over carbon efficiency target approaches.
- CO_2 is the dominant greenhouse gas in developing countries (from fossil fuels and land-use). Measurement of other gases might be too difficult to justify their inclusion.

Guide to Contents

(I) Benefits of Targets-and-Trade A scheme in which non-Annex I countries are invited to adopt binding emission targets in the general vicinity of their BAU paths, and then to trade emission permits internationally, is a scheme that has real potential economic and environmental benefits, not just for Annex I countries, but for the developing countries as well. This gives them a genuine incentive to join, which would otherwise be lacking.

(II) What Should Determine Desired Targets? Non-Annex I countries could be asked to take on targets that make some small reductions relative to BAU, and still benefit. But large cuts would render them worse off, and therefore unlikely to agree to participate. Conversely, large increases relative to BAU are unlikely to be acceptable to the Annex I countries. We explore the range of targets that the developing countries could be expected to take on. A reasonable upper bound is their BAU paths.

Even a target as generous as this would result in global environmental benefits, by forestalling leakage, as shown in **Memo II.1**: ***Emissions leakage from Annex I to non-Annex I countries.***

A reasonable lower bound is the "indifference target" which entails cuts large enough that participation no longer brings them economic benefits, because the gains from selling permits are fully offset by the losses from a stringent target. (See **Memo II.2:** ***The Trade-off between target stringency and gains from trade***).

An alternative approach to formulating a "fair" target for developing countries is to estimate statistically what pattern holds among targets already accepted by Annex I countries, and then to extrapolate to developing countries. This statistical approach is explained in **Memo II.3**: ***Progressivity of existing targets, as a guideline for developing-country targets***. This approach turns out to imply some degree of "progressivity" -- with richer countries asked to make bigger sacrifices than poor ones -- without going nearly so far as the redistribution of wealth that some poor-country representatives seem to be asking for. As an example, when the pattern is extended to China, the implied target is a 5 percent cut relative to BAU. This happens to lie inside the range spelled out in Memo II.2.

(III) Uncertainty of Measurement and Forecasting complicates the analysis further. Because BAU forecasts are uncertain, a given numerical target could turn out to be unintentionally stringent (inflicting economic costs on the country) or unintentionally lax (creating "tropical hot air"). **Memo III.1**, ***Uncertainty about Target Stringency, and proposed solutions***, explores this problem and approaches to deal with it by indexation.

Another difficulty of extending targets to developing countries is measurement of emissions. **Memo III.2**, ***What greenhouse gases are necessary to include?***, suggests simple CO2 targets might be good enough for these countries.

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I. Benefits of Targets-and-trade

It would be useful to get developing countries to agree to binding limits, even if they involved only small (or no) cuts below Business as Usual (BAU) in the first budget period. Such targets, with trading, imply gains for their economies, gains for ours, and gains for the environment.

Reasons:

- We want to forestall increases over BAU, that would occur in response to Annex I cuts if others do not take on targets. (This is leakage, as explained in Memo II.1 below.)

- The ability for Annex I countries to buy reductions from LDCs would greatly reduce the costs of meeting our targets (as CEA testimony showed). In particular, it is estimated that trading with developing countries would lower U.S. costs more than 80 percent relative to the costs of achieving the Kyoto targets solely through reductions in domestic emissions. (This is as compared to 57 percent savings from trading among Annex I countries alone).

- With targets close to BAU, the developing countries would benefit from the ability to sell emission permits achieved at costs below the world price. This actually gives them a genuine economic incentive to join, which is otherwise lacking. Illustrative calculations by CEA suggest that China would stand to gain $3.6 billion/year by joining Annex I, and India to gain [illegible]. (See Table 2. The United States would save a preliminary-estimate $11.6 billion if China joined, or $2.5 billion if India joined.)

- Further, when permits are sold, reductions in carbon dioxide emissions generate ancillary air quality benefits in the developing countries through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions.

- Establishing developing country targets now would meet the requirements of the Byrd-Hagel resolution. Agreement on modest targets in the nearer term is the first step to drawing LDCs into the system, where larger cuts relative to BAU might be possible in the longer term (in some proportion to the cuts made by richer countries that have gone before them).

II.1 Emissions leakage from Annex I to non-Annex I countries

Even if developing-country targets did no more than to hold developing countries at BAU emission levels, this would be a major environmental benefit. [redacted]. Often referred to as "leakage," this shifting in emissions reflects two economic impacts of abating emissions in Annex I:

- **World Oil Market Price Effects**. Abating carbon dioxide in Annex I countries reduces the demand for oil, thereby lowering the price of oil. With lower oil prices, some non-Annex I countries will consume more oil and increase their emissions relative to what they would have without the Annex I abatement policies.

- **Energy-Intensive Industry Migration**. Annex I abatement policies that increase the price of energy may provide an incentive for energy-intensive firms to relocate to non-Annex I countries.

Leakage is positively correlated with permit prices: higher Annex I permit prices (and higher energy price effects) will likely result in higher rates of leakage.[1] [redacted]

Table 1. Increase in Non-Annex I Emissions Under Annex I Trading

MERGE (Manne and Richels)	MRT (Charles River Assoc.s)	G^3 (Shackleton et al)
325 MMTCE	115 MMTCE	55 MMTCE

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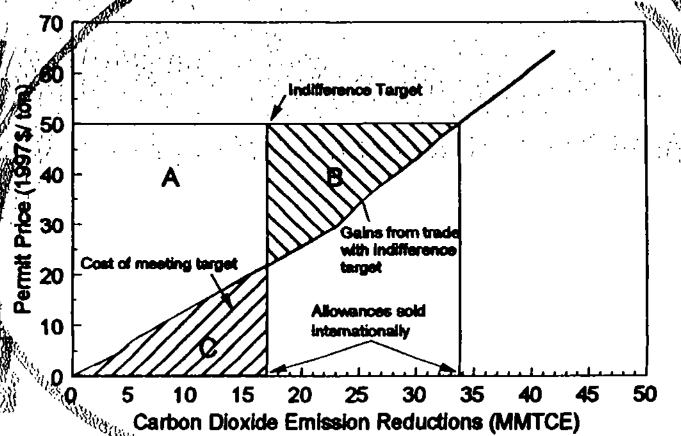
[1] However, international emissions trading can eliminate leakage among all trading participants. An effective trading market that results in equal marginal costs of abatement across all participating countries also results in equal energy price effects in all participating countries. Thus, there is no economic incentive for energy intensive firms to relocate to another country participating in trading. A full global trading system would then eliminate leakage completely. Some economic analysis indicates that while the CDM would lower costs some to Annex I countries, the project-by-project approach does not equalize energy price effects across all participating countries, and would not eliminate leakage to developing countries.

II.2 The trade-off between target stringency and gains from trade

The Administration has stated in bilateral and multilateral meetings, Congressional testimonies, and other public fora that if developing countries adopt emissions growth targets and participate in international emissions trading, they can enjoy economic gains from trade. Among other issues, this conclusion is sensitive to the stringency of the emissions growth target. The environmental gains from emissions reductions below BAU come at the price of economic costs incurred by a developing country that adopts the below-BAU target. In addition, in the cases of large non-Annex I countries, more stringent targets could have economic costs for buyers in international emissions trading. More stringent developing country targets could raise U.S. costs by restricting the supply of permits in world markets and so raising the price of permits relative to less stringent targets.

To assess the magnitude of this effect consider the target which just leaves a country no better off than no target at all. This "indifference" target is where the costs of meeting the target through domestic action just equal the net gains from selling permits in world markets.[2] Figure 1 illustrates gains from trade for a small country. The upward-sloping curve shows the rising marginal cost of increasingly stringent reductions. For small reductions from BAU, the cost is far less than the price they fetch on the world market. For a target that is equivalent to a reduction of 17 MMTC, net gains from foreign exports are B, and the cost of meeting the target is C. Since B = C in this example, the net costs from participation are nil.[3]

Figure 1. Illustrative 2010 Marginal Abatement Cost Curve and Indifference Target



Note: For simplicity, this indifference target is illustrated for a country whose participation in world permit markets does not affect world permit prices.

As a numerical example of the effects of increasing the stringency of an emissions growth target, we present results from some modeling scenarios of Annex I trading with China. These analyses assume

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[2] This analysis presumes that non-Annex I countries abate their emissions cost-effectively, e.g., through a tradable permit system or a carbon tax.

[3] This hypothetical example assumes that the country in question does not consider participation in the Clean Development Mechanism (CDM). If this country were to participate in CDM if it did not adopt a target, then its indifference target would not be at the level where net gains from trade are zero, but where expected net gains from trade would equal expected net gains from the CDM. The CDM option implies that the indifference target would be less stringent. However, including the ancillary air quality benefits associated with abating carbon dioxide, especially in countries with significant local air pollution problems, could imply that the indifference targets should be *more* stringent.

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that no other non-Annex I countries participate in international emissions trading or the CDM. If other non-Annex I countries did participate in either flexibility mechanism, the world trading price could be lower, resulting in lower gains from trade and a less stringent indifference target for China.

Table 2 provides an illustration of the effects of emissions targets more stringent than BAU on China with Annex I plus China trading. A small reduction below BAU has no real effect on the Annex I trading price, and thus no economic effects on the U.S. However, as the target becomes more stringent the trading price increases, resulting in higher total costs of compliance for the U.S.

Table 2. Effects of Various Chinese Emissions Targets with Annex I Trading

Emissions Target[1]	Permit Price (1997$/ton)	Chinese Emissions Reductions (MMTC)	Chinese Emissions Sales (MMTC)[2]	Chinese Gains from Trade (1997$)	Increase in Total U.S. Cost Relative to China BAU Target
BAU	$26/ton	276	276	$3.6 billion	not applicable
BAU - 1%	$26/ton	276	262	$3.2 billion	~$0
BAU - 5%	$29/ton	304	235	$2.4 billion	$1.3 billion
Indifference	$36/ton	343	172	$0 billion	$4.2 billion

[1] We employ the SGM BAU for China for the purposes of these calculations.
[2] Reductions in Chinese emissions less Chinese emissions sales yields net global reductions.

Imposing this "indifference" target on China, given that its participation lowers world permit prices, leads to the following conclusions:[4]

- An indifference target for China results in it foregoing $3.6 billion relative to the gains it would obtain if it were to take a BAU target.
- An indifference target for China increases annual U.S. costs by $4.2 billion or about 33% relative to a BAU target for China.

[4] The reason that Chinese participation lowers world permit prices is because BAU or near BAU targets result in more permits available on the world market.

II.3 Progressivity of existing targets, as a guideline for developing-country targets

It appears reasonable on grounds of fairness that wealthier countries should undertake greater efforts to address climate change than less-wealthy countries. While the emission targets in the Kyoto Protocol reflect the outcome of political negotiations, it is possible to discern systematic economic patterns in them. A fair target for developing countries might one that fits whatever patterns seem to hold among existing targets. In particular, this approach would allow some degree of progressivity, with richer countries making larger reductions than poor ones -- without going nearly so far as the redistribution of wealth that some poor-country representatives seem to ask for.

The Annex B targets (including the EU bubble allocation), when presented in terms of reductions below 2010 BAU, follow a pattern of progressivity (see figure 1). Note that this pattern holds for CO_2 as well as for [redacted] on some non-CO_2 GHG emissions are not available for some Annex I countries, see memo II.2). [redacted] the 30 Annex I countries presented in this figure, the average reduction from BAU is 16.1%. For the lower half of Annex I countries by per capita income, the average reduction is 5.2% below BAU.

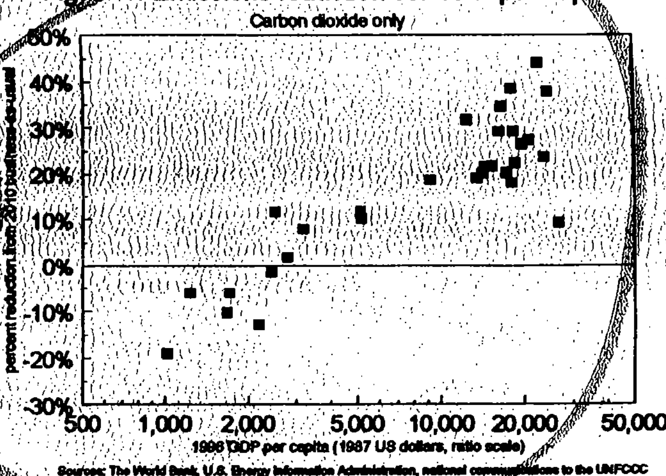

Figure 1. Emissions reduction vs. GDP per capita

We conducted statistical analyses to better understand the progressivity of the Annex B targets. We used data on Annex B countries' per capita income, emissions growth projected between 1990 and 2010, coal as a share of total energy consumption, and whether a country is a transition economy, to explain the trend in emissions targets in terms of deviations from BAU. The statistical analyses illustrate a pattern of progressivity among the existing targets: each 1% increase in per capita income implies a 0.11 to 0.17% greater sacrifice, expressed as emissions reductions from BAU. Levels of statistical significance are relatively high, suggesting that the results are meaningful. In absolute terms, an increase in income is associated with an increase in the level of the emission target. But the increase in income also implies an increase in the BAU level. The increase in BAU is *greater* than the increase in the target, implying that richer countries are making greater sacrifices. As an example, when the pattern is extrapolated to China, the implied target is a 5 percent cut relative to BAU. This happens to lie inside the range spelled out in Table 2 of Memo II.2: both China and the rest of the world gain.

This statistical approach certainly has limitations, and the results reported here are preliminary. They are sensitive to decisions about the data used. Per capita income data can change depending on the year and exchange rate used to compare countries. Estimates of BAU emissions can vary too.

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III.1 Uncertainty about target stringency and proposed solutions

Some developing countries have claimed that the uncertainty regarding projected economic performance is so great that they cannot risk adopting a binding emissions target for the first commitment period at this time. A natural response to this concern is that international agreements on these countries should be structured to reduce the risk of inadvertent stringency, and in particular to reduce the possibility of a target so stringent as to cause large economic losses to the developing countries. In addition to the concern expressed by some developing countries that adopting a binding target now for 2008 risks it being inadvertently stringent and constraining economic development, some have also expressed concern the symmetric concern on the other side, that a target may be too lax, creating "tropical hot air" and thus failing to result in environmental benefits in terms of actual emissions reductions. Thus, it is desirable both to mitigate the risk of inadvertent stringency and also mitigate the risk of inadvertently laxity. The idea is to reduce the variability of the effective stringency of the target without loosening or tightening the intended target, i.e., to reduce the variance without changing the expected value.

To attempt to address this uncertainty issue, a number of ideas have been forwarded. CEA has called its proposal an indexation or formula approach; EPA has referred to its proposal as efficiency standards. They are all versions of the general notion of agreeing today on a contract under which the numerical emission target is to depend in a specified way on future variables whose values are as yet undetermined. (The analogy is with a cost-of-living adjustment clause in a labor contract, that specifies a given increase in the wage for every cent increase in the Consumer Price Index -- thus reducing uncertainty over *real* wages.) In what follows, we assume that a country's aggregate emissions are indexed to future income alone. (We are thus omitting from past CEA proposals the possibility of including in the formula other variables like population, and are omitting from past EPA proposals the possibility of separate "efficiency standards" for individual sectors within an economy.)

It is useful to distinguish four proposals that appear in earlier memos.

(1) CEA approach (Special-case): **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by 1%.**

(2) CEA approach (General): **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by X%, where X is a number less than 1.** An advantage relative to proposal (1) is that countries that do well over the coming decade are asked to contribute a bit more than those that do not, while not being penalized unduly.

(3) EPA approach (Special-case): **For every percentage point that GDP in the years 2008-2012 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by 1%. (EPA phrases this as setting a number for the ratio of emissions to GDP; but that is the same thing.)** The advantage relative to the CEA approach is it allows even more uncertainty-

protection, with respect to fluctuations in income in the years after 2007. The disadvantage is that the country does not know how many tons it is entitled to until the end of the budget period, which could make trading difficult.

(4) EPA approach (General). [redacted] It seems to CEA that this approach has two serious drawbacks:

[redacted]

III.2 What greenhouse gases are necessary to include?

In the Kyoto Protocol, Annex B countries have targets specified in terms of a basket of six types of greenhouse gases. These targets include both emissions sources and sinks. While this comprehensive approach provides more environmental benefits, it does increase the required effort and cost of inventorying greenhouse gas emissions. Many developing countries lack the monitoring infrastructure to assess emissions of all six types of greenhouse gases. Must developing country growth targets include all greenhouse gases, or is a subset of the Annex A list of gases sufficient?

In evaluating this question, it may be useful to consider several issues.

- **Greater Climate Benefits.** A developing country growth target set below what emissions would be otherwise for only one greenhouse gas (e.g., CO2) would generate greater environmental benefits relative to a scenario where that country does not adopt a target.

- **Leakage Across Gases Unlikely.** There appears to be little opportunity in most economies for intergas leakage. For example, most efforts to abate fossil fuel-related carbon emissions would result in efficiency improvements, switching to leaner fossil fuels (e.g., natural gas) and to carbon-free sources of energy (e.g., hydropower, nuclear, wind), none of which have emissions of other types of greenhouse gases. Moreover, efforts to abate carbon dioxide in fossil fuel combustion may have ancillary reductions of energy-related methane.

- **CO_2 is Significant Majority of Greenhouse Gas Emissions**. In the United States, carbon dioxide comprises 85% of all greenhouse gas emissions (weighted by carbon equivalence). Across Annex I, carbon dioxide is, on average, 80% of each country's emissions. This trend appears to hold for some non-Annex I countries as well. In 1990, carbon dioxide comprised 88% of Korea's emissions, 85% of Mexico's emissions, and 85% of Kazakstan's emissions. In Argentina, carbon dioxide comprised 63% of 1990 emissions, with methane comprising most of the rest. It appears that carbon dioxide dominates most countries' emissions, with methane a distant second (depending on the extent and nature of agriculture). Non-Annex I countries have not reported their emissions of the synthetic gases in their national communications to date. It is not clear how revisions to the N_2O emissions estimation methodology could affect estimates of non-Annex I countries' emissions.

- **Land Use Change Could be Significant**. Carbon dioxide emissions from land use change in non-Annex I countries appear to be quite significant. Some estimate that by including land use change emissions, non-Annex I emissions exceeded Annex I emissions in 1994 (Panayotou and Sachs 1998). Emissions from land use change in non-Annex I countries in 1994 were more than one-fifth of global carbon dioxide emissions. Some statistical analysis indicates that countries' land use change activities do not become net sinks, ceteris paribus, until per capita income exceeds $3,600.

(B)

Preliminary Draft, Close Hold, Do Not Cite, March 30, 1998

A Proposal for Developing Countries: Participation in a "Target and Trade" System

I. This analysis demonstrates that the gains will be substantial if developing countries (a) accept binding targets at or slightly below their business as usual (BAU) emissions levels, and (b) trade from their respective targets. We believe that participation in a "target and trade" system should be the cornerstone of our international negotiations.

The economic and environmental rationale for such participation includes

- **Greater economic benefits to developing countries:** With targets at or only slightly below BAU, developing countries would enjoy net gains of many billions of dollars through the international sale of emission reductions achieved at lower cost than the world price.

- **Greater cost savings to the U.S.:** Participation by developing countries in international permit markets would greatly lower the costs to the U.S. of meeting its Kyoto target (as CEA testimony showed). In particular, costs would be lower than with trading among only Annex I countries.

- **Greater environmental benefits:** Targets slightly below business as usual would lower global emissions relative to a world with only Annex I targets. Further, reducing carbon dioxide emissions generates ancillary air quality benefits through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions.

- **Target and trade yields greater benefits than CDM:** While the Clean Development Mechanism will likely result in cost savings to the U.S. relative to a world with only Annex I trading, a system including effective target and trade of developing countries' emissions would yield much greater cost savings to the U.S. and greater gains to developing countries than CDM. Further, target and trade could achieve environmental benefits not achievable by pursuing CDM, which only redistributes emissions geographically.

- **The principle of full participation:** Other rationale include the long-run benefits of including developing countries into global negotiations, for example, as recognized by the Byrd-Hagel resolution. By establishing participation now, further commitments might be feasible in future periods.

II. Problem: To persuade a developing country *voluntarily* to adopt a target and then to trade permits internationally, international agreements must be structured to reduce the risk of inadvertent stringency and in particular to reduce the possibility of a target so stringent as to cause large economic losses to the developing country.

Proposed Solution: Negotiations should focus on the estimated business as usual emissions level, where this level is expressed in a way that depends on the *future* values of economic variables, such as GDP.

Rationale: Such targets would avoid the risk of inadvertent stringency associated with higher than projected economic growth between now and the beginning of the commitment period in 2008. Developing countries would face only the much smaller risk that emissions would be higher than expected, *given* the economic conditions realized in 2007.

Basic principles for implementing such an approach are:

- **Reasonable Forecasts**: The relationship between the target (putting aside any real reductions in emissions) and the values of economic variables, when applied to emissions and such variables during recent years, should predict emissions reasonably well and be without demonstrable statistical bias. Relationships that give reasonably reliable predictions reduce the risk of either inadvertent stringency or paper tons which could increase global emissions.

- **No Perverse Incentives:** The target should depend on values of economic variables only indirectly related to emissions, to avoid creating perverse incentives for developing countries to increase emissions so as to have higher targets in the commitment periods. For example, the target should not depend on energy consumption in 2007, but could reflect pre-Kyoto emissions levels.

- **Predetermined Targets:** To avoid uncertainty during the commitment period about the country's target the target should not depend on contemporaneous values of economic variables. For example, the target generally should not vary with 2008 or 2010 GDP levels, but rather with 2007 GDP.

III. Illustration: One way of implementing the solution is described below. Other ways of implementing the solution may work as well or better. The conclusions are stated below; the details of our work follow in appendix 3.

- Defining the business as usual level for a developing country as a function of its GDP and population in earlier years and setting the emissions target at that level yields a negligible risk of leaving the developing country worse off under target and trade because of inadvertent stringency. Even a target slightly below BAU would also yield negligible risk of leaving the developing country worse off.

- Emissions targets for developing countries set below their business as usual emission level would of course result in gains from trade smaller than with a BAU target, while providing environmental benefits. The higher costs of a target set below BAU are borne by both the developing countries and the Annex I countries.

There are significant gains from trade for developing countries and large cost-savings to the U.S. if even one large developing country accepts an emissions target at BAU and participates in emissions trading. Table 1 and Charts 1 through 3 illustrate these gains from trade from a baseline of full Annex I trading.

Table 1. Illustrative Gains from Trade with Developing Countries that Target and Trade

Trading Scenario	Permit Price[1] (1997$/ton)	Country Gaining	Gains from Trade with Developing Countries
Annex I only	$54	United States	not applicable
Annex I + China	$26	China	$3.6 billion/year
		United States	$11.6 billion/year[2]
Annex I + India	$47	India	$1.6 billion/year
		United States	$2.5 billion/year[2]
Annex I + Mexico	$51	Mexico	$0.9 billion/year
		United States	$1.2 billion/year[2]

[1] These scenarios do not account for the cost savings available through the Clean Development Mechanism and carbon sinks.

[2] Gains from trade for the U.S. are estimated as the change in the U.S. total cost of complying with the Kyoto Protocol relative to an Annex I only trading regime.

(5)

Chart 1. China's 2010 Marginal Abatement Cost Curve and Gains from Trade

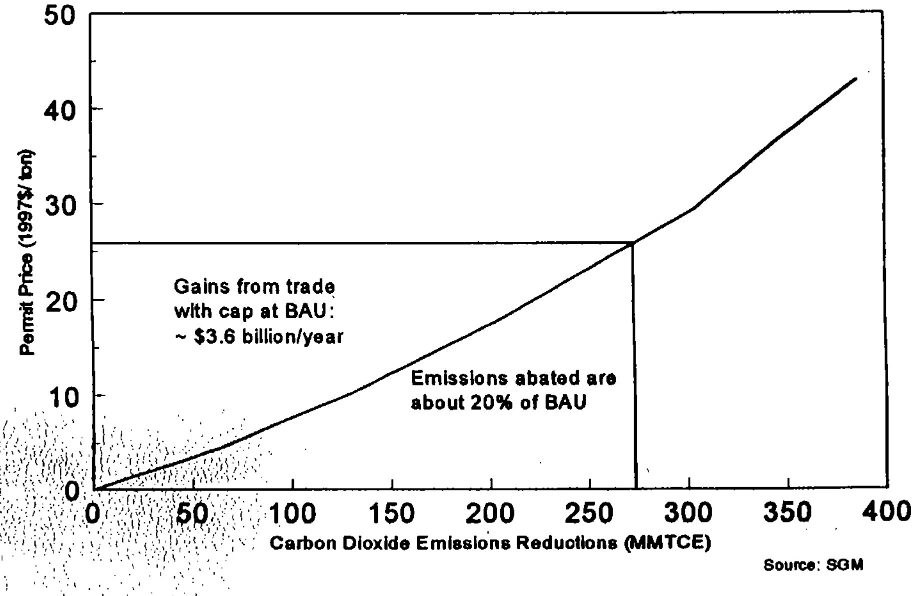


Chart 2. India's 2010 Marginal Abatement Cost Curve and Gains from Trade

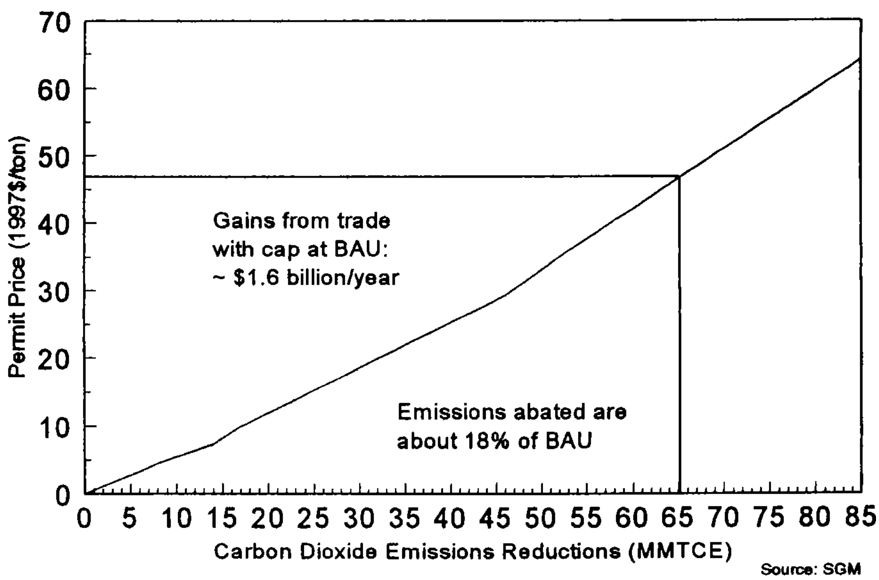
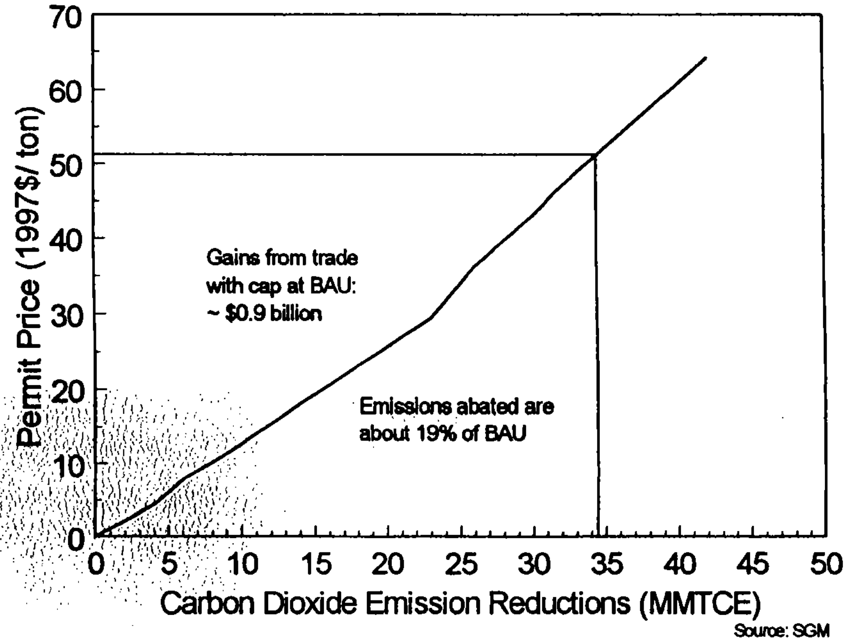


Chart 3. Mexico's 2010 Marginal Abatement Cost Curve and Gains from Trade



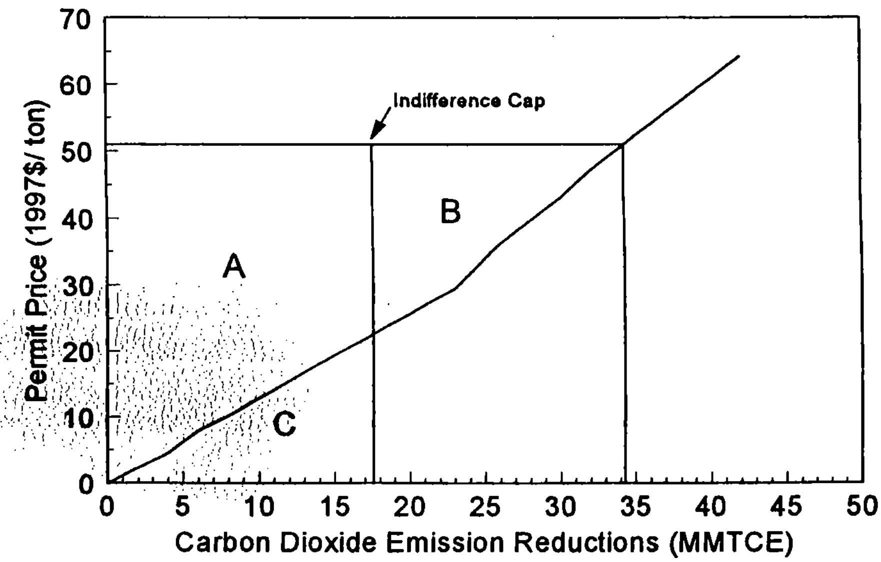
Appendix 1. Costs to the U.S. of Developing Countries Adopting Targets Below BAU

Regarding developing countries, most commonly discussed is the issue of fairness: what commitments to reduce emissions should be made by countries whose economic resources differ substantially? Generally neglected, but discussed below, is the issue of efficiency. In particular, what are the implications for U.S. costs of increasingly more stringent targets on emissions from key developing countries?

The environmental gains from emissions reductions below BAU come at the price not only of economic costs incurred by a developing country that adopts the below-BAU target, but also economic costs by Annex I. More stringent developing country targets raise U.S. costs by restricting the supply of permits in world markets and so raising the price of permits.

To assess the magnitude of this effect consider the target which just leaves a country no better off than no target at all. This "indifference" target is where the costs of meeting the target just equal the net gains from selling permits in world markets. Chart 4 illustrates gains from trade for a small country. For a target that is equivalent to a reduction from BAU of 17 MMTC, net gains from foreign exports are B, and the cost of meeting the target is C. Since B = C in this example, the net gains from trade are nil.

Chart 4. Illustrative 2010 Marginal Abatement Cost Curve and Indifference Target



Note: For simplicity, this indifference target is illustrated for a country whose participation in world permit markets does not affect world permit prices.

Table 2 provides an illustration of the effects of emissions targets more stringent than BAU on China with Annex I plus China trading. Note that a small reduction below BAU has no real effect on the Annex I trading price, and thus no economic effects on the U.S. However, as the target becomes more stringent, the Annex I trading price increases, resulting in higher total costs of compliance for the U.S. If China accepts a target below BAU, the cost of this additional stringency to the U.S. -- essentially, the cost of supplying the environmental benefits associated with these emissions reductions -- can become significant. Thus developing country participation in the form of acceptance of targets more stringent than business as usual will raise costs to the U.S.

Table 2. Effects of Various Chinese Emissions Targets with Annex I Trading

Emissions Target[1]	Permit Price (1997$/ ton)	Chinese Emissions Reductions (MMTC)	Chinese Emissions Sales (MMTC)[2]	Total Cost to U.S. of Complying with Kyoto	Cost to U.S. of Additional Stringency
BAU	$26	276	276	$13.4 b	not applicable
BAU - 1%	$26	276	262	$13.4 b	~$0
BAU - 5%	$29	304	235	$14.9 b	$22/ton
Indifference	$36	343	172	$17.9 b	$26/ton

[1] We employ the SGM BAU for China for the purposes of these calculations.
[2] Reductions in Chinese emissions less Chinese emissions sales yields net global reductions.

Imposing this "indifference" target on China, given that its participation lowers world permit prices, leads to the following conclusions.

- An indifference target for China increases annual U.S. costs by $4.5 billion or 33% relative to a BAU target for China.

- If China accepts an emissions target requiring reductions of approximately 170 MMTC below BAU, the average cost to the U.S. would be $26/ton. This is <u>not</u> the average cost of a ton of emissions purchased from China, but the average cost to the U.S. of the environmental benefits associated with China complying with a more stringent target.

Appendix 2. Ancillary Environmental Benefits of Target and Trade in Developing Countries

The voluntary reduction of greenhouse gas emissions by developing countries under a target and trade system will simultaneously reduce emissions of several pollutants, producing ancillary environmental and human health benefits in those countries. The environmental and health benefits that accrue to those developing countries are unlikely to be offset by decreases in environmental quality in the United States because of our stringent health-based air quality standards.

A recent study in *Lancet* examines the emissions of one pollutant that are reduced along with carbon emissions: airborne particulate matter (PM). The study projects that by 2020, a climate change policy scenario in which developing countries reduce emissions to 10% below their BAU could produce an annual reduction of 563,000 statistical deaths.

The analysis below adapts the predictions in the *Lancet* study to estimate the mortality risk reduced from participation by three developing countries (China, India, and Mexico) in a target and trade system. These illustrative calculations take as given the emissions reductions from BAU resulting from permit sales that are predicted by SGM. It suggests that significant public health gains could result from developing country participation in international carbon permit markets.

Table 3. The Effects of International Carbon Permit Trading on Mortality Risk Associated with Particulate Matter Emissions

Country	Predicted carbon emissions reduction from international permit sales	Share of non-Annex I population in 2010	Annual PM statistical deaths avoided in 2010 by international carbon permit trading
China	20%	23.7%	136,700
India	18%	20.3%	105,300
Mexico	19%	2.0%	19,700

For developing countries that are too "small" to affect the world permit price, adopting a carbon target more stringent than BAU and participating in international trade does not yield additional ancillary benefits relative to a BAU target. Large countries, by adopting targets below BAU, would raise the world price relative to a BAU target, and thereby achieve greater carbon emissions reductions and ancillary benefits.

<u>Caveats</u>

Major assumptions beyond those in the *Lancet* article include:

- Deaths avoided in each non-Annex I country are proportional to the country's share of non-Annex I population.

- Deaths avoided are proportional to carbon emissions reductions.

- Each key developing country is the sole non-Annex I country to adopt a target and participate in international trading.

Appendix 3. Summary of Analysis

A. Data

We have compiled data on 3 variables: emissions of carbon dioxide, GDP, and population for 117 countries for the time period 1970-1992. The carbon dioxide emissions data, measured in millions of metric tons of carbon, are from the Carbon Dioxide Information Analysis Center (Oak Ridge National Laboratory, DOE). The GDP data, measured in 1987 U.S. dollars, are from the World Bank. The population data, measured in thousands of individuals, are from the United Nations Population Division.

B. Methods

We have estimated a fixed effects linear regression on the logs of these variables, for the countries in our data set, excluding those listed in Annex I. Our regression uses four non-overlapping 5 year intervals for each country. Our forecasts include the country specific constants.

C. Results

The fixed effects regression we estimated is

$$\text{Emissions} = a\ GDP_{t-1} + b\ GDP_{t-2} + c\ \text{Population}_{t-1} + \gamma\ \text{trend}$$

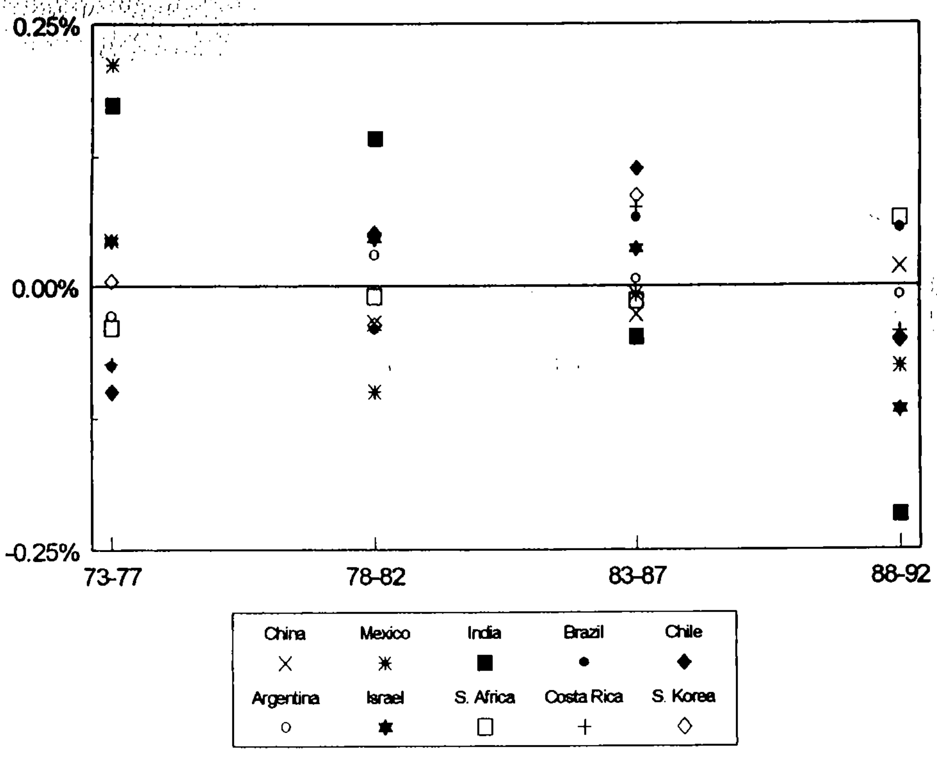
Emissions are the natural logarithm of the five year non-overlapping average of carbon emissions. All independent variables are lagged. GDP_{t-1} is the log of the gross domestic product in the year prior to the first year in the emissions variable, GDP_{t-2} is GDP in the year two years prior to the first year included in the emissions variable, and population_{t-1} is the country's population in the year prior to first year included in the emissions variable. Trend is one in the first 5 year period, and 2, 3, and 4 respectively in the subsequent 5 year periods. The useable data included 376 cross-section time series observations. The fixed effects regression used 98 degrees of freedom. The R squared was in excess of 0.99.

Table 4. Model I Results

Variable Name	Coefficient Estimate	Standard Error
GDP_{t-1}	0.9501823	0.2443047
GDP_{t-2}	-0.411297	0.23894
$Population_{t-1}$	0.4836006	0.2055439
trend	0.0073712	0.0310638

As one illustration of the model's accuracy in predicting emissions, consider the chart below that maps actual and predicted emissions using within sample data for ten selected developing countries. The predicted value is never more than 1/4 of one percent away from the actual emissions average for any of the five year intervals.

Chart 5. Error in Model I Prediction as a Fraction of Actual Emissions



(C)

Draft; close hold; CEA 2/17/99

How should growth targets for developing countries be set?
Summary of tentative consensus

This is an attempt to summarize some ideas that have been favorably received, regarding how to formulate growth targets for developing countries (in the first budget period). It must be stated from the outset that nobody wants the USG to be aggressive in making this sort of proposal internationally, for fear of appearing to be trying to impose a rigid formula on others. Rather, the point is to collect our thoughts internally, to be used if we are asked, as appropriate.

There appears to be a consensus among the Assistant Secretaries group that the aim should be targets in a range where they are low enough to produce environmental advantages (including forestalling leaking, but perhaps also small cuts relative to BAU), while high enough that to produce economic advantages (in the form of gains from trade to both buyers and sellers). That happy range is bounded by BAU on the upside and the "indifference level" on the downside (estimated, e.g., at BAU-12% for China with one model). CEA results that extrapolate from the progressive pattern of existing targets observed among Annex B countries might help choose a "fair" point within that range (e.g., estimated at -5% for China).

There also appears to be a consensus that it might be advantageous to consider "indexation" arrangements to cope with uncertainty between now and the budget period, i.e., to reduce the chance that a numerical target that was thought ex ante to be in the middle of the range turns out ex post to be either inadvertently stringent (imposing large economic costs) or inadvertently lax (creating hot air).

There is now a consensus that indexation was preferable to trying to impose a common absolute emissions/GDP standard across countries.

A majority favors setting the numerical target in 2007, though EPA (David Doniger) favors continuing the indexation through the end of the budget period (2012).

All favor considering the idea of indexing the emissions target to GDP. There were a fair number of proposals for other variables to include in the formula in addition to GDP (population, temperature, coal production, oil prices, electricity output), either uniformly across countries or on a country-by-country basis. Some argued that it should be left to the discretion of the developing country to decide what economic and/or demographic variables best explain emissions. But each individual candidate for a variable to be added was strongly opposed by a number of people and arguments.

The most unsettled question was what X should be, in the formula to allow X% higher emissions for every 1% in unexpected growth.

There was also a proposal (Victoria Greenfield, State), that unexpected reductions in income be accorded Y% lower emissions, with $Y<X$.

Example for Argentina

Step 1 -- setting expected target: BAU is for carbon emissions growth of 55% cumulatively from 1995 to 2010, or 3% per year (all data are from Argentine Government). Of this, 4.4% per year is GDP growth, -0.8% is decreasing energy/GDP, and -0.6% is decreasing emissions/energy. We could ask all LDCs to take targets that are expected to be 5% below BAU. For Argentina, the expected 2010 target would then be 50% above 1995 levels. An alternative, which might appeal to many countries, would be to let them pick their highest previous year, and set the target 50% above that.

Step 2: -- indexation to reduce uncertainty: The forecast is for 2007 GDP to be 67% above 1995 (1.044 to the 12th power). If 2007 GDP in fact turns out to be that level, then the target is as agreed. But for every 1% higher (or lower) that 2007 GDP comes in, the target for 2008-2012 will be X% higher (or lower).

But the best way to phrase to Argentina this (exact same) contract is as follows: its target will be given by [1995 + 55% - 5% - X(4.4%)15] + [X(average realized growth)15]. This way of phrasing it makes clear that it is a "growth target", and makes the proposal sound like the country can only win, and not lose, from indexation.

A tentative CEA recommendation is to set X at .7. (This is calculated as a statistical estimate of the effect of growth on BAU, .9, minus an allowance for progressivity whereby richer countries are asked to make larger cuts, .2. But an alternative favored by some in our group would be to let X be negotiated separately for each country.)
Then, for concreteness, the Argentine target becomes:

[1995 + 50% - .7(4.4%)15] + [.7(average realized growth)15]

= 1995 level + 4% + .7(accumulated growth over next 15 years).

Notice that if growth comes in as expected (4.4%), then the target is 50% above 1995 levels, or 5% below BAU.

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Growth Targets for Carbon Emissions from Developing Countries

Jeffrey A. Frankel, New Century Chair, The Brookings Institution

Introduction and Summary of Findings

As part of the effort to address the problem of Global Climate Change, the United States has advocated "growth targets" for emissions of greenhouse gases (GHG) by developing countries. A few of these countries are considering the possibility of adopting such targets, and have solicited assistance in how to formulate them. This policy brief presents some basic principles for determining what would constitute appropriate growth targets and discusses several proposals.

- **Environmental benefits**
  - Growth targets even as high as "business as usual" can yield significant **reductions in global emissions** by forestalling the "leakage" that would otherwise occur.
  - Further, when permits are sold, reductions in carbon dioxide emissions generate **ancillary air quality benefits** in the developing countries through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions.
- Targets can result in **economic gains** from trade for all sides, if they are not too stringent.
  - **Economic benefits to developing countries:** With targets at busines as usual (BAU), developing countries would enjoy net gains of billions of dollars through the international sale of emission reductions achieved at costs below the world price.
  - **Cost savings to the U.S.:** Participation by developing countries in international permit markets would greatly lower the costs of meeting its Kyoto target, as analysis by the Council of Economic Advisers has shown. It is estimated that effective trading with developing countries would lower U.S. costs more than 80 percent (as compared to 57 percent savings from trading among Annex I countries alone).
- A "fair" allocation to expect of potential new participants might be a target that fits the apparent pattern agreed among industrialized countries at Kyoto in December 1997. This approach turns out to imply some degree of "progressivity" -- with richer countries asked to make bigger sacrifices than poor ones.
- Given uncertainty about the future, fixing the precise quantitative target now would create great risks regarding the ultimate stringency of the target. It would raise concerns that a target could turn out unexpectedly stringent, unintentionally constraining economic development, on the one hand, or that the target could turn out unexpectedly lax, resulting in "hot air," on the other hand. These risks could be reduced by an indexation approach.

Growth Targets for GHG Emissions from Developing Countries

Many difficulties plague the effort to implement the Kyoto Protocol tbat was negoitatied in November 1997, and the other steps that would be necessary to make a start at reducing global emissions of greenhouse gases with the aim of mitigating global climate change. There are wide chasms to be bridged: the chasm between some Senators and environmentally-concerned scientists and citizens regarding how genuine is the problem, the chasm between the extent of popular concern and the extent of popular willingness to bear even a small increase in energy prices to address the problem, and the chasm between US and European attitudes toward international trading of emission rights. Probably the most difficult chasm that needs to be bridged is between the United States and developing countries regarding the necessity of participation by the latter in any global plan to address global climate change.

The viewpoint from the North

We cannot solve the climate change problem without participation by developing countries. (Developing countries are here defined as those outside the 38 industrialized countries -- and transition countries -- known as Annex I or Annex B countries, that agreed to binding reductions on emissions of greenhouse gases at Kyoto.) Just for starters, the U.S. Senate strongly opposes any agreement that does not include the developing countries. The Byrd-Hagel resolution, which proclaimed LDC commitment to emission targets a pre-requisite for ratifying the Kyoto treaty, was passed by a vote of 95-0.

Senators use words like "competitiveness" and "fairness" to express why they insist on full developing country participation in any plans for emission reductions. Competitiveness is not well-defined in the lexicon of economists. Paul Krugman has explained to us why competitiveness is "a dangerous obsession." And "fairness" is much in the eye of the beholder -- witness the argument by developing countries that a fair distribution of emission rights would be an equal allocation on a per capita basis. It is crucial that developing countries participate. Indeed, the President has said that he will not submit the treaty for Senate ratification until there is commitment to meaningful participation by key developing countries in the first budget period (2008-2012). But I would phrase the reasons differently than does the Congress.

There are several reasons why meaningful participation from developing countries is essential.

- First, a global problem requires a global solution. The problem is inherently one on which an individual countries can make little progress on itsr own. It can be thought of as an "international externality," "the tragedy of the commons," "free-riding," or "global public goods." Whatever you call the problem, a solution requires that all countries agree to participate together.

- The effort to address climate change will not succeed without cooperation by the developing countries because their emissions are the fastest-growing, and will surpass those from the industrialized countries early in the century if everyone proceeds according to business as usual. The crossover is projected to occur by 2010, according to the International Energy Outlook 1999 released by the U.S. Energy Information Agency. China is expected to surpass the United States as the largest single emitter by around 2020. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not go far in averting from climate change.

- If developing countries do not participate in the international regime, their emissions could potentially increase by *more* than they are currently forecast to increase under their business-as-usual baselines. This is the problem of ***leakage***. [redacted] One mechanism for such an unintended consequence of the Kyoto agreement is the relocation of carbon-intensive industries from participating to non-participating countries. Another mechanism is via the oil market. As Annex I countries comply with their targets, their demand for oil will fall, causing the price of oil to fall on world markets, thereby encouraging non-participating countries to use more oil and emit more carbon than they otherwise would have. The result would be that every ton of emission reductions in the North would be partially offset by an increase in the South.[1] [redacted]

- Finally, participation by developing countries is crucial because it would permit relatively low-cost reductions in emissions there to be substituted in place of some high-cost reductions in the industrialized countries. Greenhouse gas emissions have the same basic impact on the climate regardless of where they occur. So reductions in developing countries have the same environmental benefit as reductions in industrialized countries, even though the reductions in developing countries are often much less costly. It thus makes sense, from both an environmental and an economic perspective, to incorporate emissions reductions in developing countries into the international system.

What about "competitiveness"? One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses "loss of competitiveness" to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated. The aggregate trade balance is determined by macroeconomic forces -- the difference between saving and investment[2] -- and not by our environmental policies.

If competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- it is easier to see the possibility of negative effects. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, we need to consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already differ significantly between the U.S. and countries such as Venezuela, and yet U.S. industry is not generally fleeing to Venezuela. Third, approximately two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings.

In short, I believe it more accurate to say that we need developing country participation for the reasons I outlined above -- projected emission paths, the global nature of the public good, leakage, and cost-minimization -- than to say that we need it to avoid adverse effects on competitiveness.

The viewpoint from the South

Developing countries make several arguments on the other side.

- First, their duty is to their citizens. Specifically,

  (1a) Their priority must be raising their own economic standards of living.

  (1b) This objective includes, in addition to raising market-measured incomes, also beginning to control local air and water pollution. Such pollution already is visible and is taking a large toll on health. Controlling local pollution therefore must take precedence over controlling greenhouse gases, which are not visible and which may not have serious health effects until a century into the future.

- Second, the developing countries should not be required to take any step that entails economic sacrifice until the industrialized countries have done so. There are two reasons for this:

  (2a) the industrialized countries created the problem, and

  (2b) they are richer and can more readily afford to make sacrifices.

It is hard to disagree with these arguments. But I do not believe that the Clinton Administration is asking poor countries to forego their economic development. "Meaningful participation during the period 2008-2012" need not entail economic sacrifice by developing countries. This argument is not based on diplomatic or political "happy talk", but on sound economic logic, as we shall see.

The gains from trade

I will concentrate on the possibility that developing country participation would take the form of commitment to a quantitative growth target, with international trading. If developing countries were to join the system of targets-with-trading, it would not only have environmental and economic advantages for the rest of the world; it would also have important environmental and economic advantages for the developing countries themselves. For the sake of concreteness, let us begin by considering a plan under which developing countries do no more than commit to their "business-as-usual" (BAU) emission paths in the 2008-2012 budget period and join the trading system.

The first thing to notice is that this system is not going to hurt the developing countries. They have the right in this budget period to emit whatever amount they would have emitted anyway. They need not undertake emission reductions unless a foreign government or foreign corporation offers to pay them enough to persuade them voluntarily to do so.

One anticipates that foreign governments and foreign corporations would indeed offer to pay participating countries enough in the budget period to persuade them voluntarily to reduce emissions below their BAU paths. The reason is that it could get expensive for the United States, Europe, and Japan to reduce emissions below 1990 levels over the next ten-to-fourteen years if the reductions are made only domestically, because this is a short span of time in which to achieve such a major structural change in the US economy. But the cost of reductions is far lower in developing countries. Thus governments and corporations in industrialized countries will be able to offer terms that make emission reductions economically attractive to developing countries. The economic theory behind the gains from trading emission rights is analogous to the economic theory behind the gains from trading commodities. By doing what they do most cheaply, both sides win. In Ricardo's classic trade example, Portugal specialized in producing wine and England in producing textiles. In the current context, developing countries specialize, for example, in installing clean new-technology power-generation capacity, while industrialized countries specialize in producing the capital goods that go into those plants.

Why is it so much cheaper to make reductions in developing countries than in rich countries? One major reason is that, in industrialized countries, one would have to scrap coal-fired power plants far in advance of their 40-year useful life, in order to replace them with natural gas facilities or other cleaner technologies. This would be very expensive to do, because it would mean wasting a huge existing capital stock. In rapidly-growing developing countries, on the other hand, it is more a matter of choosing to build cleaner power-generating plants to begin with, instead of building coal-fired plants. In general, when contemplating large increases in future demand for energy, it is good to be able to plan ahead. This includes learning from the mistakes of others that have gone before, and taking advantage of their technological advances.

The gains from trade can be made more concrete with some estimated magnitudes. The Council of Economic Advisers has estimated -- using the Second Generation Model (SGM) of

Battelle Labs -- that if Mexico were to join the target-and-trade system, the gains would be roughly $1 billion per year, each, for Mexico and the United States. If India were to join, it would gain almost $2 billion per year (and the United States slightly more). If China were to join, it would gain almost $4 billion a year (and the U.S. almost $12 billion a year).[1]

An extreme example of how measures to reduce carbon emissions have low costs in developing countries is the case of subsidies to fossil fuels, especially coal, which is the most carbon-polluting form of fuel. Eliminating such subsidies would create substantial immediate benefits -- fiscal, economic, and environmental -- even before counting any benefits under a global climate change agreement. Coal supplies the majority of energy in China, for example.[2] A major reason for the heavy use of coal is that it has historically been heavily subsidized. Estimates are that coal subsidies outside the OECD totaled from $37 to $51 billion worth in 1991-92. Total fossil fuel subsidies have been much greater -- well over $200 billion in the early 1990s, though smaller now. A 1994 study estimated that removing them would reduce global emissions by 7%. A 1995 study estimated that energy subsidies currently act as a negative carbon tax of about $40 per ton, and that global CO_2 emissions would be reduced by 4 to 5 % if all energy subsidies were removed. Some countries have already reportedly reduced the dollar value of such subsidies substantially in recent years, such as China (and other Asian countries, Argentina, Brazil, South Africa, and some oil-producing countries). Non-OECD countries cut fossil fuel subsidies by half between 1990-91 and 1995-96. But more progress is needed. Subsidy cuts within a target-and-trade system would pay developing-country governments twice over -- once in the form of the money that is saved by eliminating wasteful expenditure, and then again in the form of the money that is paid by an Annex I country for the resulting emission reductions.]

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Summary of Benefits of Targets-and-trade

To summarize: It would be useful to get developing countries to agree to binding limits on emissions, even if the targets involved only small (or no) cuts below BAU in the first budget period. Such targets, with trading, imply gains for their economies, gains for ours, and gains for the environment. There are five reasons:

- We want to forestall increases over BAU, that would occur in response to Annex I cuts if others do not take on targets (leakage).

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[1] Emissions abated would be roughly 19% of Mexico's BAU. India is estimated to abate about 18% of BAU. China abates about 20 % of BAU. The worldwide price of emission permits falls by half, relative to trading among Annex I countries alone The estimated gain in each case is the area under the marginal cost of abatement curve.

[2] 76% of commercial traded fuels, including nuclear and hydro. The figures are 57 % in India and 36% in Africa. Other statistics are given in a March 1997 World Bank study.

- [redacted]

- [redacted]

- [redacted]

- [redacted]

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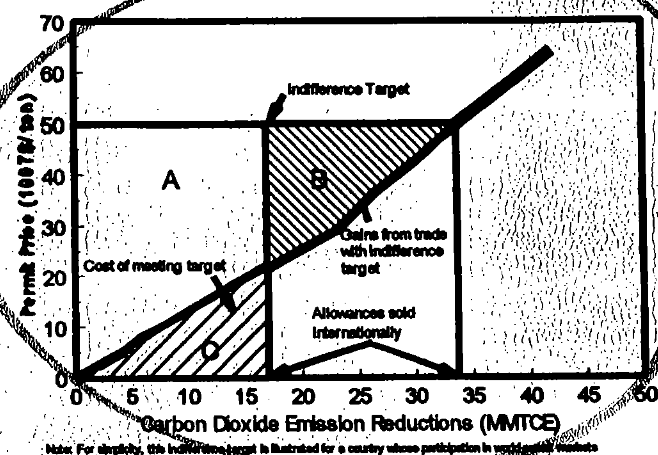
A Lower Bound Target: The "Indifference" Level

If developing countries were prepared to countenance emission targets, how should the level be determined? A reasonable number for the countries themselves to propose would be BAU targets. As noted, targets at that level have environmental and economic benefits for everyone involved. But the Annex I countries, and especially the environmentalists residing there, will respond by demanding targets that represent cuts in emissions, below the BAU path. Such a demand could also be viewed as reasonable, unless the proposed cuts were so large as to inflict economic damage. A lower bound to what could sensibly be proposed is what I will call the indifference level. Anything above BAU will not necessarily benefit Annex I countries, while anything below the indifference level will not necessarily benefit the others. Clearly the aim should be to fall somewhere in this range. For either side to propose a point outside the range would be equivalent to a rug-merchant in the bazaar asking a price higher than the customer can get the same rug for back home, or else equivlant to the customer asking a price lower than the cost to the merchant.

The environmental gains from emissions reductions below BAU come at the price of economic costs incurred by a developing country that adopts the below-BAU target. In addition, in the cases of large non-Annex I countries more stringent targets could result in higher economic costs for buyers in international emissions trading. More stringent developing country targets could raise U.S. costs of compliance by restricting the supply of permits in world markets and thereby raising the price of permits relative to less stringent targets.

Figure 1. Illustrative 2010 Marginal Abatement Cost Curve and Indifference Target



Note: For simplicity, the indifference target is illustrated for a country whose participation in world permit markets does not affect world permit prices.

To assess the stakes, consider the target that just leaves a country no better off than if it did not participate at all. This "indifference" target is where the costs of meeting the target through domestic action just equal the net gains from selling permits in world markets.[3] Figure 1 illustrates gains from trade for a small country. The upward-sloping curve shows the rising marginal cost of increasingly stringent reductions. For small reductions below BAU, say 5 million metric tons of carbon-equivalent (MMTCE), the cost is far less than the price they fetch on the world market. Further reductions are cost-efficient as well. But the cost rises with the magnitude of the reduction, tracing out the upward sloping supply curve. If the equilibrium world price is $50 a ton, then it pays this country to reduce emissions by about 34 MMTCE and sell all of this at a profit. (The last metric ton costs as much to abate as the $50 that the permit fetches on the world market.) The windfall for a country with a target that does not build in reductions relative to BAU is the entire area in the upper triangle (A+B).

It may not be considered reasonable for all these gains to go to the developing country. A requirement that the country must reduce emissions a certain amount before beginning to earn money by selling permits would balance the gains from trade more evenly. For a target that is equivalent to a reduction of 17 MMTCE below BAU, net gains from foreign exports are B, and the cost of meeting the target is C. Since B = C in this example, the net costs from participation are nil.[4] This is the indifference level.

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[3] This analysis presumes that non-Annex I countries abate their emissions cost-effectively, e.g., through a tradable permit system or a carbon tax.

[4] This hypothetical example assumes that the country in question does not reduce emissions in response to other policy initiatives. [If this country were to participate in an effectively-operating Clean Development Mechanism (CDM) under the case where it did not adopt a target, then its indifference target would not be at the level where net gains from trade are zero, but rather where expected net gains from trade would equal expected net gains from the CDM. The CDM option implies that the indifference target would

As a numerical example of the effects of increasing the stringency of an emissions growth target, consider results from some modeling scenarios of Annex I trading with China.[3] Table 2 illustrates the effects of Chinese emissions targets at various levels, assuming that China trades its permits with Annex I countries.[4]

Table 2. Effects of Various Chinese Emissions Targets with Annex I Trading

Emissions Target[1]	Permit Price (1997$/ ton)	Chinese Emissions Reductions (MMTC)	Chinese Emissions Sales (MMTC)[2]	Chinese Gains from Trade (billions 97$)	Increase in Total U.S. Cost Relative to China BAU Target
BAU	$26/ton	276	276	$3.6 b	not applicable
BAU - 1%	$26/ton	276	262	$3.2 b	~$0
BAU - 5%	$29/ton	304	235	$2.4 b	$1.3 billion
Indifference =BAU-13%	$36/ton	343	172	$0	$4.2 billion

[1] The SGM BAU is employed for China for the purposes of these calculations.
[2] Reductions in Chinese emissions less Chinese emissions sales yields net global reductions.

Imposing the "indifference" target on China would lead to the following results, given that its participation lowers world permit prices.[5]

- An indifference target for China results in it foregoing $3.6 billion relative to the gains it would obtain if it were to take a BAU target.
- An indifference target for China increases annual U.S. costs by $4.2 billion relative to a BAU target for China. (This increase is about 33% of estimated U.S. costs under global trading.)

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be less stringent. (On the other hand, including the ancillary air quality benefits associated with abating carbon dioxide, especially in countries with significant local air pollution problems, could imply that the indifference targets should be *more* stringent.)]

[5] The reason that Chinese participation lowers world permit prices is because BAU or near-BAU targets result in more permits available on the world market.

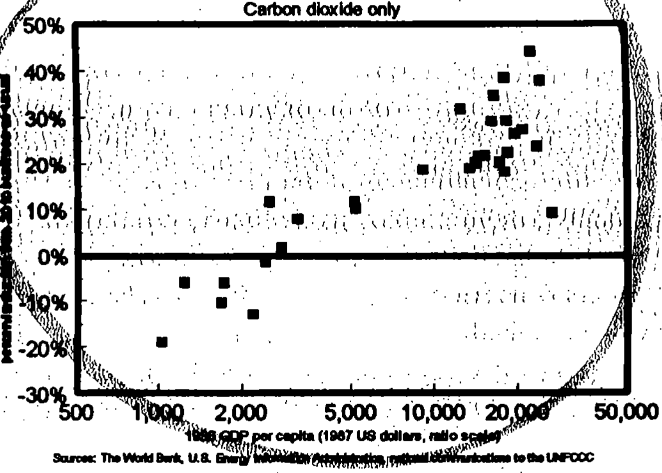
A "fair" allocation

If it is reasonable for poor countries to propose BAU targets as their opening bid, and also reasonable for rich countries to propose indifference targets as theirs, at what level would it be reasonable for a negotiated compromise to converge? While the emission targets in the Kyoto Protocol reflect the outcome of political negotiations, it is possible to discern systematic economic patterns in them. A fair target for developing countries might be one that fits whatever pattern tends to hold among existing targets. In particular, it turns out that this approach would allow some degree of progressivity, with richer countries making larger reductions than poor ones — without going nearly so far as the massive redistribution of wealth that some poor-country representatives seem to ask for.

The Annex I targets (including the allocation within EU "bubble"), when presented in terms of reductions below 2010 BAU, follow a pattern of progressivity (see figure 2). This pattern holds for CO_2 as well as for all greenhouse gas emissions. For the 30 Annex I countries presented in this figure, the average reduction from BAU is 16.1%. For the lower half of Annex I countries by per capita income, the average reduction is 5.2% below BAU.

Figure 2. Emissions reduction vs. GDP per capita

Carbon dioxide only



Statistical analyses can help us understand the progressivity of the targets. Data on four variables — Annex I countries, per capita income, emissions growth projected between 1990 and 2010, coal as a share of total energy consumption, and a dummy variable representing whether a country is a transition economy — can help explain the trend in emissions targets. The statistical analysis exhibits a pattern of progressivity among the existing targets: each 1% increase in per capita income implies a 0.11 to 0.17% greater sacrifice, expressed as emissions reductions from BAU. Levels of statistical significance are relatively high, suggesting that the results are meaningful. In absolute terms, an increase in income is associated with an increase in the level of the emission target. But the increase in income also implies an increase in the BAU level. The increase in BAU is *greater* than the increase in the target, implying that richer countries are making greater sacrifices. As an example, when the pattern is extrapolated to China the implied target is a 5 percent cut relative to BAU. This happens to lie inside the range spelled out in Table 2: both China and the rest of the world gain. It is not an unreasonable benchmark for other countries as well.

This statistical approach certainly has limitations, and the results reported here are preliminary. They are sensitive to decisions about the data used. Per capita income data can change depending on the year and exchange rate used to compare countries. Estimates of BAU emissions can vary too. But where the question of the distribution of targets seems inherently arbitrary, these results suggest an approach that incorporates the principle of progressivity while avoiding the impractical redistributive extremes proposed by some representatives of developing countries.

Uncertainty about target stringency, and a proposed solution

Some developing countries are worried that the uncertainty regarding projected economic performance is so great that they cannot risk adopting a binding emissions target for 2008 at this time. Even if a particular numerical target appears beneficial ex ante, it might turn out to be something different ex post. A response to this concern is that international agreements on these countries' targets should be structured to reduce the risk of being inadvertently stringent, and in particular to reduce the possibility of a target so stringent as to cause large economic losses to the developing countries or as to constrain economic development.

In addition to the concern expressed by some developing countries that adopting a binding target risks inadvertent stringency in the future, environmentalists have also expressed concern the symmetric concern on the other side, that a target may be too lax, creating "tropical hot air" and thus failing to result in environmental benefits in terms of actual emissions reductions relative to what would have happened in the absence of a treaty. Thus, it is desirable both to mitigate the risk of inadvertent stringency and also mitigate the risk of inadvertently laxity. The idea is to reduce the variability of the effective stringency of the target without loosening or tightening the intended target, i.e., to reduce the variance without changing the expected value.

The general notion is to agree today on a contract under which the numerical emission target is to depend in a specified way on future variables whose values are as yet undetermined. (The analogy is with a cost-of-living adjustment clause in a labor contract, that specifies a given increase in the wage for every cent increase in the Consumer Price Index – thus reducing uncertainty over *real* wages.) Future economic growth rates are probably the biggest source of uncertainty. Forecasts of GDP among East Asian countries, for example, are already very different now from what they were in 1997, and will again look different in 2007. In what follows, we assume that a country's aggregate emissions are indexed to future income alone. Other possible proposals include other variables like population or temperature in the formula.[6]

The simple version of the indexation proposal is as follows: **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by 1%.**

There is also a more general case: **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by X%, where X is a number less than 1.** An advantage relative to the simpler version of the proposal is that countries that do well over the coming decade are asked to contribute a bit more than those that do not, while not being penalized unduly for their growth. The analogy is to a progressive income tax system.

Worked-out Example for Argentina

Step 1 – setting expected target. BAU is for carbon emissions growth of 55% cumulatively from 1995 to 2010, or 3% per year (all data are from Argentine Government). Of this, 4.4% per year is GDP growth, -0.8% is decreasing energy/GDP, and -0.6% is decreasing emissions/energy. We could ask all LDCs to take targets that are expected to be 5% below BAU. For Argentina, the expected 2010 target would then be 50% above 1995 levels. An alternative, which might appeal to many countries, would be to let them pick their highest previous year, and set the target 50% above that.

Step 2 – [illegible]. The forecast is for 2007 GDP to be 67% above 1995 (1.044 to the 12th power). If 2007 GDP in fact turns out to be that level, then the target is as agreed. But for every 1% higher (or lower) that 2007 GDP comes in, the target for 2008-2012 will be X% higher (or lower).

The best way to phrase to the Argentines this contract is as follows: its target will be given by [1995 + 55% - 5% - X(4.4%)15] + [X(average realized growth)15]. This way of phrasing the proposal makes clear that it is a "growth target;" under indexation, the country can only win from growth.

For example, the implication of a tentative calculation would be to set X at .7. (This is calculated as a regression estimate of the average effect of growth on BAU, .9, minus an allowance for progressivity whereby richer countries are asked to make larger cuts, .2.)

Then, for concreteness, the Argentine target becomes:

[1995 + 50% - .7(4.4%)15] + [.7(average realized growth)15]

= 1995 level + .4% + .7(accumulated growth over next 15 years).

Notice that if growth comes in as expected (4.4%), then the target is 50% above 1995 levels, or 5% below BAU.

This example illustrates a possible approach to removing some of the economic uncertainty from the commitment of adopting a quantitative target. Another possible idea, suitable for any country willing to implement via a carbon tax or tradeable permit system would be an "escape clause" or "safety valve," which eases the quantitative limit when the price of carbon threatens to rise above a pre-agreed threshhold. Such approaches to the uncertainty problem would make it more likely that the target will turn out to fall in the range intended, where it brings benefits both environmental and economic, to developing countries and industrialized countries alike.

Endnotes

1. [redacted]

Table 1. Increase in Non-Annex I Emissions Under Annex I Trading

MERGE (Manne and Richels)	MRT (Charles River Assoc.s)	G^3 (Shackleton et al)
325 MMTCE	115 MMTCE	55 MMTCE

2. The only attempt to model the intertemporal dimensions of this problem with which I am familiar is by McKibben, Wilcoxen, and Shackleton, via the G-cubed model. But if one is truly interested in the trade balance, the proper analytical framework is probably the classic "transfer problem." It suggests that, in a world in which the United States would be buying permits from other countries, the effect on the US balance in goods and services would be positive. (The effect on broader measures of the balance of payments could well be negative.)

3. These analyses assume that no other non-Annex I countries participate in international emissions trading or the CDM. If other non-Annex I countries did participate in either flexibility mechanism, the world trading price could be lower, resulting in lower gains from trade and a less stringent indifference target for China.

4. A small reduction below BAU has no real effect on the Annex I trading price, and thus no economic effects on the U.S. However, as the target becomes more stringent the trading price increases, resulting in higher total costs of compliance for the U.S.

5. Data on some non-CO_2 GHG emissions are not available for some Annex I countries, however.

6. The rich countries are afraid of mentioning population, for fear of giving a platform to the utterly unrealistic proposal to give equal per capita emission rights to all countries. Nevertheless, some less extreme version of including a role for population seems fair. (One possibility is equal weight on three variables: shares of global population, shares of output, and shares of pre-Kyoto emission levels.) The argument for including the temperature over the coming decade is not that it will contain much scientific information regarding the true magnitude of the climate change problem -- weather fluctuations are far too noisy for that -- but rather that it will contain information regarding the political willingness of people to pay the costs of more stringent targets.

7. There exists an alternative proposal that I would reject: [redacted]

8. A more accurate forecast might use different coefficients for different kinds of countries. An alternative that is more practical politically would be to let X be negotiated separately for each country.

Growth Targets for GHG Emissions from Developing Countries:

Introduction and Summary of Findings

The United States has advocated emissions growth targets for non-Annex I countries. As these countries consider the possibility of adopting such targets, several have solicited assistance from the United States. The tasks of providing technical assistance to these countries and working with the international community to develop an understanding of what constitutes "appropriate non-Annex I targets" require a further refinement of the US position on developing country growth targets. This paper presents some basic principles for growth targets and discusses several proposals.

Principles **Recognizing the interests of developing countries, the United States interest, and the economic and environmental impacts of emissions targets, there are three basic guiding principles for emissions growth targets:**

- **Targets should result in environmental benefits;**
- **Targets should be consistent with continued economic development; and**
- **Targets should be of a form that allows developing countries to participate in international emissions trading, to reduce the economic costs of attaining given targets.**

Findings While there is a general consensus on these basic principles, a further elaboration on some of the key issues involving these principles can help facilitate the effort toward a position on the form, magnitude, and timing of a developing country growth target. In reviewing existing data, ongoing research, and in conducting our own analyses, we have found that:

- Growth targets even as high as BAU can yield significant reductions in global emissions by forestalling the leakage that would otherwise occur.
- Targets can result in economic gains from trade for all sides, if they are not too stringent.
- A "fair" allocation to expect of potential new participants might be a target that fits the apparent pattern among Annex B countries. This approach turns out to imply some degree of "progressivity" -- with richer countries asked to make bigger sacrifices than poor ones.
- Given uncertainty about the future, to fix the precise quantitative target now would create great risks regarding the ultimate stringency of the target; it would raise concerns that a target unintentionally constrains economic development, on the one hand, or that the target could result in hot air, on the other hand. These risks would be reduced by indexation approaches.
- Approaches to index targets to income growth between now and the commitment period have some advantages over carbon efficiency target approaches.
- CO_2 is the dominant greenhouse gas in developing countries (from fossil fuels and land-use). Measurement of other gases might be too difficult to justify their inclusion.

Guide to Contents

(I) Benefits of Targets-and-Trade A scheme in which non-Annex I countries are invited to adopt binding emission targets in the general vicinity of their BAU paths, and then to trade emission permits internationally, is a scheme that has real potential economic and environmental benefits, not just for Annex I countries, but for the developing countries as well. This gives them a genuine incentive to join, which would otherwise be lacking.

(II) What Should Determine Desired Targets? Non-Annex I countries could be asked to take on targets that make some small reductions relative to BAU, and still benefit. But large cuts would render them worse off, and therefore unlikely to agree to participate. Conversely, large increases relative to BAU are unlikely to be acceptable to the Annex I countries. We explore the range of targets that the developing countries could be expected to take on. A reasonable upper bound is their BAU paths.

Even a target as generous as this would result in global environmental benefits, by forestalling leakage, as shown in **Memo II.1**: ***Emissions leakage from Annex I to non-Annex I countries.***

A reasonable lower bound is the "indifference target" which entails cuts large enough that participation no longer brings them economic benefits, because the gains from selling permits are fully offset by the losses from a stringent target. (See **Memo II.2:** ***The Trade-off between target stringency and gains from trade***).

An alternative approach to formulating a "fair" target for developing countries is to estimate statistically what pattern holds among targets already accepted by Annex I countries, and then to extrapolate to developing countries. This statistical approach is explained in **Memo II.3**: ***Progressivity of existing targets, as a guideline for developing-country targets.*** This approach turns out to imply some degree of "progressivity" -- with richer countries asked to make bigger sacrifices than poor ones -- without going nearly so far as the redistribution of wealth that some poor-country representatives seem to be asking for. As an example, when the pattern is extended to China, the implied target is a 5 percent cut relative to BAU. This happens to lie inside the range spelled out in Memo II.2.

(III) Uncertainty of Measurement and Forecasting complicates the analysis further. Because BAU forecasts are uncertain, a given numerical target could turn out to be unintentionally stringent (inflicting economic costs on the country) or unintentionally lax (creating "tropical hot air"). **Memo III.1**, ***Uncertainty about Target Stringency, and proposed solutions***, explores this problem and approaches to deal with it by indexation.

Another difficulty of extending targets to developing countries is measurement of emissions. **Memo III.2**, ***What greenhouse gases are necessary to include?***, suggests simple CO2 targets might be good enough for these countries.

(6)

I. Benefits of Targets-and-trade

It would be useful to get developing countries to agree to binding limits, even if they involved only small (or no) cuts below Business as Usual (BAU) in the first budget period. Such targets, with trading, imply gains for their economies, gains for ours, and gains for the environment.

Reasons:

- We want to forestall increases over BAU that would occur in response to Annex I cuts if others do not take on targets. (This is leakage, as explained in Memo II.1 below.)

- The ability for Annex I countries to buy reductions from LDCs would greatly reduce the costs of meeting our targets (as CEA testimony showed). In particular, it is estimated that trading with developing countries would lower U.S. costs more than 80 percent relative to the costs of achieving the Kyoto targets solely through reductions in domestic emissions. (This is as compared to 57 percent savings from trading among Annex I countries alone.)

- With targets close to BAU, the developing countries would benefit from the ability to sell emission permits achieved at costs below the world price. This actually gives them a genuine economic incentive to join, which is otherwise lacking. Illustrative calculations by CEA suggest that China would stand to gain $3.6 billion/year by joining Annex I, and India to gain $1.5 billion/year. (See Table 2. The United States would save a preliminary-estimate $11.6 billion if China joined, or $2.5 billion if India joined.)

- Further, when permits are sold, reductions in carbon dioxide emissions generate ancillary air quality benefits in the developing countries through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions.

- Establishing developing country targets now would meet the requirements of the Byrd-Hagel resolution. Agreement on modest targets in the nearer term is the first step to drawing LDCs into the system, where larger cuts relative to BAU might be possible in the longer term (in some proportion to the cuts made by richer countries that have gone before them).

II.1 Emissions leakage from Annex I to non-Annex I countries

Even if developing-country targets did no more than to hold developing countries at BAU emission levels, this would be a major environmental benefit. [redacted]. Often referred to as "leakage," this shifting in emissions reflects two economic impacts of abating emissions in Annex I:

- **World Oil Market Price Effects**. Abating carbon dioxide in Annex I countries reduces the demand for oil, thereby lowering the price of oil. With lower oil prices, some non-Annex I countries will consume more oil and increase their emissions relative to what they would have without the Annex I abatement policies.

- **Energy-Intensive Industry Migration**. Annex I abatement policies that increase the price of energy may provide an incentive for energy-intensive firms to relocate to non-Annex I countries.

Leakage is positively correlated with permit prices; higher Annex I permit prices (and higher energy price effects) will likely result in higher rates of leakage.[1] [redacted]

Table 1. Increase in Non-Annex I Emissions Under Annex I Trading

MERGE (Manne and Richels)	MRT (Charles River Assoc.s)	G^3 (Shackleton et al)
325 MMTCE	115 MMTCE	55 MMTCE

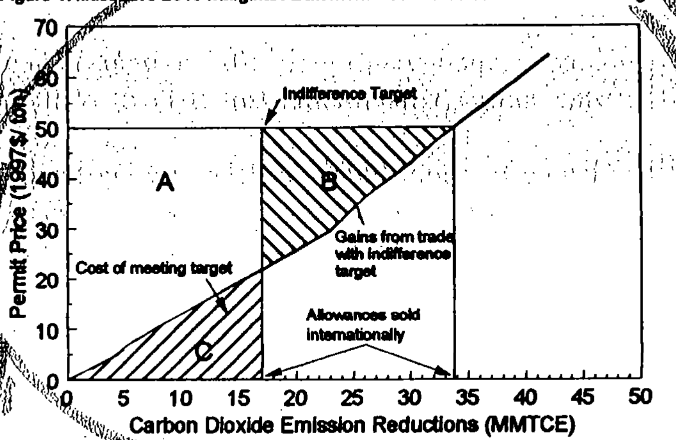
[1] However, international emissions trading can eliminate leakage among all trading participants. An effective trading market that results in equal marginal costs of abatement across all participating countries also results in equal energy price effects in all participating countries. Thus, there is no economic incentive for energy intensive firms to relocate to another country participating in trading. A full global trading system would then eliminate leakage completely. Some economic analysis indicates that while the CDM would lower costs some to Annex I countries, the project-by-project approach does not equalize energy price effects across all participating countries, and would not eliminate leakage to developing countries.

II.2 The trade-off between target stringency and gains from trade

The Administration has stated in bilateral and multilateral meetings, Congressional testimonies, and other public fora that if developing countries adopt emissions growth targets and participate in international emissions trading, they can enjoy economic gains from trade. Among other issues, this conclusion is sensitive to the stringency of the emissions growth target. The environmental gains from emissions reductions below BAU come at the price of economic costs incurred by a developing country that adopts the below-BAU target. In addition, in the cases of large non-Annex I countries, more stringent targets could have economic costs for buyers in international emissions trading. More stringent developing country targets could raise U.S. costs by restricting the supply of permits in world markets and so raising the price of permits relative to less stringent targets.

To assess the magnitude of this effect consider the target which just leaves a country no better off than no target at all. This "indifference" target is where the costs of meeting the target through domestic action just equal the net gains from selling permits in world markets.[2] Figure 1 illustrates gains from trade for a small country. The upward-sloping curve shows the rising marginal cost of increasingly stringent reductions. For small reductions from BAU, the cost is far less than the price they fetch on the world market. For a target that is equivalent to a reduction of 17 MMTC, net gains from foreign exports are B, and the cost of meeting the target is C. Since B = C in this example, the net costs from participation are nil.[3]

Figure 1. Illustrative 2010 Marginal Abatement Cost Curve and Indifference Target



Note: For simplicity, the indifference target is illustrated for a country whose participation in world permit markets does not affect world permit prices.

As a numerical example of the effects of increasing the stringency of an emissions growth target, we present results from some modeling scenarios of Annex I trading with China. These analyses assume

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[2] This analysis presumes that non-Annex I countries abate their emissions cost-effectively, e.g., through a tradable permit system or a carbon tax.

[3] This hypothetical example assumes that the country in question does not consider participation in the Clean Development Mechanism (CDM). If this country were to participate in CDM if it did not adopt a target, then its indifference target would not be at the level where net gains from trade are zero, but where expected net gains from trade would equal expected net gains from the CDM. The CDM option implies that the indifference target would be less stringent. However, including the ancillary air quality benefits associated with abating carbon dioxide, especially in countries with significant local air pollution problems, could imply that the indifference targets should be *more* stringent.

that no other non-Annex I countries participate in international emissions trading or the CDM. If other non-Annex I countries did participate in either flexibility mechanism, the world trading price could be lower, resulting in lower gains from trade and a less stringent indifference target for China.

Table 2 provides an illustration of the effects of emissions targets more stringent than BAU on China with Annex I plus China trading. A small reduction below BAU has no real effect on the Annex I trading price, and thus no economic effects on the U.S. However, as the target becomes more stringent the trading price increases, resulting in higher total costs of compliance for the U.S.

Table 2. Effects of Various Chinese Emissions Targets with Annex I Trading

Emissions Target[1]	Permit Price (1997$/ ton)	Chinese Emissions Reductions (MMTC)	Chinese Emissions Sales (MMTC)[2]	Chinese Gains from Trade (1997$)	Increase in Total U.S. Cost Relative to China BAU Target
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Indifference	$36/ton	343	172	$0 billion	$4.2 billion

[1] We employ the SGM BAU for China for the purposes of these calculations.
[2] Reductions in Chinese emissions less Chinese emissions sales yields net global reductions.

Imposing this "indifference" target on China, given that its participation lowers world permit prices, leads to the following conclusions:[4]

- An indifference target for China results in it foregoing $3.6 billion relative to the gains it would obtain if it were to take a BAU target.

- An indifference target for China increases annual U.S. costs by $4.2 billion or about 33% relative to a BAU target for China.

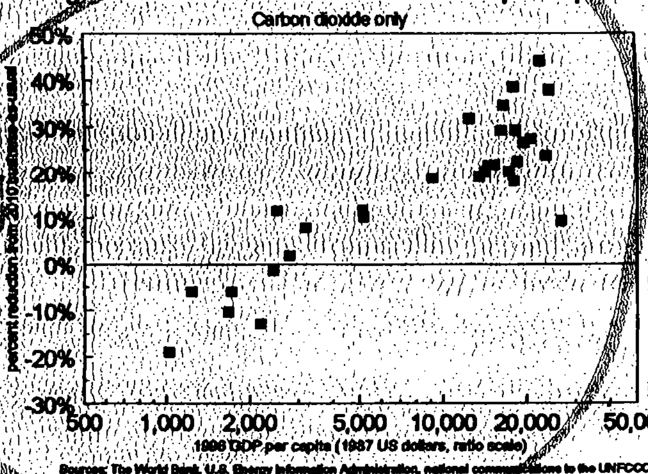
[4] The reason that Chinese participation lowers world permit prices is because BAU or near BAU targets result in more permits available on the world market.

II.3 Progressivity of existing targets, as a guideline for developing-country targets

It appears reasonable on grounds of fairness that wealthier countries should undertake greater efforts to address climate change than less-wealthy countries. While the emission targets in the Kyoto Protocol reflect the outcome of political negotiations, it is possible to discern systematic economic patterns in them. A fair target for developing countries might one that fits whatever progressivity seems to hold among existing targets. In particular, this approach would allow some degree of progressivity, with richer countries making larger reductions than poor ones -- without going nearly so far as the redistribution of wealth that some poor-country representatives seem to ask for.

The Annex B targets (including the EU bubble allocation), when presented in terms of reductions below 2010 BAU, follow a pattern of progressivity (see figure 1). Note that this pattern holds for CO_2 as well as for all greenhouse gas emissions, (although data on some non-CO_2 GHG emissions are not available for some Annex I countries, see memo II.2). [redacted] the 30 Annex I countries presented in this figure, the average reduction from BAU is 16.1%. For the lower half of Annex I countries by per capita income, the average reduction is 5.2% below BAU.

Figure 1: Emissions reduction vs. GDP per capita



We conducted statistical analyses to better understand the progressivity of the Annex B targets. We used data on Annex B countries' per capita income, emissions growth projected between 1990 and 2010, coal as a share of total energy consumption, and whether a country is a transition economy, to explain the trend in emissions targets in terms of deviations from BAU. The statistical analyses illustrate a pattern of progressivity among the existing targets: each 1% increase in per capita income implies a 0.11 to 0.17% greater sacrifice, expressed as emissions reductions from BAU. Levels of statistical significance are relatively high, suggesting that the results are meaningful. In absolute terms, an increase in income is associated with an increase in the level of the emission target. But the increase in income also implies an increase in the BAU level. The increase in BAU is *greater* than the increase in the target, implying that richer countries are making greater sacrifices. As an example, when the pattern is extrapolated to China, the implied target is a 5 percent cut relative to BAU. This happens to lie inside the range spelled out in Table 2 of Memo II.2; both China and the rest of the world gain.

This statistical approach certainly has limitations, and the results reported here are preliminary. They are sensitive to decisions about the data used. Per capita income data can change depending on the year and exchange rate used to compare countries. Estimates of BAU emissions can vary too.

10

III.1 Uncertainty about target stringency and proposed solutions

Some developing countries have claimed that the uncertainty regarding projected economic performance is so great that they cannot risk adopting a binding emissions target for the first commitment period at this time. A natural response to this concern is that international agreements on these countries' targets should be structured to reduce the risk of inadvertent stringency, and in particular to reduce the possibility of a target so stringent as to cause large economic losses to the developing countries. In addition to the concern expressed by some developing countries that adopting a binding target now for 2008 risks it being inadvertently stringent and constraining economic development, some have also expressed concern the symmetric concern on the other side, that a target may be too lax, creating "tropical hot air" and thus failing to result in environmental benefits in terms of actual emissions reductions. Thus it is desirable both to mitigate the risk of inadvertent stringency and also mitigate the risk of inadvertently laxity. The idea is to reduce the variability of the effective stringency of the target without loosening or tightening the intended target, i.e., to reduce the variance without changing the expected value.

To attempt to address this uncertainty issue, a number of ideas have been forwarded. CEA has called its proposal an indexation or formula approach; EPA has referred to its proposal as efficiency standards. They are all versions of the general notion of agreeing today on a contract under which the numerical emission target is to depend in a specified way on future variables whose values are as yet undetermined. (The analogy is with a cost-of-living adjustment clause in a labor contract that specifies a given increase in the wage for every cent increase in the Consumer Price Index -- thus reducing uncertainty over *real* wages.) In what follows, we assume that a country's aggregate emissions are indexed to future income alone. (We are thus omitting from past CEA proposals the possibility of including in the formula other variables like population, and are omitting from past EPA proposals the possibility of separate "efficiency standards" for individual sectors within an economy.)

It is useful to distinguish four proposals that appear in earlier memos.

(1) CEA approach (Special-case): **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by 1%.**

(2) CEA approach (General): **For every percentage point that GDP in 2007 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by X%, where X is a number less than 1.** An advantage relative to proposal (1) is that countries that do well over the coming decade are asked to contribute a bit more than those that do not, while not being penalized unduly.

(3) EPA approach (Special-case): **For every percentage point that GDP in the years 2008-2012 turns out to be higher (or lower) than forecast, the emissions target is raised (or lowered) by 1%. (EPA phrases this as setting a number for the ratio of emissions to GDP; but that is the same thing.)** The advantage relative to the CEA approach is it allows even more uncertainty-

protection, with respect to fluctuations in income in the years after 2007. The disadvantage is that the country does not know how many tons it is entitled to until the end of the budget period, which could make trading difficult.

(4) EPA approach (General). [redacted] It seems to CEA that this approach has two serious drawbacks: 15

[redacted]

[redacted]

III.2 What greenhouse gases are necessary to include?

In the Kyoto Protocol, Annex B countries have targets specified in terms of a basket of six types of greenhouse gases. These targets include both emissions sources and sinks. While this comprehensive approach provides more environmental benefits, it does increase the required effort and cost of inventorying greenhouse gas emissions. Many developing countries lack the monitoring infrastructure to assess emissions of all six types of greenhouse gases. Must developing country growth targets include all greenhouse gases, or is a subset of the Annex A list of gases sufficient?

In evaluating this question, it may be useful to consider several issues.

- **Greater Climate Benefits.** A developing country growth target set below what emissions would be otherwise for only one greenhouse gas (e.g., CO2) would generate greater environmental benefits relative to a scenario where that country does not adopt a target.

- **Leakage Across Gases Unlikely.** There appears to be little opportunity in most economies for intergas leakage. For example, most efforts to abate fossil fuel-related carbon emissions would result in efficiency improvements, switching to leaner fossil fuels (e.g., natural gas) and to carbon-free sources of energy (e.g., hydropower, nuclear, wind), none of which have emissions of other types of greenhouse gases. Moreover, efforts to abate carbon dioxide in fossil fuel combustion may have ancillary reductions of energy-related methane.

- **CO_2 is Significant Majority of Greenhouse Gas Emissions.** In the United States, carbon dioxide comprises 85% of all greenhouse gas emissions (weighted by carbon equivalence). Across Annex I, carbon dioxide is, on average, 80% of each country's emissions. This trend appears to hold for some non-Annex I countries as well. In 1990, carbon dioxide comprised 88% of Korea's emissions, 85% of Mexico's emissions, and 85% of Kazakstan's emissions. In Argentina, carbon dioxide comprised 63% of 1990 emissions, with methane comprising most of the rest. It appears that carbon dioxide dominates most countries' emissions, with methane a distant second (depending on the extent and nature of agriculture). Non-Annex I countries have not reported their emissions of the synthetic gases in their national communications to date. It is not clear how revisions to the N_2O emissions estimation methodology could affect estimates of non-Annex I countries' emissions.

- **Land Use Change Could be Significant.** Carbon dioxide emissions from land use change in non-Annex I countries appear to be quite significant. Some estimate that by including land use change emissions, non-Annex I emissions exceeded Annex I emissions in 1994 (Panayotou and Sachs 1998). Emissions from land use change in non-Annex I countries in 1994 were more than one-fifth of global carbon dioxide emissions. Some statistical analysis indicates that countries' land use change activities do not become net sinks, ceteris paribus, until per capita income exceeds $3,600.

(B)

Preliminary Draft, Close Hold, Do Not Cite, March 30, 1998

A Proposal for Developing Countries:
Participation in a "Target and Trade" System

I. This analysis demonstrates that the gains will be substantial if developing countries (a) accept binding targets at or slightly below their business as usual (BAU) emissions levels, and (b) trade from their respective targets. We believe that participation in a "target and trade" system should be the cornerstone of our international negotiations.

The economic and environmental rationale for such participation includes

- **Greater economic benefits to developing countries:** With targets at or only slightly below BAU, developing countries would enjoy net gains of many billions of dollars through the international sale of emission reductions achieved at lower cost than the world price.

- **Greater cost savings to the U.S.:** Participation by developing countries in international permit markets would greatly lower the costs to the U.S. of meeting its Kyoto target (as CEA testimony showed). In particular, costs would be lower than with trading among only Annex I countries.

- **Greater environmental benefits:** Targets slightly below business as usual would lower global emissions relative to a world with only Annex I targets. Further, reducing carbon dioxide emissions generates ancillary air quality benefits through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions.

- **Target and trade yields greater benefits than CDM:** While the Clean Development Mechanism will likely result in cost savings to the U.S. relative to a world with only Annex I trading, a system including effective target and trade of developing countries' emissions would yield much greater cost savings to the U.S. and greater gains to developing countries than CDM. Further, target and trade could achieve environmental benefits not achievable by pursuing CDM, which only redistributes emissions geographically.

- **The principle of full participation:** Other rationale include the long-run benefits of including developing countries into global negotiations, for example, as recognized by the Byrd-Hagel resolution. By establishing participation now, further commitments might be feasible in future periods.

II. Problem: To persuade a developing country *voluntarily* to adopt a target and then to trade permits internationally, international agreements must be structured to reduce the risk of inadvertent stringency and in particular to reduce the possibility of a target so stringent as to cause large economic losses to the developing country.

Proposed Solution: Negotiations should focus on the estimated business as usual emissions level, where this level is expressed in a way that depends on the *future* values of economic variables, such as GDP.

Rationale: Such targets would avoid the risk of inadvertent stringency associated with higher than projected economic growth between now and the beginning of the commitment period in 2008. Developing countries would face only the much smaller risk that emissions would be higher than expected, *given* the economic conditions realized in 2007.

Basic principles for implementing such an approach are:

- **Reasonable Forecasts**: The relationship between the target (putting aside any real reductions in emissions) and the values of economic variables, when applied to emissions and such variables during recent years, should predict emissions reasonably well and be without demonstrable statistical bias. Relationships that give reasonably reliable predictions reduce the risk of either inadvertent stringency or paper tons which could increase global emissions.

- **No Perverse Incentives:** The target should depend on values of economic variables only indirectly related to emissions, to avoid creating perverse incentives for developing countries to increase emissions so as to have higher targets in the commitment periods. For example, the target should not depend on energy consumption in 2007, but could reflect pre-Kyoto emissions levels.

- **Predetermined Targets:** To avoid uncertainty during the commitment period about the country's target the target should not depend on contemporaneous values of economic variables. For example, the target generally should not vary with 2008 or 2010 GDP levels, but rather with 2007 GDP.

III. Illustration: One way of implementing the solution is described below. Other ways of implementing the solution may work as well or better. The conclusions are stated below; the details of our work follow in appendix 3.

- Defining the business as usual level for a developing country as a function of its GDP and population in earlier years and setting the emissions target at that level yields a negligible risk of leaving the developing country worse off under target and trade because of inadvertent stringency. Even a target slightly below BAU would also yield negligible risk of leaving the developing country worse off.

- Emissions targets for developing countries set below their business as usual emission level would of course result in gains from trade smaller than with a BAU target, while providing environmental benefits. The higher costs of a target set below BAU are borne by both the developing countries and the Annex I countries.

There are significant gains from trade for developing countries and large cost-savings to the U.S. if even one large developing country accepts an emissions target at BAU and participates in emissions trading. Table 1 and Charts 1 through 3 illustrate these gains from trade from a baseline of full Annex I trading.

Table 1. Illustrative Gains from Trade with Developing Countries that Target and Trade

Trading Scenario	Permit Price[1] (1997$/ton)	Country Gaining	Gains from Trade with Developing Countries
Annex I only	$54	United States	not applicable
Annex I + China	$26	China	$3.6 billion/year
		United States	$11.6 billion/year[2]
Annex I + India	$47	India	$1.6 billion/year
		United States	$2.5 billion/year[2]
Annex I + Mexico	$51	Mexico	$0.9 billion/year
		United States	$1.2 billion/year[2]

[1] These scenarios do not account for the cost savings available through the Clean Development Mechanism and carbon sinks.
[2] Gains from trade for the U.S. are estimated as the change in the U.S. total cost of complying with the Kyoto Protocol relative to an Annex I only trading regime.

Chart 1. China's 2010 Marginal Abatement Cost Curve and Gains from Trade

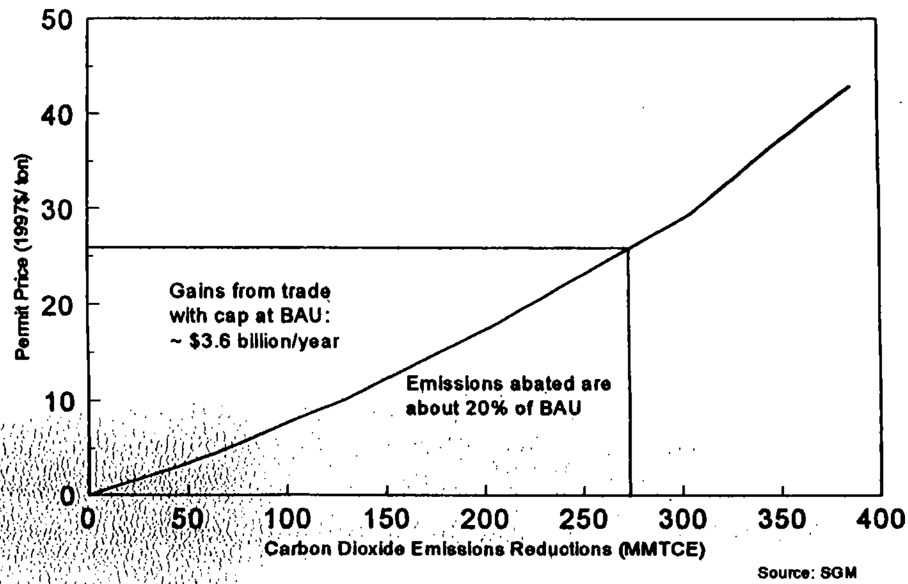


Chart 2. India's 2010 Marginal Abatement Cost Curve and Gains from Trade

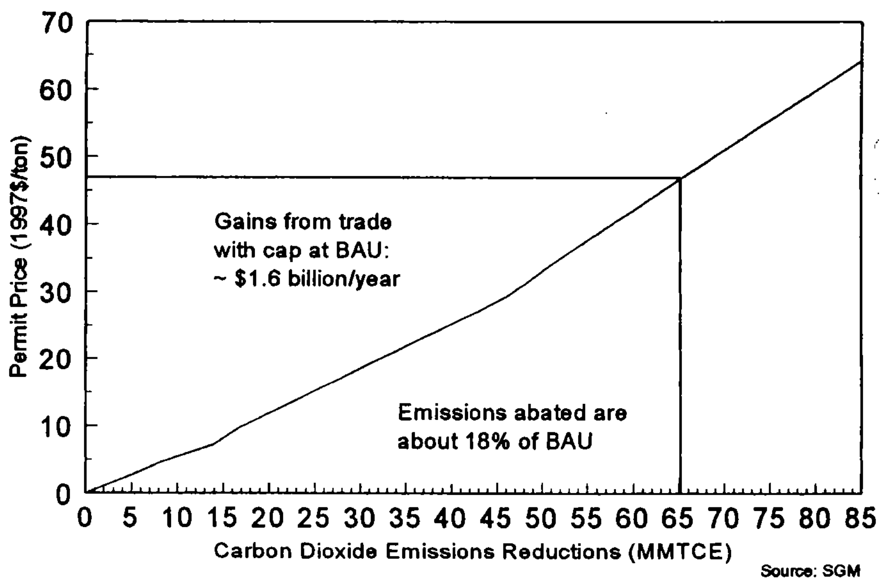
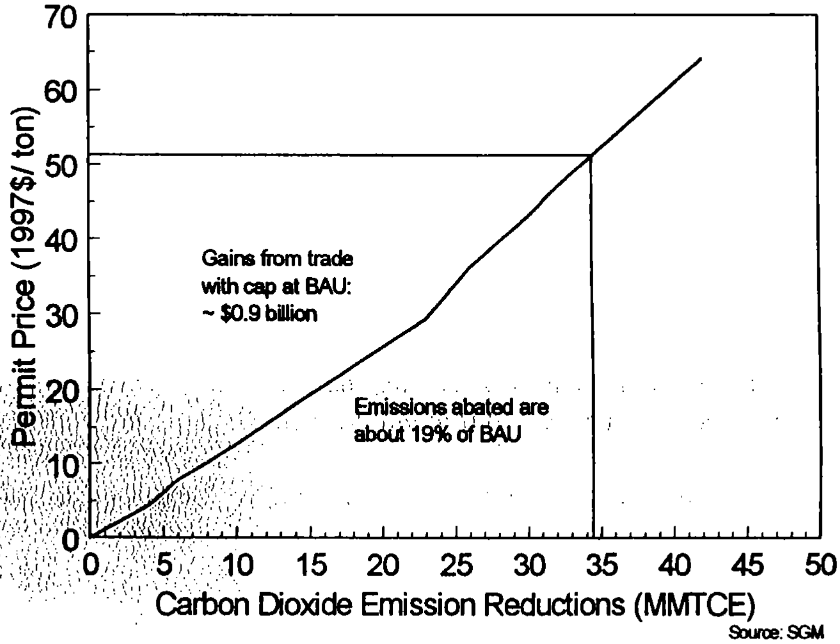


Chart 3. Mexico's 2010 Marginal Abatement Cost Curve and Gains from Trade



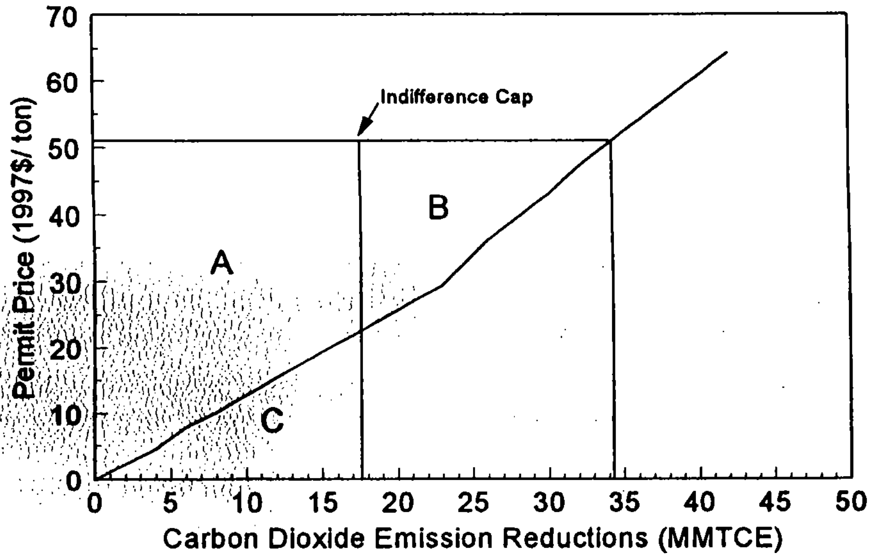
Appendix 1. Costs to the U.S. of Developing Countries Adopting Targets Below BAU

Regarding developing countries, most commonly discussed is the issue of fairness; what commitments to reduce emissions should be made by countries whose economic resources differ substantially? Generally neglected, but discussed below, is the issue of efficiency. In particular, what are the implications for U.S. costs of increasingly more stringent targets on emissions from key developing countries?

The environmental gains from emissions reductions below BAU come at the price not only of economic costs incurred by a developing country that adopts the below-BAU target, but also economic costs by Annex I. More stringent developing country targets raise U.S. costs by restricting the supply of permits in world markets and so raising the price of permits.

To assess the magnitude of this effect consider the target which just leaves a country no better off than no target at all. This "indifference" target is where the costs of meeting the target just equal the net gains from selling permits in world markets. Chart 4 illustrates gains from trade for a small country. For a target that is equivalent to a reduction from BAU of 17 MMTC, net gains from foreign exports are B, and the cost of meeting the target is C. Since B = C in this example, the net gains from trade are nil.

Chart 4. Illustrative 2010 Marginal Abatement Cost Curve and Indifference Target



Note: For simplicity, this indifference target is illustrated for a country whose participation in world permit markets does not affect world permit prices.

Table 2 provides an illustration of the effects of emissions targets more stringent than BAU on China with Annex I plus China trading. Note that a small reduction below BAU has no real effect on the Annex I trading price, and thus no economic effects on the U.S. However, as the target becomes more stringent, the Annex I trading price increases, resulting in higher total costs of compliance for the U.S. If China accepts a target below BAU, the cost of this additional stringency to the U.S. -- essentially, the cost of supplying the environmental benefits associated with these emissions reductions -- can become significant. Thus developing country participation in the form of acceptance of targets more stringent than business as usual will raise costs to the U.S.

Table 2. Effects of Various Chinese Emissions Targets with Annex I Trading

Emissions Target[1]	Permit Price (1997$/ ton)	Chinese Emissions Reductions (MMTC)	Chinese Emissions Sales (MMTC)[2]	Total Cost to U.S. of Complying with Kyoto	Cost to U.S. of Additional Stringency
BAU	$26	276	276	$13.4 b	not applicable
BAU - 1%	$26	276	262	$13.4 b	~$0
BAU - 5%	$29	304	235	$14.9 b	$22/ton
Indifference	$36	343	172	$17.9 b	$26/ton

[1] We employ the SGM BAU for China for the purposes of these calculations.
[2] Reductions in Chinese emissions less Chinese emissions sales yields net global reductions.

Imposing this "indifference" target on China, given that its participation lowers world permit prices, leads to the following conclusions.

- An indifference target for China increases annual U.S. costs by $4.5 billion or 33% relative to a BAU target for China.

- If China accepts an emissions target requiring reductions of approximately 170 MMTC below BAU, the average cost to the U.S. would be $26/ton. This is not the average cost of a ton of emissions purchased from China, but the average cost to the U.S. of the environmental benefits associated with China complying with a more stringent target.

Appendix 2. Ancillary Environmental Benefits of Target and Trade in Developing Countries

The voluntary reduction of greenhouse gas emissions by developing countries under a target and trade system will simultaneously reduce emissions of several pollutants, producing ancillary environmental and human health benefits in those countries. The environmental and health benefits that accrue to those developing countries are unlikely to be offset by decreases in environmental quality in the United States because of our stringent health-based air quality standards.

A recent study in *Lancet* examines the emissions of one pollutant that are reduced along with carbon emissions: airborne particulate matter (PM). The study projects that by 2020, a climate change policy scenario in which developing countries reduce emissions to 10% below their BAU could produce an annual reduction of 563,000 statistical deaths.

The analysis below adapts the predictions in the *Lancet* study to estimate the mortality risk reduced from participation by three developing countries (China, India, and Mexico) in a target and trade system. These illustrative calculations take as given the emissions reductions from BAU resulting from permit sales that are predicted by SGM. It suggests that significant public health gains could result from developing country participation in international carbon permit markets.

Table 3. The Effects of International Carbon Permit Trading on Mortality Risk Associated with Particulate Matter Emissions

Country	Predicted carbon emissions reduction from international permit sales	Share of non-Annex I population in 2010	Annual PM statistical deaths avoided in 2010 by international carbon permit trading
China	20%	23.7%	136,700
India	18%	20.3%	105,300
Mexico	19%	2.0%	19,700

For developing countries that are too "small" to affect the world permit price, adopting a carbon target more stringent than BAU and participating in international trade does not yield additional ancillary benefits relative to a BAU target. Large countries, by adopting targets below BAU, would raise the world price relative to a BAU target, and thereby achieve greater carbon emissions reductions and ancillary benefits.

<u>Caveats</u>

Major assumptions beyond those in the *Lancet* article include:

- Deaths avoided in each non-Annex I country are proportional to the country's share of non-Annex I population.
- Deaths avoided are proportional to carbon emissions reductions.

- Each key developing country is the sole non-Annex I country to adopt a target and participate in international trading.

Appendix 3. Summary of Analysis

A. Data

We have compiled data on 3 variables: emissions of carbon dioxide, GDP, and population for 117 countries for the time period 1970-1992. The carbon dioxide emissions data, measured in millions of metric tons of carbon, are from the Carbon Dioxide Information Analysis Center (Oak Ridge National Laboratory, DOE). The GDP data, measured in 1987 U.S. dollars, are from the World Bank. The population data, measured in thousands of individuals, are from the United Nations Population Division.

B. Methods

We have estimated a fixed effects linear regression on the logs of these variables, for the countries in our data set, excluding those listed in Annex I. Our regression uses four non-overlapping 5 year intervals for each country. Our forecasts include the country specific constants.

C. Results

The fixed effects regression we estimated is

$$\text{Emissions} = a\ \text{GDP}_{t-1} + b\ \text{GDP}_{t-2} + c\ \text{Population}_{t-1} + \gamma\ \text{trend}$$

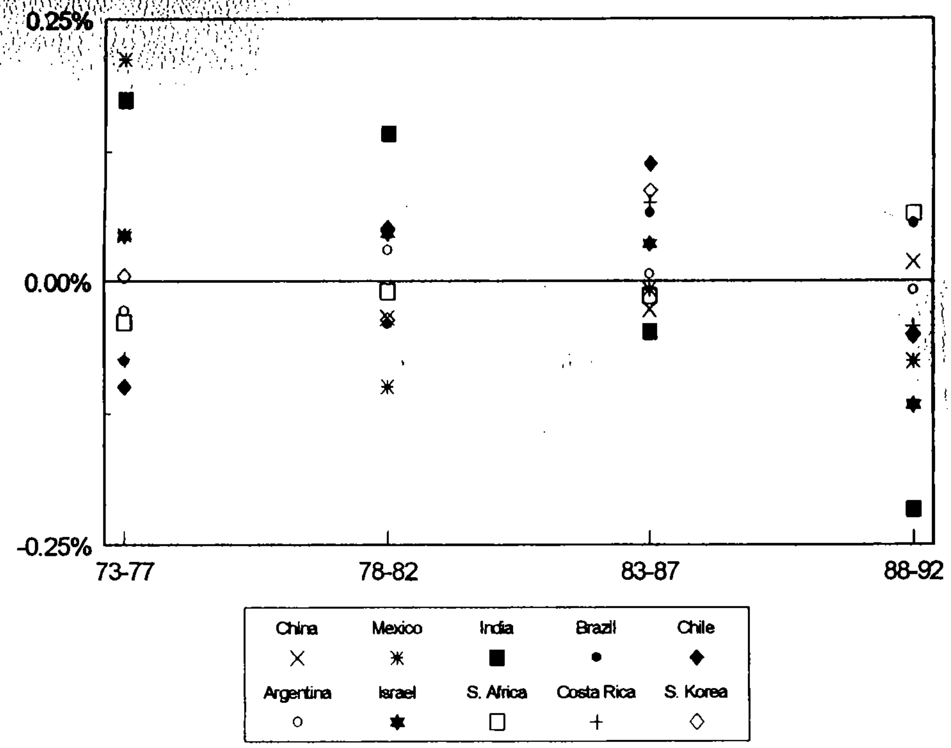
Emissions are the natural logarithm of the five year non-overlapping average of carbon emissions. All independent variables are lagged. GDP_{t-1} is the log of the gross domestic product in the year prior to the first year in the emissions variable, GDP_{t-2} is GDP in the year two years prior to the first year included in the emissions variable, and population_{t-1} is the country's population in the year prior to first year included in the emissions variable. Trend is one in the first 5 year period, and 2, 3, and 4 respectively in the subsequent 5 year periods. The useable data included 376 cross-section time series observations. The fixed effects regression used 98 degrees of freedom. The R squared was in excess of 0.99.

Table 4. Model I Results

Variable Name	Coefficient Estimate	Standard Error
GDP_{t-1}	0.9501823	0.2443047
GDP_{t-2}	-0.411297	0.23894
$Population_{t-1}$	0.4836006	0.2055439
trend	0.0073712	0.0310638

As one illustration of the model's accuracy in predicting emissions, consider the chart below that maps actual and predicted emissions using within sample data for ten selected developing countries. The predicted value is never more than 1/4 of one percent away from the actual emissions average for any of the five year intervals.

Chart 5. Error in Model I Prediction as a Fraction of Actual Emissions



(C)

Draft; close hold; CEA 2/17/99

How should growth targets for developing countries be set?
Summary of tentative consensus

This is an attempt to summarize some ideas that have been favorably received, regarding how to formulate growth targets for developing countries (in the first budget period). It must be stated from the outset that nobody wants the USG to be aggressive in making this sort of proposal internationally, for fear of appearing to be trying to impose a rigid formula on others. Rather, the point is to collect our thoughts internally, to be used if we are asked, as appropriate.

There appears to be a consensus among the Assistant Secretaries group that the aim should be targets in a range where they are low enough to produce environmental advantages (including forestalling leaking, but perhaps also small cuts relative to BAU), while high enough that to produce economic advantages (in the form of gains from trade to both buyers and sellers). That happy range is bounded by BAU on the upside and the "indifference level" on the downside (estimated, e.g., at BAU-12% for China with one model). CEA results that extrapolate from the progressive pattern of existing targets observed among Annex B countries might help choose a "fair" point within that range (e.g., estimated at -5% for China).

There also appears to be a consensus that it might be advantageous to consider "indexation" arrangements to cope with uncertainty between now and the budget period, i.e., to reduce the chance that a numerical target that was thought ex ante to be in the middle of the range turns out ex post to be either inadvertently stringent (imposing large economic costs) or inadvertently lax (creating hot air).

There is now a consensus that indexation was preferable to trying to impose a common absolute emissions/GDP standard across countries.

A majority favors setting the numerical target in 2007, though EPA (David Doniger) favors continuing the indexation through the end of the budget period (2012).

All favor considering the idea of indexing the emissions target to GDP. There were a fair number of proposals for other variables to include in the formula in addition to GDP (population, temperature, coal production, oil prices, electricity output), either uniformly across countries or on a country-by-country basis. Some argued that it should be left to the discretion of the developing country to decide what economic and/or demographic variables best explain emissions. But each individual candidate for a variable to be added was strongly opposed by a number of people and arguments.

The most unsettled question was what X should be, in the formula to allow X% higher emissions for every 1% in unexpected growth.

There was also a proposal (Victoria Greenfield, State), that unexpected reductions in income be accorded Y% lower emissions, with $Y<X$.

Example for Argentina

Step 1 -- setting expected target: BAU is for carbon emissions growth of 55% cumulatively from 1995 to 2010, or 3% per year (all data are from Argentine Government). Of this, 4.4% per year is GDP growth, -0.8% is decreasing energy/GDP, and -0.6% is decreasing emissions/energy. We could ask all LDCs to take targets that are expected to be 5% below BAU. For Argentina, the expected 2010 target would then be 50% above 1995 levels. An alternative, which might appeal to many countries, would be to let them pick their highest previous year, and set the target 50% above that.

Step 2: -- indexation to reduce uncertainty: The forecast is for 2007 GDP to be 67% above 1995 (1.044 to the 12th power). If 2007 GDP in fact turns out to be that level, then the target is as agreed. But for every 1% higher (or lower) that 2007 GDP comes in, the target for 2008-2012 will be X% higher (or lower).

But the best way to phrase to Argentina this (exact same) contract is as follows: its target will be given by: [1995 + 55% - 5% - X(4.4%)15] + [X(average realized growth)15]. This way of phrasing it makes clear that it is a "growth target", and makes the proposal sound like the country can only win, and not lose, from indexation.

A tentative CEA recommendation is to set X at .7. (This is calculated as a statistical estimate of the effect of growth on BAU, .9, minus an allowance for progressivity whereby richer countries are asked to make larger cuts, .2. But an alternative favored by some in our group would be to let X be negotiated separately for each country.)

Then, for concreteness, the Argentine target becomes:

[1995 + 50% - .7(4.4%)15] + [.7(average realized growth)15]

= 1995 level + 4% + .7(accumulated growth over next 15 years).

Notice that if growth comes in as expected (4.4%), then the target is 50% above 1995 levels, or 5% below BAU.

(C)

Draft; close hold; CEA 2/17/99

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= 1995 level + 4% + .7(accumulated growth over next 15 years)

Notice that if growth comes in as expected (4.4%), then the target is 50% above 1995 levels, or 5% below BAU.

Global Climate Change
30 May 97

BAU

*1990 – 1338 mmtc
2000 – 1516 +15%
2010 – 1693 +30%
2020 – 1805 ~40%

Fact Sheet

What's happening to the climate?

- **Climate Change in the last century**:
  -- Global temperatures have increased between 0.3 and 0.6 degrees Celsius
  -- Sea levels have risen between 10 and 25 centimeters
  -- Experts believe these changes are unlikely to be entirely natural in origin

- **Estimated Climate Change over the next century**:
  -- Within a reasonable range of emissions scenarios, global temperatures are likely to increase between 1 and 3 degrees Celsius
  -- Sea levels may rise between 50 and 94 cm.
  -- Because of the temperature inertia of the earth, climate change would continue for some time even with drastic immediate action.

Why is it happening?

- **Four gases account for 99.5%** of anthropogenic sources of greenhouse gases. They are, in descending order of importance, carbon dioxide, methane, nitrous oxide, and fluorocarbons. These gases remain in the atmosphere for a long time (decades to centuries).

- **Greenhouse gases have been accumulating:** Atmospheric concentrations of GHGs have grown significantly (1750-1992): Carbon dioxide -- 30%; methane 145%; nitrous oxide -- 15%.

Concentrations of Greenhouse Gases (parts per million)

Gas	Preindustrial (1750)	1992	2100 (upper bound, business-as-usual)
Carbon Dioxide	280	358	650
Methane*	-	43	77
Nitrous Oxide*	-	92	119
Fluorocarbons	0	.04	.18

* in CO2 Equivalent concentrations

6b/yr.

The US Situation

US responsible for 21% of global GHG emissions (25% of the CO_2 emissions from fossil fuel burning).

Breakdown of GHG Emissions:

By Gas (mmtce)		By Sector	
Carbon Dioxide	1406	30%	Utilities
Methane	178	27%	Transportation (fastest growing)
Nitrous Oxide	40		

Carbon Dioxide represents 86% of the global warming potential of US emissions.

Emissions of Carbon by Energy Source:

Energy Source	Average Carbon Produced (metric tons of carbon)
one metric ton coal	.63
one gallon motor gasoline	.00267
1bbl crude oil	.119
one mcf natural gas	.0145

5lb c/g

Emissions predicted to be 200 million metric tons (mmt) over 1990 levels by 2000

Economics of a Climate Change Policy

Effect of Carbon Tax, *$100 carbon tax would increase, in the short run*:

- gasoline -- $0.27/gal (currently $1.14 for unleaded regular)
- coal -- $63/ton (currently $27/ton CIF)
- petroleum -- $12 per bbl (currently $17/bbl)
- natural gas -- $1.45 per 1000 cf (currently $2.04 at wellhead)

- electricity from coal-fired plants -- $.10/kwh (currently $.03/kwh)
- electricity from natural gas combined cycle (NGCC) -- $.0035/kwh (currently $.040/kwh)

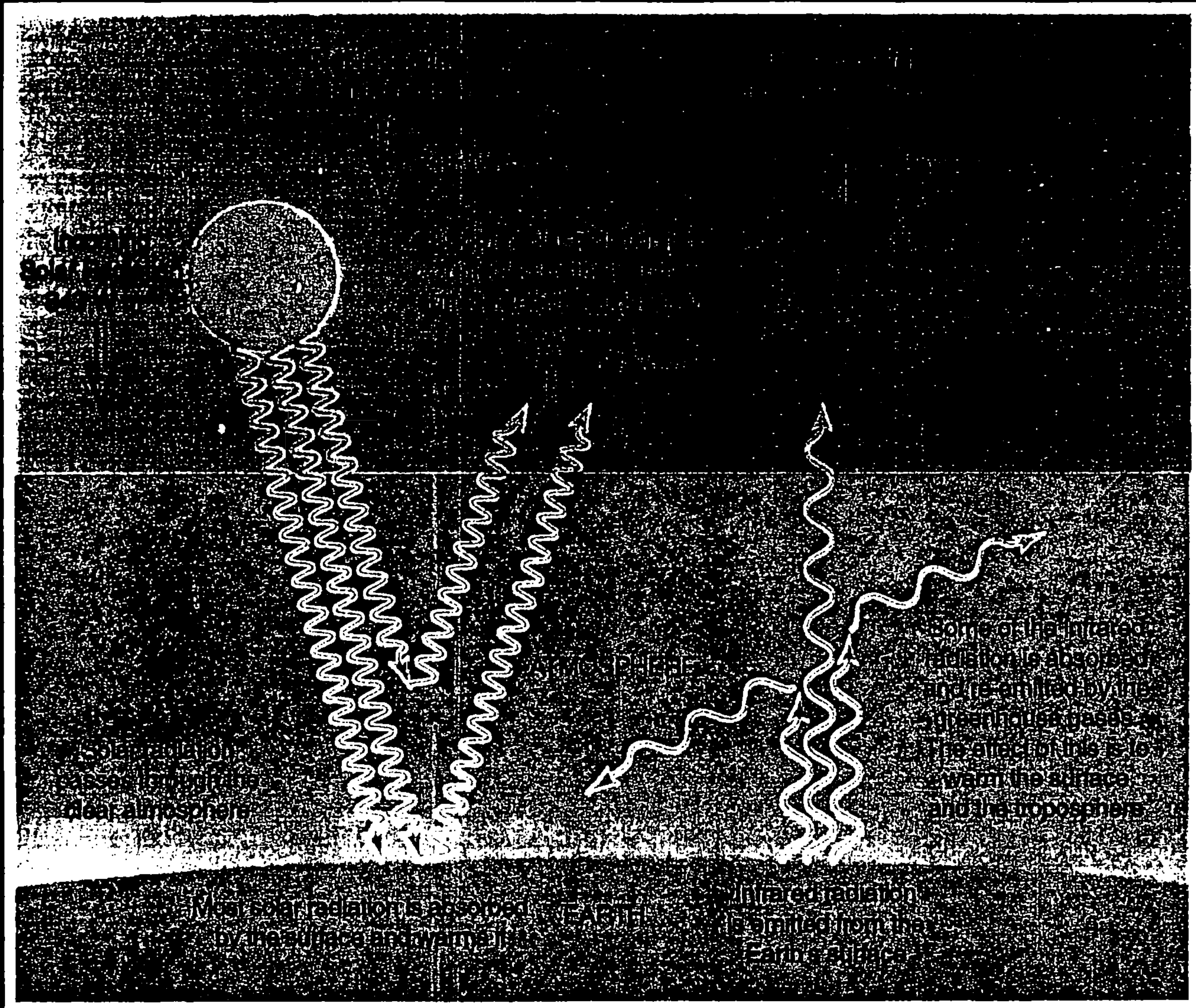
Energy Infrastructure Costs

Coal fired generating capacity in 1993 was 302,000,000 kw
Capital costs for NGCC plants is $500/kw, for coal fired plants is $142/kwh
Rough Estimate: Replacing 10% of coal fired plants with NGCC plants

Industries Most Affected by Reducing CO_2 Emissions

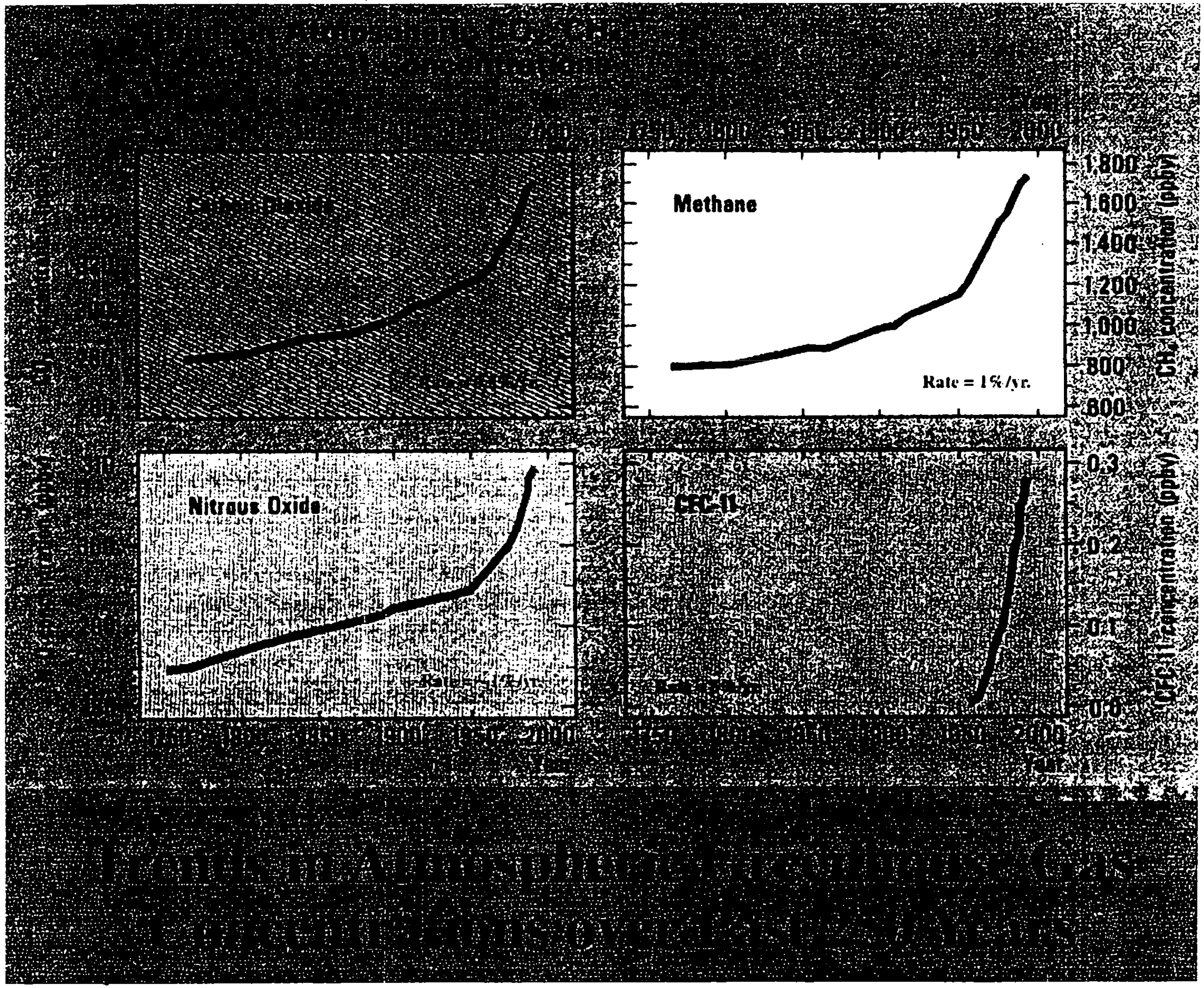
coal mining	gas and oil producers	agriculture
petrochemicals	steel	automobile
utilities	aluminum	cement

The Greenhouse Effect



ppmv

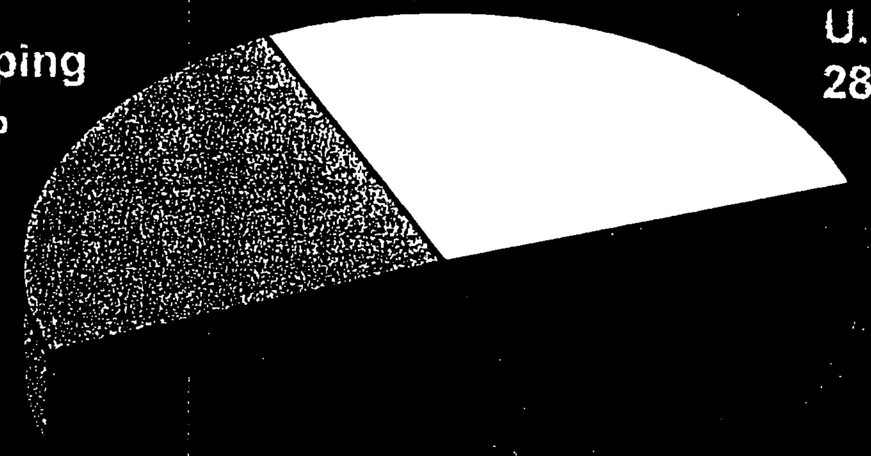
ppbv



Methane
Rate = 1%/yr.
1,800
1,600
1,400
1,200
1,000
800
600
CH4 Concentration (ppbv)
Nitrous Oxide
0.3
0.2
0.1
0.0
2000

1950-1990: Cumulative CO_2 Emissions from Fossil Energy and Cement Production

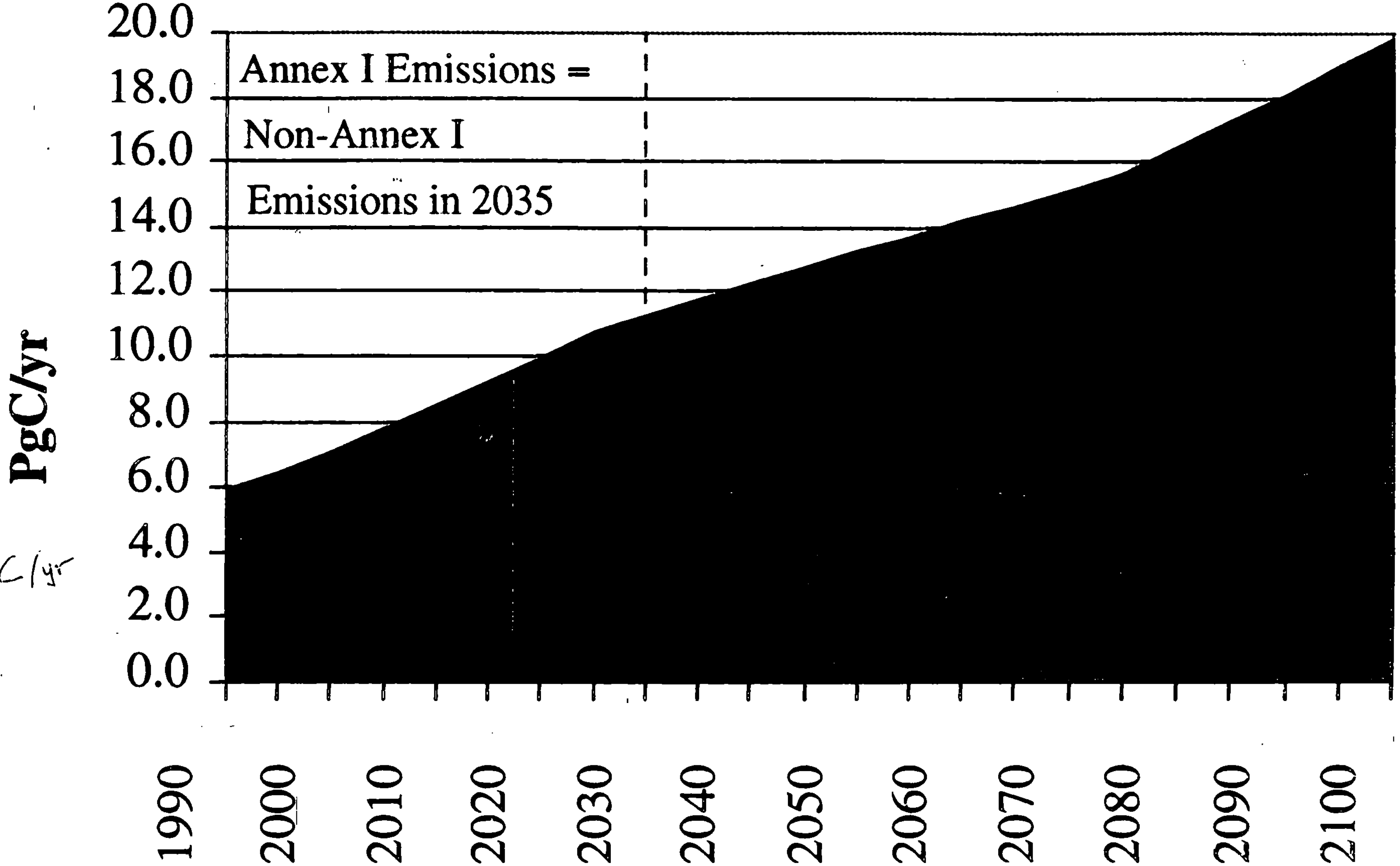
Global Total: 583 Billion Tonnes CO_2



Source: Marland *et al.* (1995)

EPA

Annex I and Non-Annex I Fossil Fuel Carbon Emissions: BAU

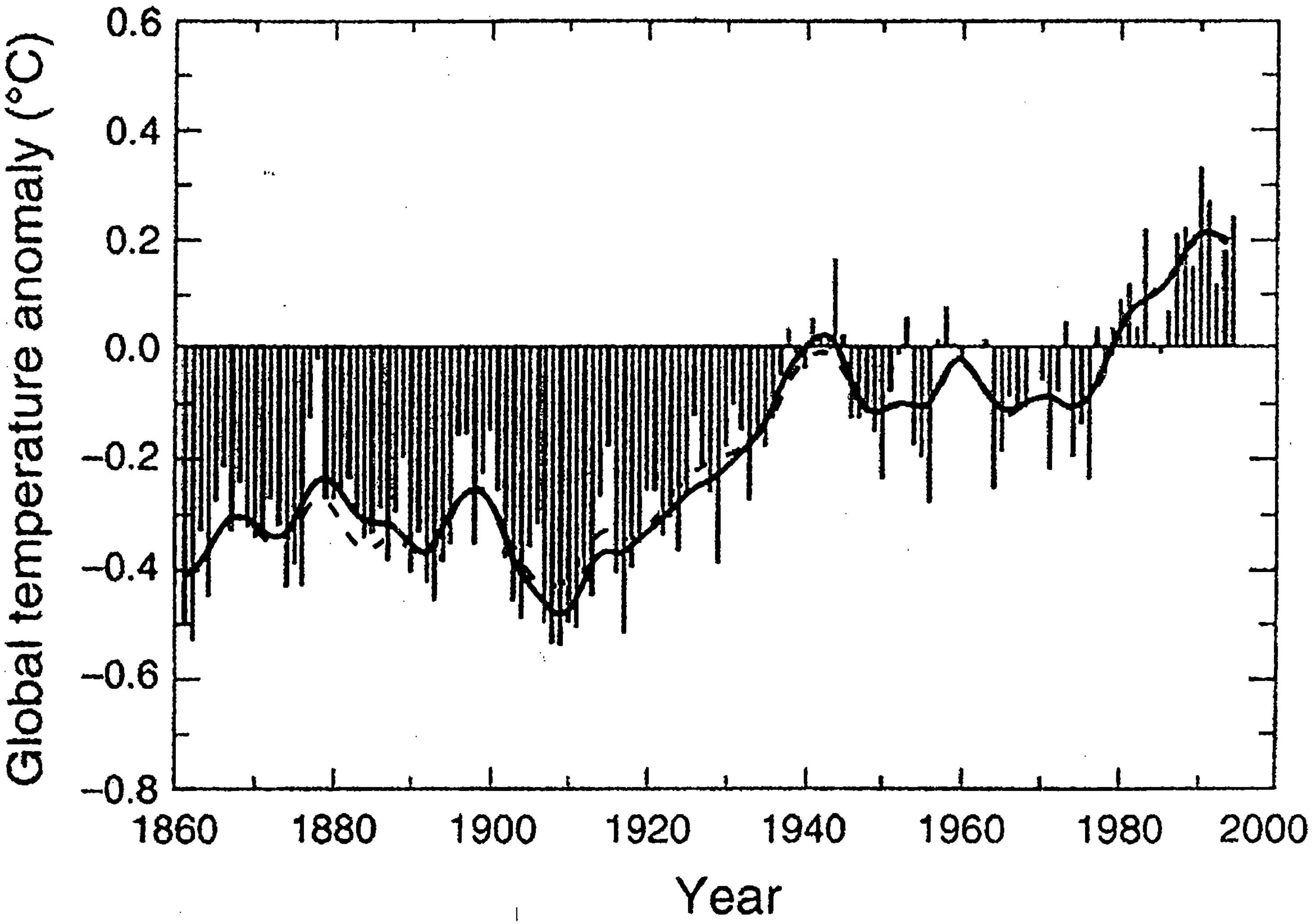


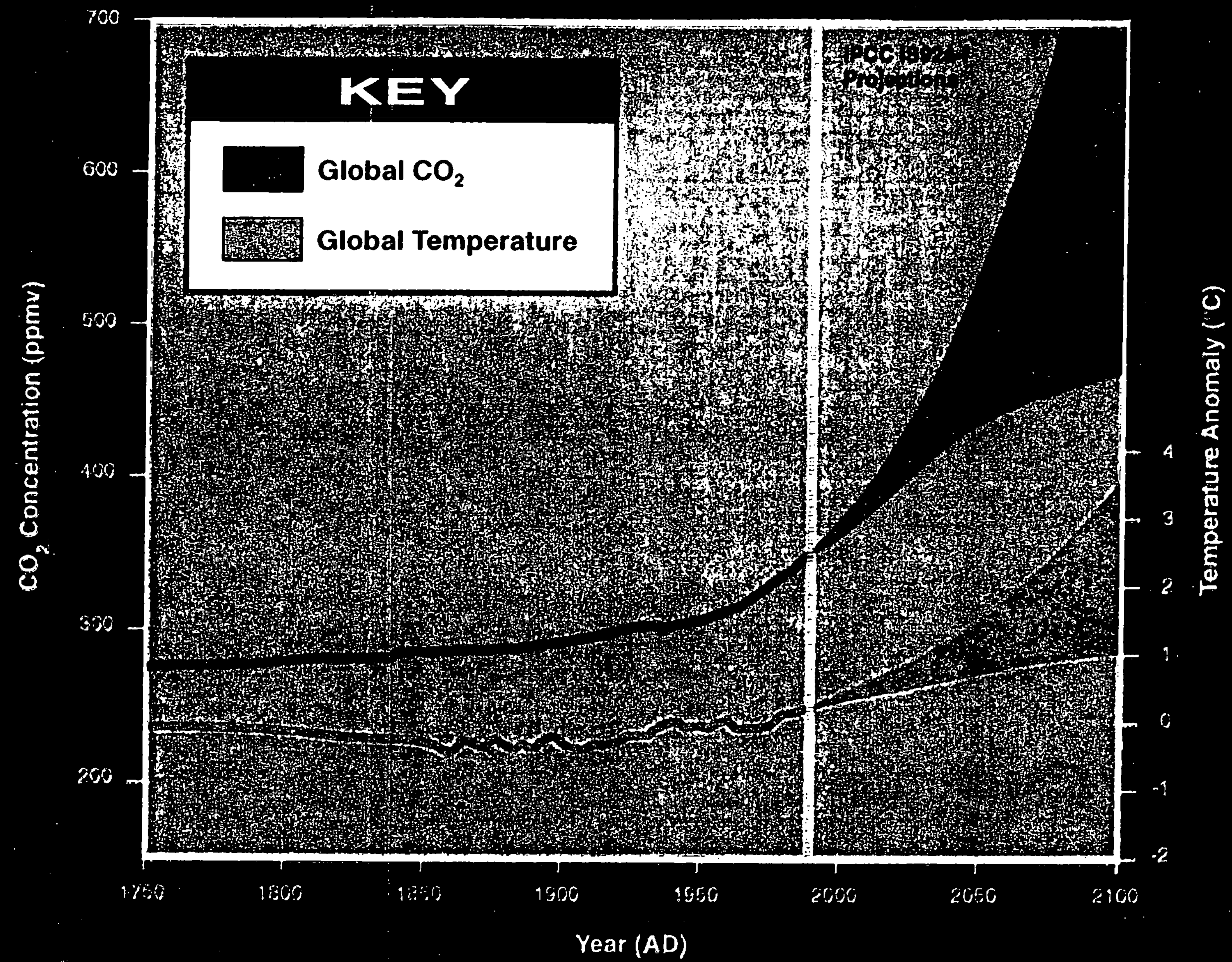
PgC/yr

Does it matter to ~~emissions~~ concentration if we burn all our coal over 100 yrs. or 1000 yrs.

Combined Land-Surface Air and Sea Surface Temperatures

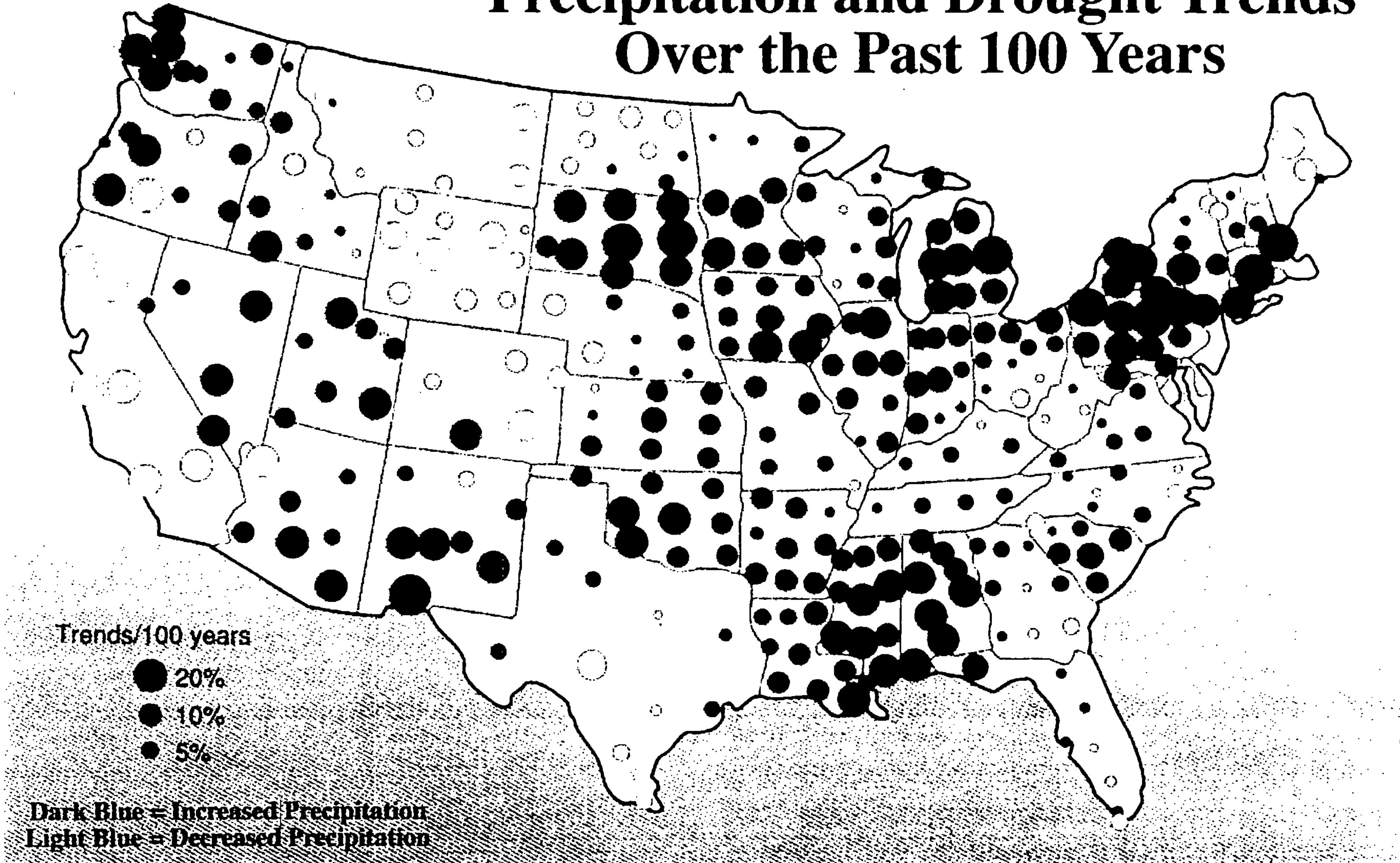
Temperatures from 1861 to 1994 relative to 1961 to 1990





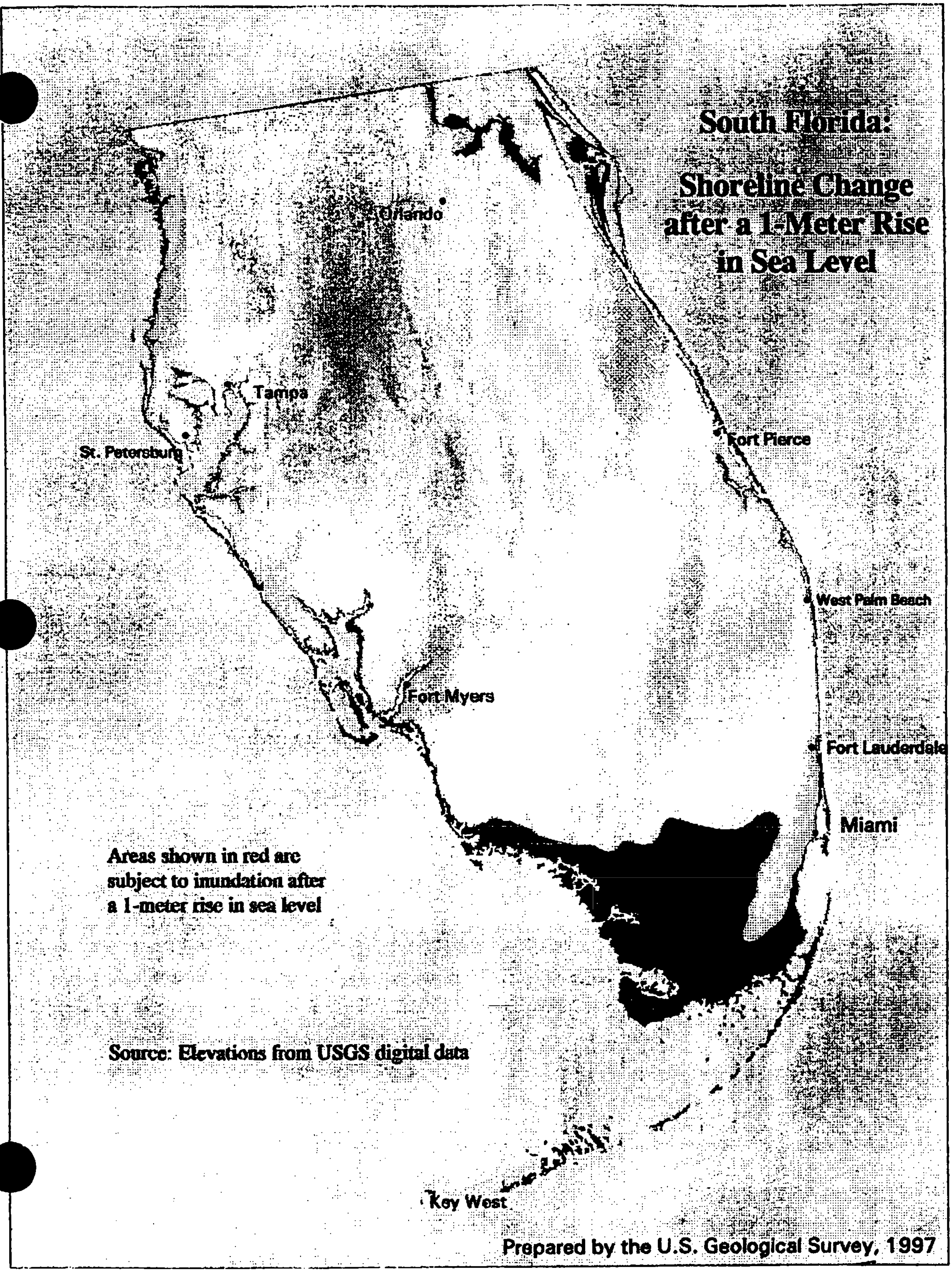
KEY
Global CO_2
Global Temperature
Projections
CO_2 Concentration (ppmv)
700
600
500
400
300
200
Temperature Anomaly (°C)
4
3
2
1
0
-1
-2
1750
1800
1850
1900
1950
2000
2050
2100
Year (AD)

Precipitation and Drought Trends Over the Past 100 Years

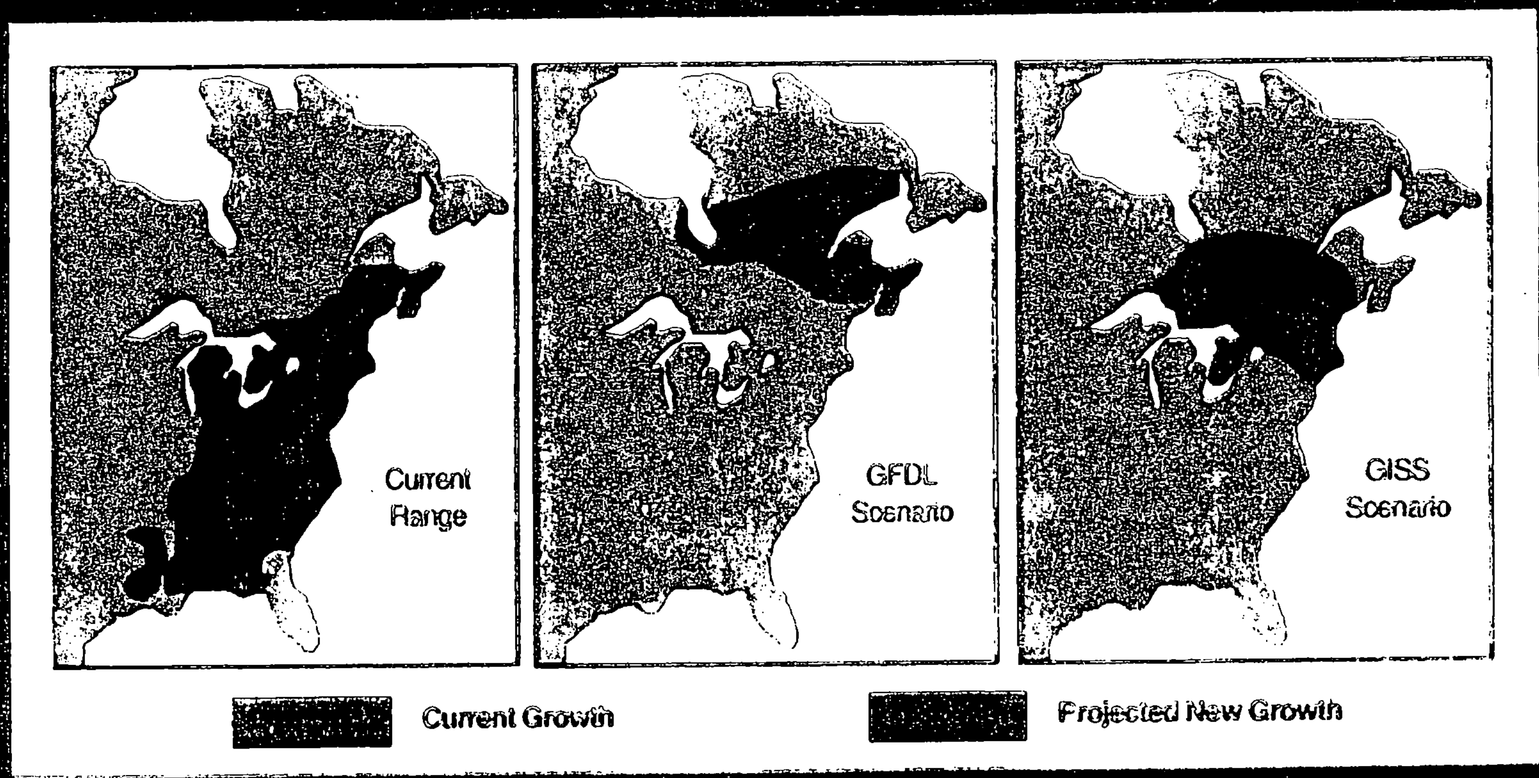


Detailed analysis of these data suggest that "since about 1970 precipitation has tended to remain above the twentieth century mean, averaging about 5% higher than the previous 70 years. Such an increase hints at a change in climate."

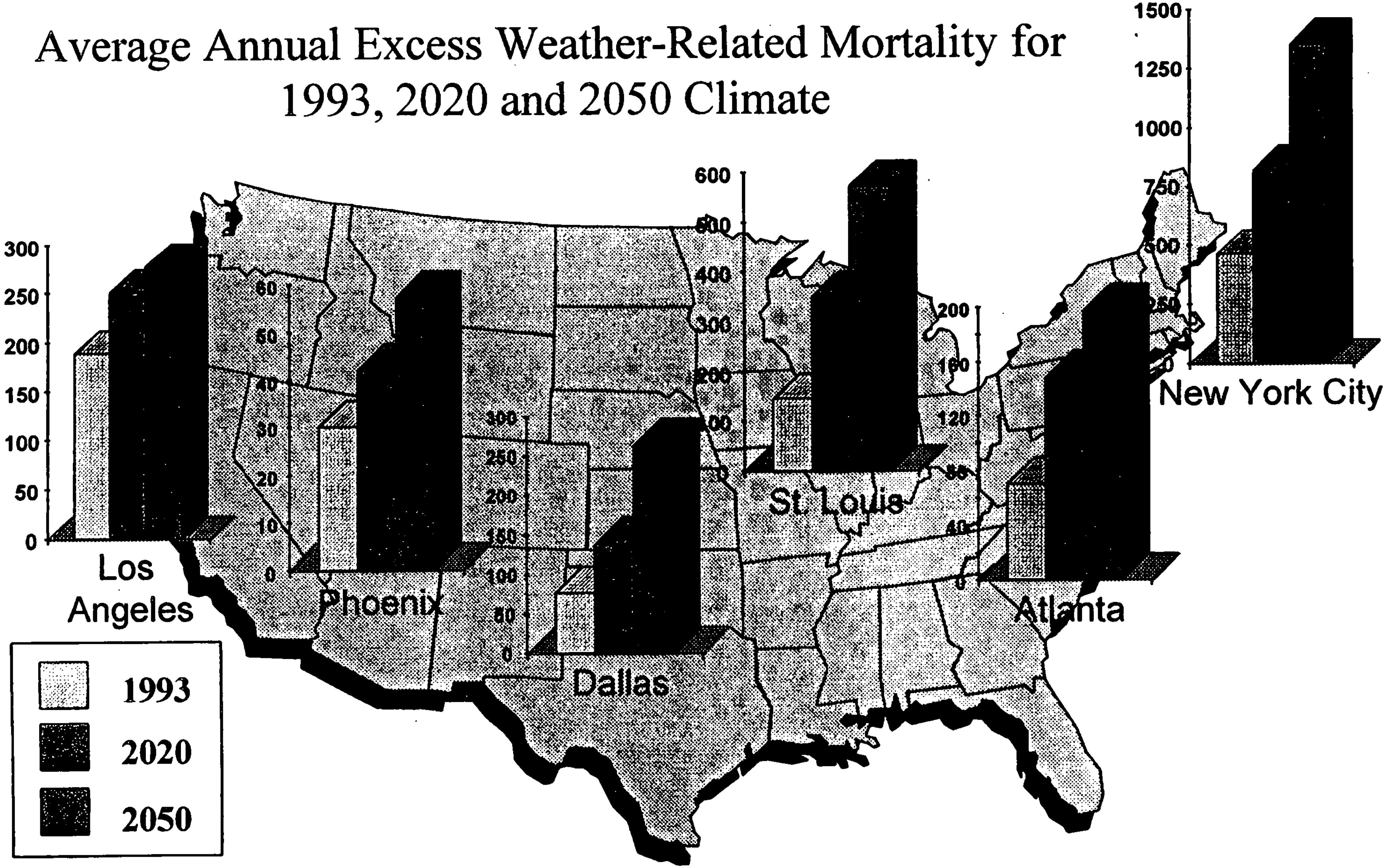
Source: Karl et al, Consequences, Vol. 1, No. 1, Spring 1995


South Florida:
Shoreline Change after a 1-Meter Rise in Sea Level
Orlando
Tampa
St. Petersburg
Fort Pierce
West Palm Beach
Fort Myers
Fort Lauderdale
Miami
Areas shown in red are subject to inundation after a 1-meter rise in sea level
Source: Elevations from USGS digital data
Key West
Prepared by the U.S. Geological Survey, 1997

Current and Projected Ranges of Beech Trees in the U.S.



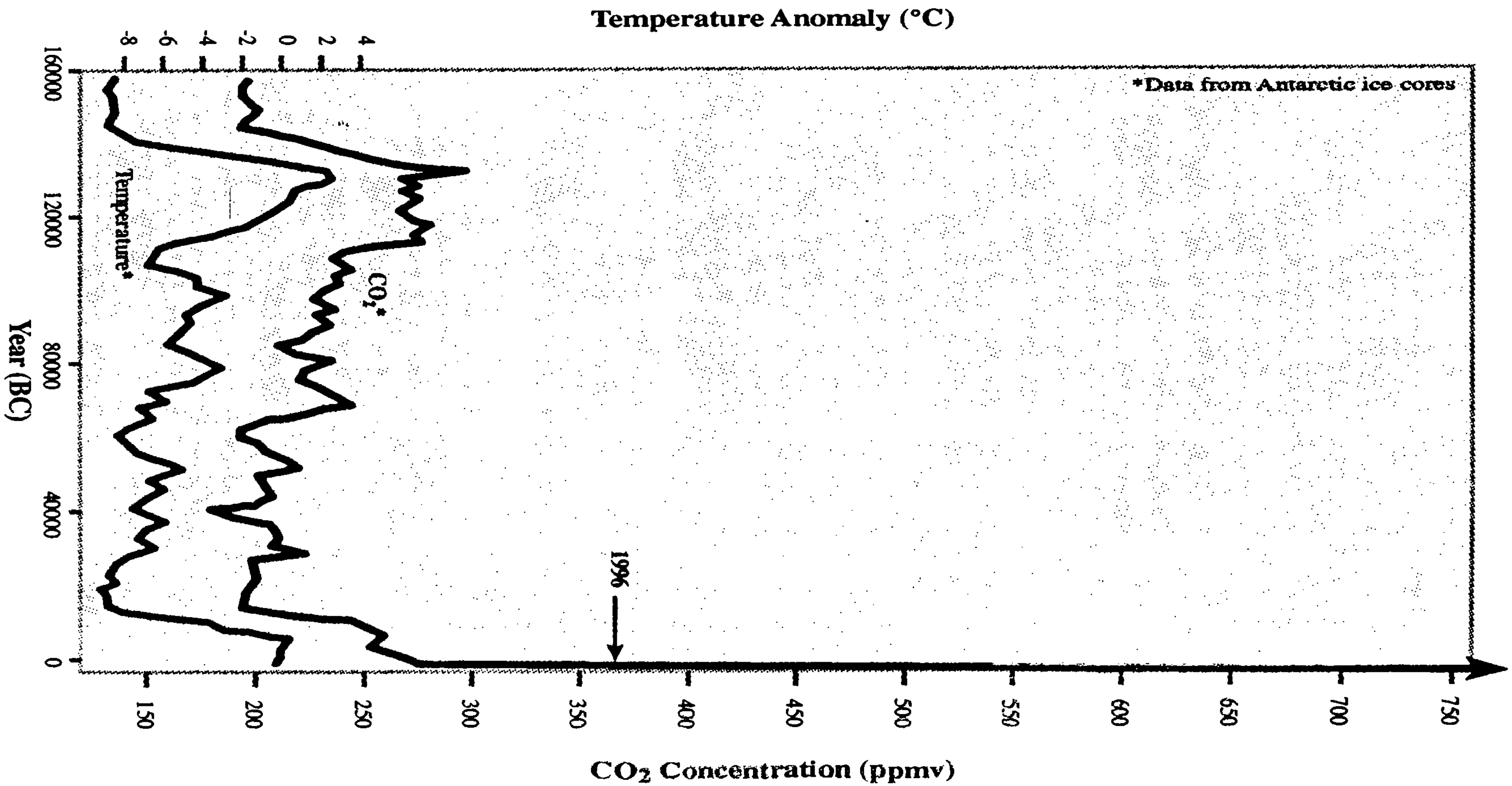
Average Annual Excess Weather-Related Mortality for 1993, 2020 and 2050 Climate



Sources: Kalkstein and Green (1997); Chestnut et al.(1995)

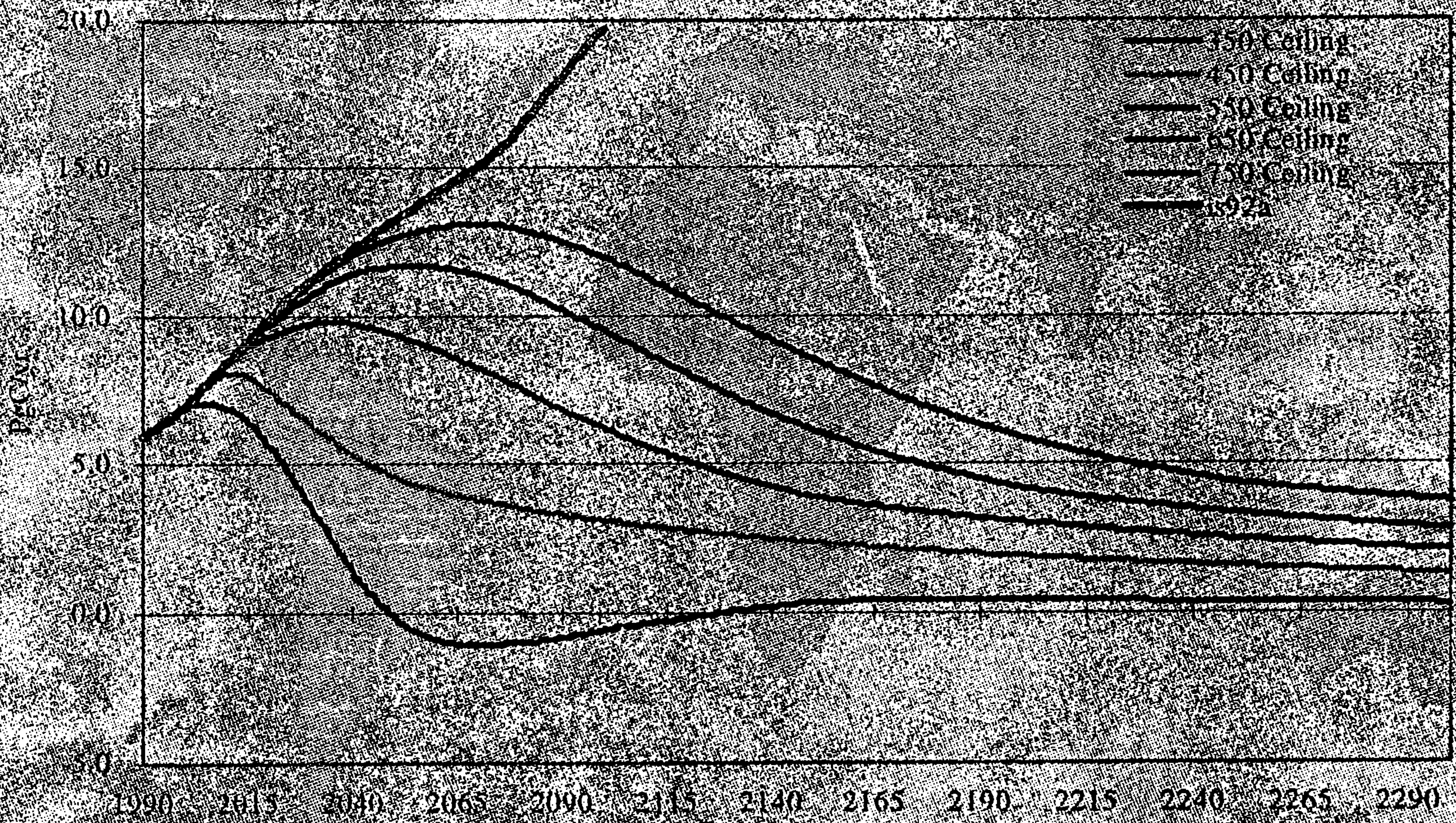
GFDL89 Climate Change Scenario

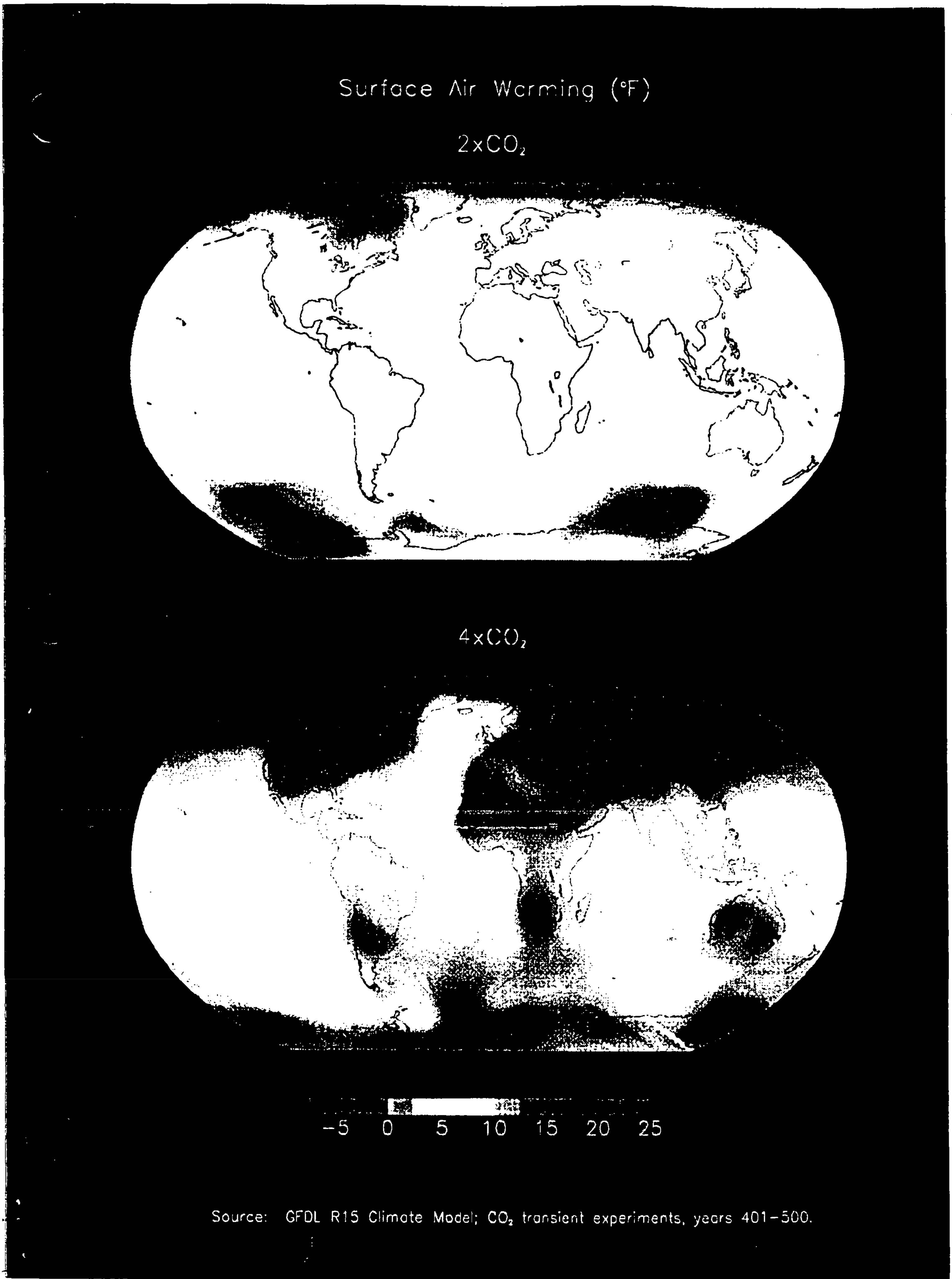
Note: Includes both summer and winter mortality. Assumes full acclimation to changed climate

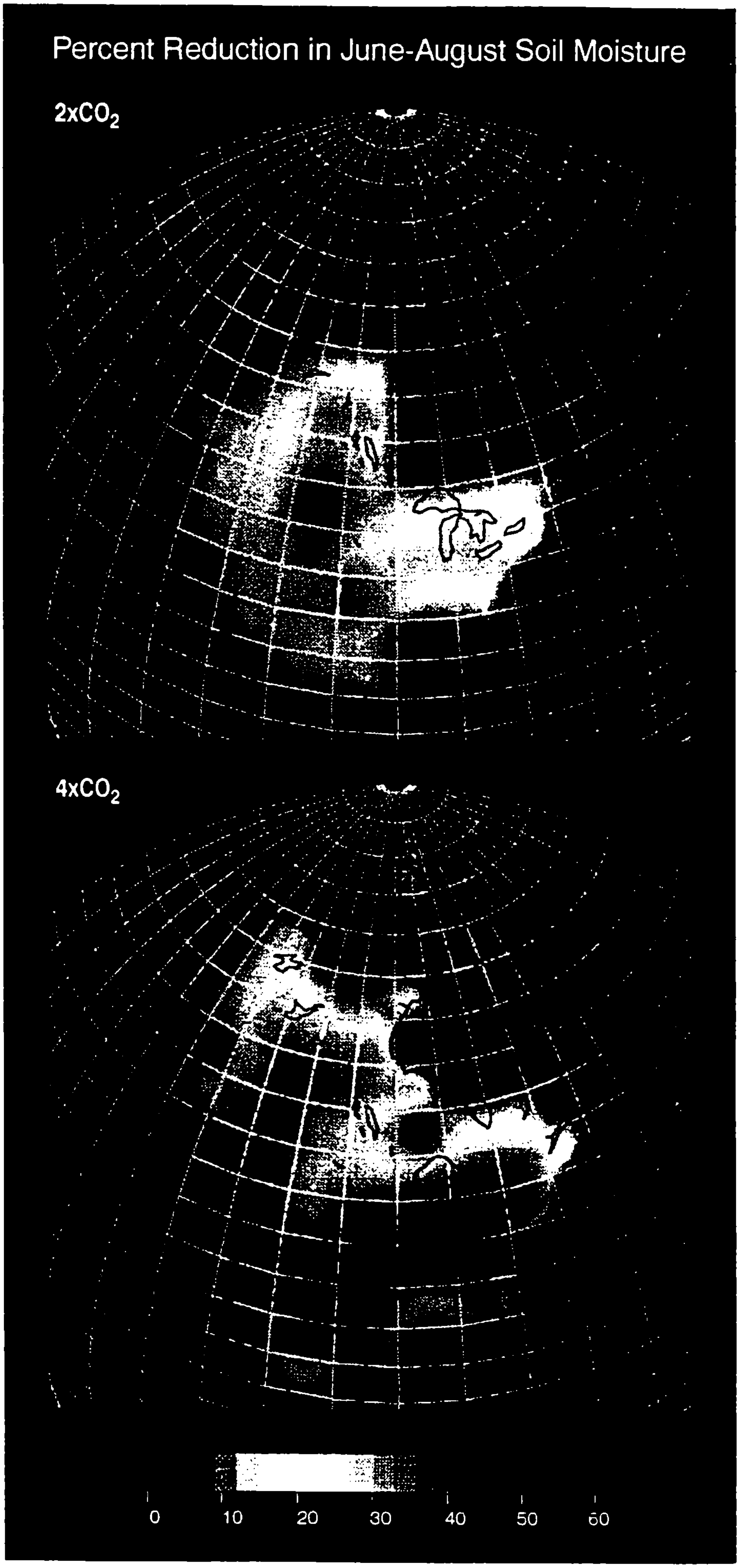


Temperature Anomaly (°C)
-8 -6 -4 -2 0 2 4
*Data from Antarctic ice cores
Temperature*
CO2*
1996
Year (BC)
160000 120000 80000 40000 0
150 200 250 300 350 400 450 500 550 600 650 700 750
CO2 Concentration (ppmv)

ATMOSPHERIC STABILIZATION EMISSIONS PATHS




Surface Air Warming (°F)
$2 \times CO_2$
$4 \times CO_2$
-5 0 5 10 15 20 25
Source: GFDL R15 Climate Model; CO_2 transient experiments, years 401-500.


Percent Reduction in June-August Soil Moisture
2xCO2
4xCO2
0
10
20
30
40
50
60

A Brief Overview of Global Climate Change Issues
30 May 97

Scientific consensus: There is now fairly wide scientific consensus that anthropogenic global warming is occurring. While uncertain, the effects of climate change on crop yields, sea levels, disease patterns, and storm frequency could nevertheless be far-reaching. For the policy maker, climate change offers a somewhat imposing set of complications: the potential for irreversible damages or costs, a very long planning horizon, long time lags between emissions and effects, a global scope, wide regional variations, and multiple greenhouse gases of concern. This memo focuses on the economic impacts of climate change, with particular attention given to modeling the cost of achieving various mitigation goals and targets, the economic instruments available to lower greenhouse gas emissions, and the consequences on global climate change of non-compliance on the part of non-Annex I countries.

Timing: The U.S. is currently engaged in international negotiations concerning limits on greenhouse gas emissions with the goal of signing an agreement in Kyoto, Japan in December 1997. Some key equity and efficiency issues will need to be addressed in a somewhat limited amount of time.

Modeling: Numerous models have been developed to examine the potential economic impacts of stricter greenhouse gas mitigation requirements. However, there is no clear consensus in the literature on what the economic impacts may actually be. Estimated global CO_2 abatement costs relative to the baseline projection range from a 0.1% loss of GNP for a 14% reduction of emissions to a 5.7% loss of GNP for an 88% reduction of emissions. Studies of U.S. CO_2 abatement costs relative to the baseline projection range from a 1.2% gain in GNP for a 21% reduction in emissions to a 10.9% loss of GNP for a 96% reduction in emissions. These results indicate a serious lack of consensus on the magnitude of the impact that anthropogenic warming will have on the domestic and international economy.

In a recent study by Stanford's Energy Modeling Forum (EMF), researchers compared a diverse group of economic models employing different methodologies. Standardizing these models by assuming common exogenous parameters yielded remarkably similar results. This suggests that the choice of methodology is secondary to the choice of values for population growth, per capita income, energy intensity, and technical progress.

In particular, assumptions of the rate of improvement in the energy/GDP ratio have caused some degree of controversy in certain economic impact models. Current studies typically focus on the rate of autonomous energy efficiency improvement (AEEI), which tends to be a good approximation of the rate of change in the energy/GDP ratio when energy prices remain relatively flat. Long term historical evidence suggests a number in the range of 0.5 to 1.0 percent per year. The modeling group (Interagency Analysis Team--IAT) believes that the announcement of a global warming accord and the need to meet these strict mitigation goals will prompt businesses to accelerate the implementation of energy efficient methods of production. This alleged "announcement effect" is incorporated in these models by assuming a rate of improvement in the energy/GDP ratio of between 1.25 and 1.75 percent per year. This more closely approximates the

1973 to 1985 average in the U.S. of 2.0 percent per year, which provides the modelers with a justification for using a relatively high value of energy/GDP. However, after adjusting for the quadrupling of energy prices over that time period, the implied AEEI from 1973 to 1985 becomes 0.5 percent. This weakens considerably the assumption that energy/GDP falls in a range of 1.25 to 1.75 percent per year.

Goals and Targets (emission budgets): Two key terms are floating around in the discussions to set mitigation goals and targets. The first is the level of greenhouse gas emissions, which is a flow. The second is the level of greenhouse gas concentrations, which is a stock. It is important to note the difference in the implications of the two measures. For a long time now, the concentration of greenhouse gases in the earth's atmosphere has been increasing. This comes from a past flow of emissions above the implied steady state flow necessary to maintain a stable climate. In order to bring the concentration of greenhouse gases down to what scientists consider a more environmentally stable level, it becomes necessary to decrease current emissions well below the steady state rate.

Many different emission reduction requirements have been suggested. A recent Dutch proposal would cut EU emissions of six greenhouse gases to 10% below 1990 levels in 2005 and to 15% below 1990 levels by 2010. Similar plans have been proposed for the U.S., with the Climate Change Action Plan (CCAP) designed to reduce domestic emissions to 1990 levels by the year 2000. Some analysts point to a need for designing a mitigation proposal capable of providing some degree of equity across countries. It has been suggested that industrialized countries be required to decrease their level of energy/GDP while permitting developing countries to increase this same measure. However, it becomes increasingly difficult at the global level to incorporate high levels of both efficiency and equity into any mitigation proposal.

Economic Instruments: It is clear that a desire to lower greenhouse gas emissions necessitates the creation of certain economic incentives for the U.S. as well as for the rest of the world. Economic instruments available to achieve the required reductions in emissions range from simple command and control mechanisms to carbon taxes to a system of tradable permits. For a global treaty, a tradable permit system that is subject to enforcement is the only potentially cost-effective arrangement where a dictated level of emissions is attained with certainty. It is widely believed that a choice of tradable permits at the international level would provide maximum flexibility for instrument choice at the domestic level.

Non-Annex I Cooperation: Considerable scientific evidence suggests that no single country is sufficiently important or powerful enough to control global carbon emission in the short term or in the long run. If non-Annex I countries (those countries not characterized by advanced industrialized economies) do not alter their emissions path, global emissions levels will continue to increase even if all industrialized countries completely eliminate all emissions. This situation is exacerbated by the fact that, if controls of some sort were adopted only in the industrialized countries, "dirty" industries would migrate to the non-Annex I nations. Clearly, the U.S. would bear the costs of eliminating domestic CO_2 emissions but global emissions would continue to rise without cooperation from non-Annex I countries.

Common Economic Perspectives on Climate Issues:

Many economists believe that the risks posed from global climate change are a real. But given the level of uncertainty surrounding the predictions, they also argue that it seems best to proceed pragmatically--taking out a small insurance premium (i.e., carbon tax) as we learn more about the magnitude of climate change, its translation into changes in climates around the globe, and the impacts of those climate changes on human welfare and natural environment. The key features that most economists agrees with are:

1. *The relevant economic and physical processes operate globally and over decades rather than years.* Few observers foresee substantial climate change for at least several decades, after emissions and atmospheric concentrations have increased substantially. Most plausible emissions scenarios involve a significant human-induced increase in climate change over the next century, with much of the increase coming from emissions of countries that are not now wealthy.

2. *Important and probably long-lived uncertainties are ubiquitous.* There are numerous unanswered questions about the biophysical systems, potential thresholds, and economic impacts. We do not know which regions will get warmer, which will cooler; which will get wetter, which will get drier; which will get stormier; which will get calmer.

3. *The climate issue involves potentially huge stakes, both economic and environmental.* It would be mad to experiment with the survival of the human race. However, models predict annual costs on the order of several percent of world income, dwarfing the costs of reversing the ozone hole (CFCs). Developed countries are looking at 1-2% drop in GDP; developing countries will not agree to transform their energy sectors unilaterally given that it will reduce that rate at which they could increase per capita wealth. The developing countries face health risks from poor drinking water and malaria right now that demand their immediate attention. Economic growth is the main engine to reduce these real risks happening today.

4. *Analyses of globally optimal climate policies generally do not support imposing burdensome emission reduction policies over the next decade or so, though very stringent policies may be optimal thereafter.* Since damages seem to depend on long-term concentrations, the argument for an optimal emissions reduction path is we should start off slow and then drop like a stone. The rationale is that in the future we will know more about the consequences of our actions, we will have developed cheaper abatement methods, we will have had time to invest to prepare for their use, and we will be wealthier.

5. *Any serious program to control global emissions is almost certain to involve substantial international transfers, the pattern of which may change over time.* The modeling runs suggest that with a trading system the US will be buying over $ billion dollars worth of permits from the former Soviet Union. Congress may not look kindly on this size transfer.

6. *Whatever the merits of the case for doing so, there is currently little political support for devoting substantial resources to the issue, and there is no obvious reason to expect this to change anytime soon.* Convincing the public that a \$0.25-\$0.40 increase in gas prices is a good idea will be a significant challenge.

Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations

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THE ultimate goal of the UN Framework Convention on Climate Change is to achieve "stabilization of greenhouse-gas concentrations...at a level that would prevent dangerous anthropogenic interference with the climate system". With the concentration targets yet to be determined, Working Group I of the Intergovernmental Panel on Climate Change developed a set of illustrative pathways for stabilizing the atmospheric CO_2 concentration at 350, 450, 550, 650 and 750 p.p.m.v. over the next few hundred years[1,2]. But no attempt was made to determine whether the implied emissions might constitute a realistic transition away from the current heavy dependence on fossil fuels. Here we devise new stabilization profiles that explicitly (albeit qualitatively) incorporate considerations of the global economic system, estimate the corresponding anthropogenic emissions requirements, and assess the significance of the profiles in terms of global-mean temperature and sea level changes. Our findings raise a number of important issues for those engaged in climate-change policy making, particularly with regard to the optimal timing of mitigation measures.

The IPCC Working Group I (WGI) concentration profiles (S350–S750; Fig. 1) were constructed under the following constraints: (1) prescribed initial (1990) concentration and rate of change of concentration; (2) a range of prescribed stabilization levels and attainment dates; and (3) the requirement that the implied emissions should not change too abruptly. Inverse calculations

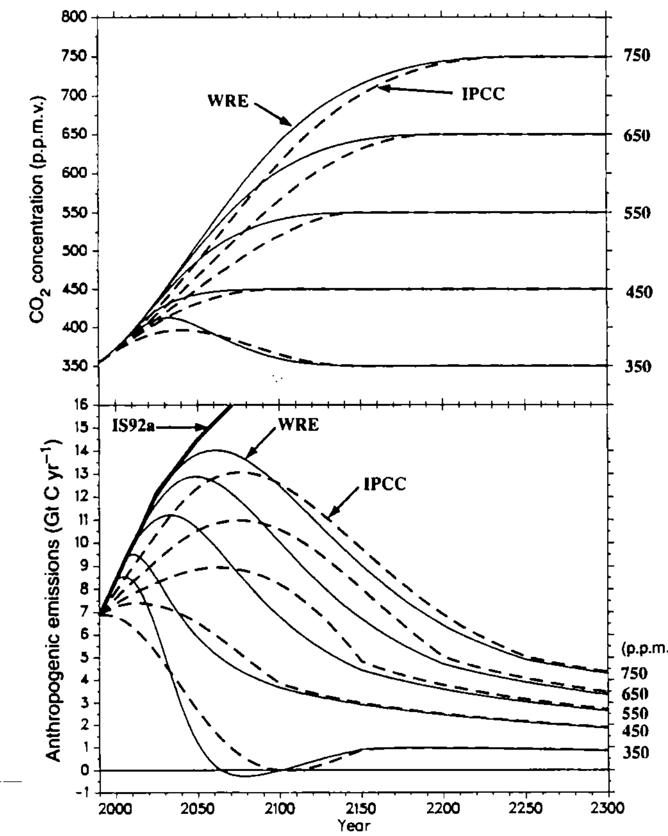

FIG. 1 Top, IPCC WGI[1,2] (dashed lines) and revised concentration profiles (WRE (this paper), solid lines) for stabilization of CO_2 at 350–750 p.p.m.v. Bottom, implied anthropogenic emissions using the model of Wigley[5]. IS92a is shown (thicker line) for comparison. Emissions were calculated following the procedure in ref. 1 in which the terrestrial biosphere sink is characterized solely by CO_2 fertilization of net primary productivity. The implications of using CO_2 fertilization as the sole terrestrial sink are discussed in ref. 4. The post-1990 inverse calculations were initialized by specifying a value for the 1980s-mean net deforestation (D_n80s). This determines the magnitude of the CO_2 fertilization factor. In the calculations in refs 1 and 2, D_n80s was taken as 1.6 Gt C yr^{-1}. This value has subsequently been revised downwards to 1.1 Gt C yr^{-1} (ref. 2), the value used here. Other minor budget changes have been made to accord with most recent data.

were then used to determine the emission rates required to achieve stabilization via the specified pathways. These show that stabilization requires an eventual and sustained reduction of emissions to substantially below current levels. Furthermore, some have interpreted the results for the IPCC pathways to imply that an immediate reduction in emissions (relative to the central IPCC "existing policies" or "business as usual" emissions scenario, IS92a[3]) is required to achieve any of the stabilization targets.

The WGI analysis was not intended as a recommendation for policy, but it will be carefully scrutinized for its policy implications. Consequently, it is important to understand what the analysis does and does not tell us. The first conclusion of the IPCC analysis, that meeting any of the prescribed targets will require emissions to decline eventually to levels well below today's, is robust. One cannot conclude from the WGI results, however, that an immediate reduction in emissions is required if we are to stabilize concentrations at 750 p.p.m.v. or below. The WGI emissions results correspond to just one of a range of possible pathways toward a particular concentration target. Stabilization at the same level, via different concentration routes, would produce different emissions.

What therefore are appropriate criteria for selecting a concentration (and hence emissions) time-path? Some guidance is found in the Framework Convention itself. Article 3 states that "policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost". Thus, if two paths were indistinguishable in terms of their environmental implications, then the path with the lower mitigation (that is, emissions reduction) costs would be preferred. If two paths differed in terms of their environmental impacts, the issue becomes one of balancing benefits and costs. Here we examine alternative pathways for meeting the prescribed concentration targets. We then consider both the economic (costs) and environmental (benefits) implications of choosing one concentration trajectory over another.

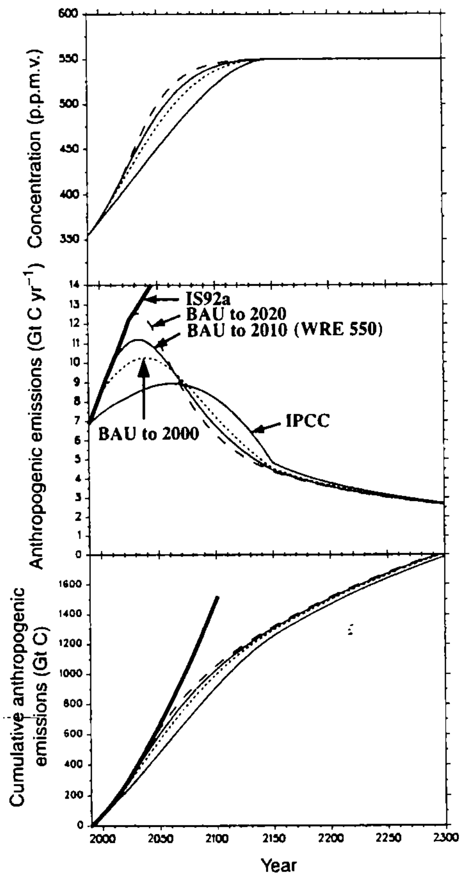

FIG. 2 Comparison of different concentration pathways (top panel) and implied emissions (middle) for stabilization of CO_2 levels at 550 p.p.m.v. in AD 2150. The pathways are: the original IPCC WGI S550 case[1]; the revised profile shown in Fig. 1 based on following BAU background emissions for 20 years, from 1990 to 2010 (WRE 550); and alternative revised profiles in which BAU is followed by 10 (BAU to 2000) or 30 years (BAU to 2020). The bottom panel shows the corresponding cumulative emissions. IS92a values are shown for comparison (thicker dashed lines).

In revising the IPCC WGI profiles, we add an additional constraint to the three noted above: that the resulting emissions trajectories initially track a 'business as usual' (BAU) path. This is an idealization of the assumption that the initial departure from BAU would be slow. We also assume that the higher the concentration target, the longer the adherence to BAU. This produces quite different concentration pathways, complementing the ones defined by IPCC WGI.

If we constrain emissions to follow BAU initially, the required concentration paths must depend on what we assume for this baseline scenario. We concentrate here on results for the central IPCC scenario (IS92a[3]). A higher baseline (such as IS92e or f) will lead to higher initial emissions. For a lower baseline such as IS92c, the task of stabilization of CO_2 concentrations at a level around 500 p.p.m.v. would require little action[4]. To derive the new profiles, we followed IS92a concentrations for 10–30 years and then fitted a smooth curve to the stabilization levels and dates used in ref. 1, using the same Padé approximant method. Figure 1 compares the new profiles with the WGI profiles. Further details are given in ref. 4.

The emissions implied by these new pathways (Fig. 1, lower panel) were obtained using the model of Wigley[5]. Although the precise values are model-specific, as shown by the inter-model comparison of Enting *et al.*[1], the qualitative character of the results and the relative differences in emissions due to concentration pathway differences are not.

The WGI analysis suggests that an immediate departure from the BAU path is required to meet all CO_2 concentration targets. Figure 1 shows that this is not so for concentration targets of 450 p.p.m.v. and above. Furthermore, for targets of 550 p.p.m.v. and above, the maximum rates of emissions decline are similar in both the new and WGI cases (but more prolonged in the former).

Figure 2 compares the old (WGI) and new results in more detail for the 550 p.p.m.v. stabilization case, and assesses the sensitivity of the results to the length of the interval over which BAU emissions are followed. The upper panel shows the WGI pathway and revised pathways following BAU for 10, 20 and 30 years (the 20-year case is that considered earlier). The emissions differences (middle panel) are striking in terms of the implied carbon intensity of the global energy system in the early decades of the next century. The different cumulative emissions pathways diverge initially and then become nearly parallel as one approaches and moves beyond the stabilization point (AD 2150 in this case). Cumulative emissions are noticeably higher in the cases that follow IS92a initially (a result that applies to all stabilization levels). This is because the products of early emissions have a longer time to be removed from the atmosphere, and because the associated higher concentrations give stronger oceanic and terrestrial sinks. Thus, later emissions reductions allow greater total CO_2 production, particularly for higher stabilization levels. These cumulative emissions differences, not considered by IPCC[2], may have important economic implications.

We now turn to how mitigation costs might vary with the choice of concentration profile. The rising emissions baseline that we use corresponds to an assumption that, in the absence of policy intervention, CO_2 emissions will continue to grow. This is consistent with the overwhelming majority of studies recently reviewed by the IPCC[6]. The implication is that stabilizing concentrations will entail some positive mitigation costs. A growing baseline, however, does not imply the absence of "no regrets" emissions reduction options (that is, with zero or negative mitigation costs). Such options are typically included in sizeable

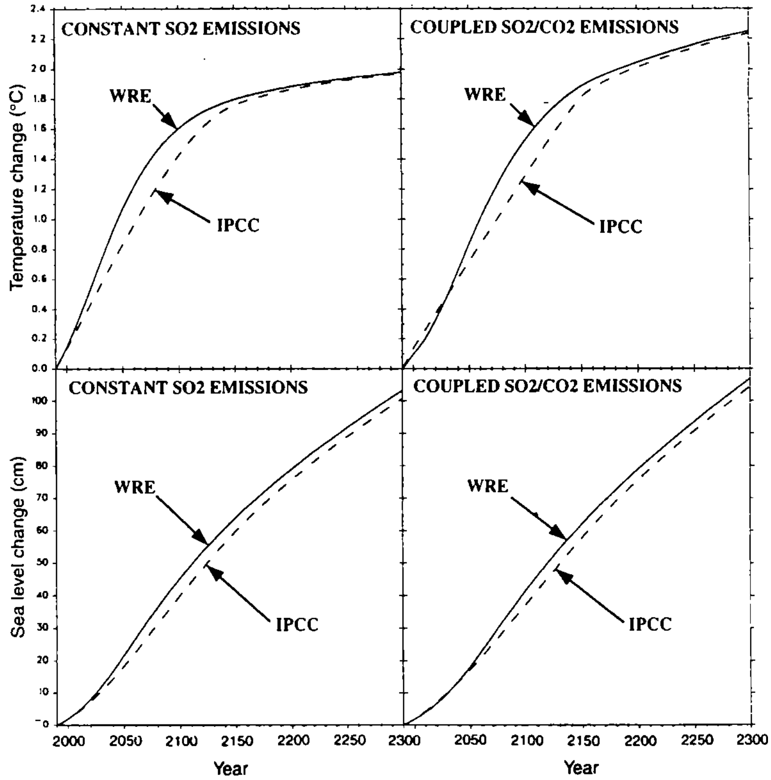

FIG. 3 Global-mean temperature (upper panels) and sea level changes (lower panels) for the S550 and WRE550 concentration stabilization pathways shown in Fig. 1. Results are from the models used in ref. 17, using the latest IPCC WGI estimate of the radiative forcing to 1990 and best-guess values of the climate sensitivity and ice-melt model parameters. Sea level changes include the contributions from oceanic thermal expansion, and ice melt from the world's glaciers and small ice caps, Greenland, and Antarctica. For the left panels, SO_2 emissions are held constant at their 1990 level. For the right panels, the effects of changes in anthropogenic SO_2 emissions (S) are added, with these changes directly coupled to those of fossil CO_2 emissions (F; values from Fig. 1) using $S = [S(1990)/F(1990)]F$. In both cases, the effects of non-CO_2 greenhouse-gases are accounted for by scaling CO_2 forcing by 1.33, the mean scaling for the IS92 emissions scenarios (compare ref. 21).

quantities in most economic analyses[7,8]. A growing baseline only means that economically competitive low-carbon alternatives are in insufficient supply to arrest future growth in carbon emissions. Conversely, if one were to assume that there are ample no-cost options to produce a falling emissions baseline, stabilization would entail little if any mitigation costs[9].

Several analysts have studied how mitigation costs might vary with the timing of the emissions reductions. For example, Nordhaus[10] and Manne and Richels[11] have identified cost-effective mitigation strategies for meeting a range of concentration targets. These studies show that to maintain cost-effectiveness, emissions tend to adhere longer to BAU the higher the concentration target (as assumed *a priori* here). Richels and Edmonds[12], in examining alternative emissions reduction pathways for stabilization at 500 p.p.m.v., found that the pathway can be just as important as the concentration stabilization level in determining the ultimate cost. Pathways involving modest reductions below a BAU scenario in the early years followed by sharper reductions later on were found to be less expensive than those involving substantial reductions in the short term. A similar conclusion can be found in Kosobud *et al.*[13].

Viewing the stabilization issue as a carbon budget allocation problem helps explain why concentration pathways with higher near-term emissions have lower overall mitigation costs. Because cumulative emissions are approximately independent of the concentration pathway, for each stabilization level there is, roughly, a fixed allowable amount of CO_2 to be released. The basic choice is, therefore, how this budget is to be allocated over time. From this perspective, the reasons for drawing more heavily on the budget in the early years are: (1) *Positive marginal productivity of capital.* With the economy yielding a positive return on capital[14], the further in the future an economic burden (here, emissions reduction) lies, the smaller is the set of resources that must be set aside today to finance the burden. (2) *Capital stock.* Stock for energy production and use is typically long-lived (for example, power plant, housing and transport). The current system is configured based upon a set of expectations about the future. Unanticipated changes will be costly. Time is therefore needed to reoptimize the capital stock. (3) *Technical progress.* There is ample evidence for past and potential future improvements in the efficiency of energy supply, transformation and end-use technologies. Thus, the availability of low-carbon substitutes will probably improve and their costs reduce over time. In addition, as the emissions budget will be somewhat larger (that is, greater cumulative emissions) for pathways with higher emissions earlier, dependence on higher-cost, carbon-free alternatives is reduced.

We must stress that, even from the narrow perspective of a cost-effectiveness analysis, our results should not be interpreted as suggesting a "do nothing" or "wait and see" policy. First, all stabilization pathways still require future capital stock to be less carbon intensive than under a BAU scenario. As most energy production and use technologies are long-lived, this has implications for current investment decisions. Second, new supply options typically take many years to enter the market place. To ensure sufficient quantities of low-cost, low-carbon substitutes in the future requires a sustained commitment to research, development and demonstration today. Third, any available "no regrets" measures for reducing emissions should be adopted immediately. Last, it is clear from Fig. 1 that one cannot go on deferring emissions reductions indefinitely, and that the need for substantial reductions of emissions is sooner the lower the concentration target.

It is, of course, also important to examine the environmental consequences of selecting one concentration or emissions trajectory over another. This is because different concentration pathways imply, not only different emissions reduction costs, but also different benefits in terms of averted environmental impacts. In benefit-cost analyses of climate change policy options, it is common to use global-mean temperature and sea level rise as coarse indicators of the extent of climate impacts[14,15]. We therefore calculate how these indicators are affected by differences in the pathways to stabilization at an atmospheric CO_2 concentration of 550 p.p.m.v., based on the model of Wigley and Raper[16,17]. We first consider the direct effects of greenhouse-gas concentration changes, and then how these results may be modified by SO_2 emissions. All results use the central IPCC-recommended estimate of climate sensitivity[18] (2.5 °C equilibrium global-mean warming for a doubling of atmospheric CO_2 levels) and best-guess ice-melt model parameters[17].

Figure 3 (left panels) shows that, if greenhouse gases alone are considered, both temperature change and sea level rise would be noticeably affected by the choice of pathway towards stabilization at 550 p.p.m.v. These results, however, depend critically on how SO_2 emissions are assumed to change in the future. For the greenhouse-gas-alone case, we have assumed these emissions to remain constant at their 1990 level. As an alternative, we also consider a case where SO_2 emissions are closely coupled to fossil-fuel-derived CO_2 emissions. This case is consistent with the IPCC (IS92) emissions scenarios, except for IS92d, out to at least 2050 (ref. 3). It could occur if developing countries were less successful than developed countries in decoupling SO_2 and CO_2 emissions. In global-mean terms, SO_2/CO_2 emissions coupling leads to compensation between the reduced warming from reduced CO_2 emissions and an increased warming due to reduced SO_2 emissions[19,20].

To demonstrate the significance of this link, we give a specific example. This example is not meant to provide quantitative information on environmental impacts (which, for climate change, cannot be achieved through global-mean temperature alone), but to draw attention to aerosol influences as a critical factor in assessing the benefit–cost balance. Figure 3 compares global-mean temperature and sea level results for constant SO_2 emissions (left panels) with those for directly coupled CO_2 and SO_2 emissions (right panels). With SO_2 coupling, the lower-emissions case (S550) actually has warmer temperatures out to around 2040. This is because the much shorter lifetime of aerosols leads to a more rapid radiative forcing response to SO_2 emissions changes than to CO_2 emissions changes, allowing the former to dominate initially (compare refs 19,20). For sea level, coupling has a similar but less marked effect.

The market (for example, agriculture, timber and fisheries) and non-market (for example, biodiversity, environmental quality and human health) implications of these results are unclear: do pathway-related differentials up to ~0.2 °C in global-mean temperature and 4 cm in global-mean sea level change translate into significantly higher damages and, if so, are these large enough to offset the reduced cost of a more economical transition away from fossil fuels? The answer depends on the regional details associated with these changes, and the sensitivities of impact categories to changes in important climate variables. Both aspects are highly uncertain. Nevertheless, it is clear that the choice of emissions path requires the consideration of both costs and benefits. □

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A Brief History of the Administration Position on Global Climate Change

1. **Global Climate Change**. Growing concentrations of greenhouse gases are believed to result in global climate change. The possible risks include loss of coastal areas from rising sea levels; changes in rainfall and agricultural productivity; and an increased incidence of diseases such as malaria, yellow fever, and cholera. Carbon dioxide (CO2) accounts for approximately 86% of the total global warming potential of all U.S. anthropogenic emissions not covered by the Montreal Protocol to protect stratospheric ozone. Combustion of fossil fuels, primarily coal and oil, is the main source (85% of all emissions).

2. **Climate Change Action Plan.** In June 1992, the United States signed the Framework Convention on Climate Change whose primary objective is to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate." In October 1993, President Clinton announced the Administration's Climate Change Action Plan (CCAP) with a goal of stabilizing U.S. anthropogenic emissions of greenhouse gases at 1990 levels by 2000 . The plan blends market incentives, voluntary initiatives, research and development, improved regulatory frameworks. Voluntary programs include the Green Lights program to improve lighting efficiency and Climate Challenge program to inventory emissions by utilities. The US is not on target to achieve this CCAP goal, emissions are predicted to be about 200 million metric tons (mmt) over 1990 levels by 2000.

3. **Wirth's Statement**. In July 1996, Under Secretary of State Tim Wirth expressed concern that the Convention goals were not being met and announced that the "United States recommends that future negotiations focus on an agreement that sets a realistic, verifiable and binding medium-term emissions target." Wirth also called for the use of "market -based solutions that are flexible and cost-effective." The Administration also stated at this time that the call for binding targets does not imply that it is abandoning voluntary programs under the CCAP.

4. **The Kyoto Treaty**. Negotiations to amend the Rio Treaty or to sign a protocol are scheduled for completion by December 1997. The U.S. issued a position paper for the latest preparatory meeting (December, 1996) which expands on the Wirth's July 1996 statement. The major points were:

(1) The need to examine an international greenhouse gas emissions trading system among annex I (OECD plus former Soviet block) countries.

(2) Joint implementation (projects that reduce emissions below baseline in host country which are credited to the target of the partner country) between annex I and the rest of the world.

(3) The need for a concerted global effort that eventually would mean targets for all countries.

(4) Support for multi-year, rather than single year, targets.

(5) Urge consideration of a right to bank and borrow permits.

5. **Interagency Analysis Team (IAT)**. Since last fall the Interagency Analysis Team (IAT), chaired by Ev Ehrlich, Undersecretary of Commerce, has been modeling the economic impacts of alternative options for the Kyoto treaty. Three models were used to compare two basic cases:

- The base case -- i.e., with no new policies.
- The climate treaty case, in which the U.S. caps total greenhouse emissions, and then allows domestic firms to trade rights to emit carbon ("cap and trade"), with several variations.

Variations examined to date include:

--cap U.S. emissions at 1990 levels by 2010; hold emissions constant after that;
--cap U.S. emissions at 1990 levels by 2010, plus or minus 10 percent;
--cap U.S. emissions at 1990 levels by 2020;
--auction permits, or give them to existing emitters ("grandfathering");
--use auction proceeds to reduce the deficit or to reduce business and personal taxes;
--allow no trading, trading only within Annex 1, or worldwide trading.

The modelers have produced comparisons of several variables: levels of GDP, of real consumption, fuel consumption and price by fuel type, and price of carbon permits. The variable most likely to be displayed is the price of carbon permits (the implicit tax on carbon), together with changes in price of different fuels.

For example, to stabilize emissions at 1990 levels in 2010, one of the models (SGM) calculated the following permit prices ($1995) per ton of carbon for the year 2010:

	---rate of energy efficiency improvement---	
case	base case	very fast
U.S. stabilizes without trading	110	57
with Annex 1 trading only	96	55
with worldwide trading	n/a	19

The same model calculates that permit prices in Western Europe would be about three times as high for each variation.

Speed of technical change. CEA and Treasury have been concerned for some time that the IAT is assuming very fast technical change in its modeling of climate control costs. We believe the chosen range is much higher than the historical evidence can support. In the base case, the energy/GDP ratio improves at one percent annually, which we believe is on the high side of historical experience; econometric estimates of the rate of energy efficiency improvement, apart from price effects, range from 0.5 to 1.0 percent annually. In the policy cases, the energy/GDP ratio improves at 1.25 to 1.75 percent annually.

Announcement effect. The IAT asserts that the rate of energy efficiency improvement will jump from 1 percent to 1.25 percent annually solely because of the "announcement effect"--i.e., merely from the government's announcement of a policy. The idea is that once the U.S. signs a treaty limiting carbon emissions, more money will flow into R&D on energy efficiency. This assumption means that we will reach one-third of our reduction goal for free. Most economists, however, would say that people will not respond to an announcement unless they believe it would be costly not to. People may very well invest more in innovation, but at some cost. Treasury and CEA staff have sent a memo to Ev Ehrlich asking that the models also be run using rates of technical change consistent with historical evidence.

Emission banking and borrowing. An efficient trading program requires *when* and *where* flexibility. This means *emission banking*, allowing firms save or borrow emission credits. A minimum-cost control path would allow higher emissions in the near term in exchange for lower emissions later. In contrast, an early-action control path is expensive for three reasons: it requires the premature retirement of the capital stock, it fails to take advantage of technological changes, and it crowds out other productive investment. Unfortunately, intertemporal trading has not been discussed recently, and no longer seems to be on the agenda. Jeff Frankel has pressed the idea of emissions *windows* rather than single-year targets. If the window is wide enough, this is equivalent to emissions banking.

6. **Statement by Arrow, Solow, Nordhaus, et al.** During the IAT modeling effort, on February 13, the press carried a story that 2000 economists, including six Nobel laureates, signed a statement supporting measures to reduce the threat of climate change. The statement endorses conclusions from last year's report by the Intergovernmental Panel on Climate Change (IPCC), that governments should take steps to reduce the threat of damage from global warming, that proper policies can significantly reduce greenhouse gas emissions without harming the American economy, and that market-based policies can significantly lower the costs of control. Some within the Administration have claimed that this statement endorses the Administration's position. In fact, the statement is far more general than the Administration's position.

ECONOMISTS' STATEMENT ON CLIMATE CHANGE

"We the undersigned agree that:

I. The review conducted by a distinguished international panel of scientists under the auspices of the Intergovernmental Panel on Climate Change has determined that "the balance of evidence suggests a discernible human influence on global climate." As economists, we believe that global climate change carries with it significant environmental, economic, social, and geopolitical risks, and that preventive steps are justified.

II. Economics studies have found that there are many potential policies to reduce greenhouse-gas emissions for which the total benefits outweigh the total costs. For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve

U.S. productivity in the longer run.

III. The most efficient approach to slowing climate change is through market-based policies. In order for the world to achieve its climatic objectives at minimum cost, a cooperative approach among nations is required --- such as an international emissions trading agreement. The United States and other nations can most efficiently implement their climate policies through market mechanisms, such as carbon taxes or the auction of emissions permits. The revenues generated from such policies can effectively be used to reduce the deficit or to lower existing taxes."

Development of US Position on Specific Issues

(Only major changes to the US position are noted.)

Date/ Event	Flexibility (JI & Trading)	Non-Annex I Involvement	Emissions Budgets
June 1992 Signing of FCCC		Developing nations should (voluntarily & with Annex I support) begin **monitoring and reporting**.	
April 1995 COP-1 & Berlin Mandate		**No new commitments, will work to implement current commitments.** Agreement specifies that no new commitments will apply to non-an. I nations, but that negotiations on new commitments will begin after work on BM is completed.	
Oct. 1995 AGBM-2	**Idea introduced.** The US urged Parties to consider approaches which "could provide parties with greater flexibility in where emissions are reduced... Examples of such approaches include multi-perty emissions objectives, coupled with emisssions trading or joint implementation..."	**US seeks to recommend ways all parties can become involved.** "We do not intend through our proposals here to suggest any new commitments on the part of developing countries. ... What we would like to do, however, is to examine what the existing commitments imply -- and to recommend ways in which all parties can move toward a more successful set of actions..." Mostly dealing with identifying JI projects and reporting/monitoring.	**Idea first introduced** "An alternative approach that the U.S. urges the parties to consider would be to establish a limit on total emissions over a specified period. ... In connection... it would be useful to consider whether to provide an incentive for early reductions, and if so, how." (US Statement, Agenda item 3(b))

Date/ Event	Flexibility (JI & Trading)	Non-Annex I Involvement	Emissions Budgets
March 1996 AGBM-3	"The inclusion of [several FCCC articles] ... underscores the agreement among parties that any future step must provide flexibility in theimplementation of obligations." (March 6 US Intervention)	**US insists all parties need to be involved at some point in the process.** "Advancing the implementation of Parties' commitments under Article 4.1 entails more than reporting on their current activities. The US believes there is a tremendous potential for all countries, including developing countries, to further their objectives for economic development and growth and to protect the earth's climate system..."	
July 17, 1996 COP-2	**Binding targets conditional on flexibility.** "... the medium-term target must be met through maximum flexibility in the selection of implementation measures, including the use of measures such as reliable activities implemented jointly and trading mechanisms — around the world." (T. Wirth)	**Reaffirmed.** "While we recognize that developed countries have the responsibility to lead, we also believe that this effort must be a partnership with all nations. We stand ready to continue our efforts to provide technical expertise to work with developing countries to reduce GHG emissions, and to continue the partnership we have developed with many." (T. Wirth statement)	
Dec, 1996 AGBM-5			"The US believes that the target set in the next step should cover a multi-year period... [and] also strongly supports inclusion of the option for banking between multi-year average target periods." (Intervention on QELROs)
Jan, 1997	**Current Proposal**		

Economic Impacts

NO TREATY. Briefly, the short-term US economic impacts of **NO treaty** will not be that large-- only 3% of US livelihoods are earned in agriculture and other climate-sensitive outdoor activities. Nordhaus estimated that there would be a 1% drop in US GNP for a 3°C warming. Agriculture and forestry have been estimated to benefit from climate change. The impact on developing countries would be larger given that their economies are much more dependent on agriculture.

TREATY. The short-term economic impacts of a **treaty** could be significant (0.5 - 1.5% annual drop in GDP) if the US gets locked into a tight emissions budget without flexibility (i.e., no emission trading, no joint implementation). [This estimate is based on the more objective results from the Energy Modeling Forum (EMF) in Stanford. The percentage result is robust across different modeling runs. The IAT results are within the lower range]. In the medium term, the worst-case scenarios predict a 2.6% drop in GDP by the year 2020. CEA prepared a review of published literature indicating the estimated range of impacts. The median price of carbon in these studies was $82 per ton. The median impact on GDP by 2020 was -0.6% of GDP.

Schmalensee's back of the envelope-- take the EMF results and make two adjustments--add in the costs of short term transition costs and the costs associated with the fact that we are not likely to have very efficient regulatory regime. The likely costs could double.

Overestimation of costs. Some proponents of a tight emissions budget will claim that economists always overestimate the costs of compliance (e.g., the SO2 market where current permit prices ($120) are considerably less than predicted prices ($750-500)). It is often true-- estimates of economic costs of tighter environmental protection are often too high relative to actual costs. Usually this is due to a combination of factors including changing market fundamentals (e.g., lower energy prices), changes in the actual design of the program. While control costs may not be as high as predicated, these people ignore the fact that environmental regulation has still been a significant drag on the US economy (about 0.2% annual decline).

Innovation and technological solutions. Some will argue that the costs of carbon policy will not be significant because tighter environmental regulations will induce innovative technological silver bullets that will reduce overall costs. But these innovative offsets do not cover the costs of the extra compliance. While case studies can be found to support the innovation offset argument, the real question is whether there is a ubiquitous free lunch across the smorgasbord of US firms? The evidence suggests the answer is "no." US firms and the federal government currently spend at least $100 billion on pollution abatement and control. The magnitude of the cost offsets, as measured by the Commerce Department's Bureau of Economic Analysis, is about $2 billion, less than 2 percent of estimated environmental expenditures. Even if the cost offsets are doubled, tripled, or quadrupled to account for unreported benefits, *net annual spending* on environmental protection is still about $100 billion (in 1992).

Another counter to the claim is that technological solutions are also exaggerated. Recall the days of nuclear power when the slogan was that with nuclear power electricity would be "too cheap to meter."

What actions will decrease the costs of any given emission budget.

- **Flexibility** through carbon trading systems and joint implementation. CEA has fought hard for flexibility so that the most cost-savings can be attained.

- **Faster** technological change.

- **Increased** capital investment.

EPA's strategy. In the Domestic meetings, the EPA argues that the costs of a carbon policy will be low given the existence of flexible programs such as emission trading and JI. In the International meetings, EPA then argues for overly strict standards for trading and JI; these high transaction costs will prevent the substantial potential costs reductions to go unrealized because few nations will want to participate. In effect, they say "look the costs will be low if flexibility exists", but their actions are to restrict flexibility. The EPA is saying let's have a policy but let's keep the carbon reductions at home--make the US economy pay its own way.

A Technical Point on Technological Change
30 May 97

- There is a key technical assumption embedded in the IAT modeling efforts---the assumed *autonomous* rate of technological change. Firms are assumed to adopt more energy-efficient, less carbon-intensive production activities (e.g., use less coal and more natural gas); consumers are assumed to adopt more energy-efficient, less-carbon intensive consumption patterns (e.g., electric cars that get 55 mpg). This autonomous rate is often measured by the energy-to-GDP ratio (E/GDP); it is also measured by the carbon-to-GDP ration (C/GDP).

- The *autonomous* rate of technological change is assumed to be **independent** of the relative prices in the model. This is the so called "announcement effect," where people change their preferences in light of the global climate change treaty. I have dubbed this behavior the "theory of non-price policy response." People see the light once they have been awakened by the Kyoto treaty. And they then lower their marginal rates of time preference or lower their risk aversion, thus causing them to use more energy-efficient technologies that they would have otherwise ignored because they were too costly.

- The **faster** the rate of this autonomous technological change the **softer the blow** to the economy when the regulator introduces a carbon tax. The autonomous progress pushes the economy into more energy-efficient, less carbon intensive activities for free. Therefore, the higher the rate the lower the price shock from a carbon policy. The price shock is lower because the economy has already been moving toward the goal of less carbon on its own. The more people adjust independent of price, the smaller the blow when the carbon policy pushes the economy the rest of the way to the goal by changing relative prices. If we assume people are already on board, they do not need as big of a push. This is a critical assumption because it can be manipulated to reduce the estimated GDP losses from alternative emission budgets.

- The historical rate of **autonomous** technological change is between -0.1 and -0.5% drop in E/GDP per year. Note that the historical **total rate** of change (price-induced and non-price induced) ranges between +0.2 to -2.9% drop in E/GDP per year. Most of this rate is price-driven around the time of the two oil crises in the 1970s. Some researchers have explained all the variation in the E/GDP ratio by price and input substitution, implying that the autonomous rate is near zero.

- The IAT modelers have assumed two autonomous rates of change: -1.25% and -1.75% drop in E/GDP once the Kyoto treaty is announced. **CEA and Treasury** have argue from the beginning that these autonomous rates are too large; and do not match up with historical rates. We have dubbed this the "great leap forward." In effect what these rates do is push a larger fraction of the economy into more energy-efficiency for free than we should expect given historical evidence. Therefore, when we introduce the carbon policy, the shock to the system is softened.

- For example, consider the Markal-Macro model. The table below shows that the "starting point" assumption of 1.25 E/GDP yields an implied carbon tax of $145 in 2010 (which translates into a 39 cent gas tax). If a very faster autonomous rate is assumed (1.75), the carbon tax falls to $77 in 2010 (21 cent gas tax). Now if we go the other way and assume an autonomous rate (0.75) closer to historical non-price rates (0.1 to 0.5), carbon tax increases to $162 (45 cent gas tax). **This is a significant range.**

Markal-Macro Model (stabilize at 1990 levels in 2010 without international emission trading)

Autonomous technological change (E/GDP)	**Carbon price in 2010 (per ton)**	**Equivalent gas tax (2010)**	**Carbon price in 2020 (per ton)**	**Equivalent gas tax (2020)**
High (0.75)	$162	$0.45	$192	$0.52
Higher (1.25)	$145	$0.39	$130	$0.35
Very high (1.75)	$77	$0.21	$35	$0.09

- The other two models, DRI and SGM, have even lower carbon prices because they have also presumed that the economy is shifting toward more energy-efficiency independent of price. In fact, the DRI model reduces its energy use by about 10% in 2010 independent of price. Therefore, it should be no surprise that when the carbon policy shifts relative prices, the shock to the economy is smaller than would otherwise be expected. EPA has started to rationalize this autonomous rate as a "change due to expected price increases." If that is the case, the models are double counting the price effect--once with the expected-price-autonomous change and once with the actual price effect. They cannot have it both ways.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

MEMBER

June 9, 1997

MEMORANDUM FOR DAVID B. SANDALOW

FROM: ALICIA H. MUNNELL
JEFFREY A. FRANKEL

SUBJECT: POTUS Memo on Climate Change

Thank you for the opportunity to comment on the decision memo before it goes to the principals for review. We are very concerned with the memo as drafted, and cannot sign off without some significant changes that will make it more useful for the President and Vice President. Our comments fall into four categories.

1. **The CEA position mischaracterized.** Because of the way the memo is constructed, the CEA position is described incorrectly in the current draft. CEA believes that Option 2 is an expensive option--more expensive than portrayed in the accompanying tables--and not consistent with an optimal path that maximizes the benefit-cost ratio as recommended by most economists. Nevertheless, we believe that global climate change is a potentially significant problem that can be solved only by the participation of both developed and developing countries. For this reason, we would be willing to go beyond what most economists recommend as an optimal path for efficient emission reduction if, and only if, we could secure (a) LDC commitment to "evolution," that is, eventual accession to emission limits similar to the Annex I countries; and (b) a flexible international trading system. We would like this reasoning spelled out in the discussion of Option 2 in the memo.

Second, our view of unilateral action should be stated as follows:

"If no agreement is reached in Kyoto, the CEA believes that the U.S. should consider taking smaller unilateral actions to show good faith internationally, to start educating the American people, and to begin creating the incentives for energy-efficient investments."

2. **Economic impacts of emission restraints understated.** The tables presented in Appendix C show the most optimistic plausible outcomes from the alternative emission restraints. As such, they should be included. But to give a fairer sense of the possible economic impacts, the memo should also include a second set of tables that assume (1) a lower rate of autonomous

technological change (as suggested by the majority of the outside reviewers); and (2) a less optimal recycling of the domestic permit revenue such as reducing the personal income tax. In addition, all tables should include the decline in consumption as well as the decline in GDP.

3. **Option 3 not well-developed**. If the President and Vice President do not want to sign on to a program with the enormous economic and political implications of Option 2, they need to have a viable alternative. As presented, Option 3 does not satisfy that criteria. Characterizing Option 3 as calling for "emission levels peaking at 2010, returning to 1990 levels in the longer term, and declining thereafter" would be more consistent with the international agenda. It would also be useful to spell out the benefits of such a proposal--namely, that its provisions are more likely to be adopted than those of the more ambitious plan, and that phasing in new energy efficient capital as old capital wears out is far more efficient than the more rapid option..

4. **The pros and cons of the options are not clearly spelled out**. Each option should have a list of the three or four strongest arguments for and against. These should be more substantive than "take the high ground," or "would equate your performance...with George Bush's...." For example, suggested pros and cons for Option 2 would be as follows:

Pros

- Would allow the United States to show leadership on global climate change.
- Would increase the likelihood of reaching agreement at Kyoto.
- If adopted, would produce substantial collateral benefits such as reductions in ozone and PM.
- Coupled with demands for developing country participation and flexibility, provides a principled way of negotiating internationally.

Cons

- Would dramatically alter the Nation's fiscal structure, raising $100-$200 billion per year if emission permits were auctioned.
- Would raise the price of gasoline by as much as 40 cents per gallon; would as much as quadruple the price of coal from $28/ton to $113/ ton.
- Would reduce GDP by as much as 0.6 percent in 2010, and reduce consumption by as much as 1.0 percent.
- Would have enormous regional and industry impacts.

Finally, we have attached some detailed editorial comments.

As we said at the beginning, we view the four points discussed above as being so serious that they preclude sending the memo even to the principals until the issues have been addressed.

ISSUE FOR DECISION

In your trips to the Denver Summit of the Eight (June 20-22) and UN General Assembly Special Session on Environment and Development (June 26), what should you say concerning the U.S. position on emissions levels under the climate treaty?

NEED FOR DECISION

To date, the U.S. has not supported any specific emissions levels under the climate treaty. Other countries and domestic constituencies are calling on us to state our views. At the Denver Summit of the Eight, Chancellor Kohl and others will press you on this issue. At the UNGA Special Session, media attention to this issue will be high. Both meetings offer excellent opportunities to advance and explain our position.

[2010-2020 "medium term"]

I. BACKGROUND

Climate change is an issue of vast scale. Decisions on the issue posed in this memorandum could have significant environmental, economic and political consequences.

The build-up of greenhouse gases in the atmosphere threatens fundamentally to alter the Earth's climate. Currently, greenhouse gas concentrations are at their highest level in more than 200,000 years. (See Appendix A). Absent policy interventions, concentrations by the end of the next century will reach the highest level in more than *50 million* years. Impacts are predicted to include sea level rise, the spread of infectious disease, more frequent and severe droughts and floods, loss of forest cover and shifts in agriculturally-productive regions. Absent policy interventions, global average temperatures by the end of the next century are projected to increase 2-6.5 degrees F., sea-level rise is projected to inundate more than 9000 square miles in the United States (with Florida and Louisiana most vulnerable) and an additional 50-80 million people are projected to contract malaria worldwide. According to a NOAA study, average July temperatures in Washington, D.C. by the end of the next century are expected to increase by 5-15 degrees F. (with greater humidity).

The cost of reducing greenhouse gas emissions is potentially substantial. The principal source of such emissions is the burning of fossil fuels, which powers the global economy. Meeting the emissions targets proposed by the European Union, for example, is projected to reduce U.S. GDP in 2005 by 0.1-1.0%, increase gasoline prices in 2010 by 20-25 cents per gallon and increase coal prices in 2010 by almost 180%. Without a well-functioning system of international emissions trading, these figures would roughly double. Private capital outflows associated with an international emissions trading regime are predicted to be roughly $5 billion per year. Significantly, modeling indicates that economic losses from some policies are largely transitory: after an initial loss, the economy rebounds and catches up to its original growth path. Costs depend significantly on rates of technological innovation. Effects on some sectors of the economy will be much larger than effects on the economy as a whole.

This administration has been active on this issue since Earth Day 1993, at which time you pledged to return U.S. greenhouse gas emissions to 1990 levels by the year 2000, and then to continue the trend of reduced emissions. In October 1993, we issued the Climate Change Action Plan, made up of several dozen mostly voluntary programs, designed to meet that goal. (Due to Congressional budget cuts and other factors, the goal will be missed by a wide margin). U.S. negotiators have shaped the international climate change negotiations by calling for binding emissions targets, "flexibility" provisions (such as international emissions trading and joint implementation) that would significantly lower costs of meeting those targets, and the participation of developing countries. You have spoken to this issue several times in the past year, including in the 1997 State of the Union, where you called for "reduc[ing] the greenhouse gases that challenge our health even as they change our climate."

The politics of this issue are difficult, at best. For many environmental groups, strong action on climate change is a litmus test for your environmental policy. If you fail to speak decisively on this issue in Denver (at the Summit) or New York (at the UNGA Special Session), their criticism will be intense. On the other hand, much of the business community is strongly opposed to action on climate change. Fossil fuel and heavy manufacturing companies are poised vigorously to attack any policies the environmental community might support. Labor is increasingly opposed to action on climate change, largely in deference to the concerns of the United Mine Workers. Southern and western Republicans on the Hill are very skeptical about this agenda, as are midwestern and coal state Democrats.

On June 4, the Los Angeles Times wrote "At two international summits this month, President Clinton will no doubt take some heat about U.S. sluggishness in combating global warming...The United States, which produces nearly one-quarter of all fossil fuel emissions and has an environmentally savvy administration, is the logical mediator of a compromise proposal."

II. OPTIONS

Earlier this week, we identified several options for principals concerning the U.S. position on emissions levels in the international climate change negotiations. Each option was defined in terms of a broad directional statement you might offer at the Denver Summit or UNGA Special Session.

The meeting produced a considerable convergence of views. Most agencies (State, Commerce, Transportation, Energy, Agriculture, EPA, AID, OSTP and CEA) supported an option in which you would call for "stabilizing emissions in the medium term and reducing thereafter." In the parlance of the climate change negotiations, this means stabilizing greenhouse gas emissions at 1990 levels by roughly 2010 and reducing to lower levels thereafter.

Several caveats are important:

First, many of these agencies conditioned their support on success in obtaining flexibility provisions (e.g., international emissions trading, joint implementation) and the participation of developing countries. These agencies generally believe that any statement you make concerning emissions levels should be coupled with a strong statement on the importance of these additional provisions. Some agencies believe we should not accept any agreement at Kyoto unless developing countries agree to negotiate quantitative emissions limits.

Second, the Treasury Department has significant concerns. ~~Larry Summers, in particular~~ Treasury, spoke forcefully about the economic and political costs of stabilization and urged a less ambitious approach. ~~Summers noted that~~ cost estimates are based on the assumption that underlying economic growth rates through 2010 will average just over 2%, and that costs of achieving any target would increase if these growth rates were higher. Treasury also focused on the potential wealth transfers possible under some control regimes, noting that

? Not clear -

these transfers could be several times the size of the tax cuts contemplated in the balanced budget agreement. OMB expressed similar concerns.

Third, many participants noted the magnitude of this decision for the second term agenda. There is a widely held view that we cannot take this on without you and the Vice President making this a top tier issue during the next several years.

Fourth, at least one agency (Energy) conditioned its support on strong administration backing for increased funding for greenhouse gas-related technology programs in the years ahead.

Finally, one agency (CEA) stated that the U.S. should take unilateral action to reduce greenhouse gas emissions if no agreement is reached in Kyoto.

In light of the foregoing, and after further discussions, we are identifying four options for you in Denver and New York. They are:

Option 1: Call for "significantly reducing emissions in the medium term."

Comment: Interior Department supports this option, stating that strong measures are necessary to protect the resources it manages. Such a statement would be interpreted to be consistent with the E.U. proposal (a 10-15% cut from 1990 emissions levels by 2010).

This option could impose very large costs on the U.S. economy. Environmental benefits could also be large, especially when non-climate benefits (such as reducing fine particles and ozone) are considered. Many environmental groups would be pleased, but business and labor would be very strongly opposed. Without significant changes in the political landscape, the prospects for ratification by the Senate in the next several years would be close to zero.

Option 2: Call for "stabilizing emissions in the medium term and reducing thereafter." Emphasize that flexibility and the participation of all nations (including developing countries) are essential to addressing this problem.

Comment: This is the recommendation from most of the Cabinet. It allows you to take the high ground: committing the U.S. to meaningful emissions reductions, while insisting on other principles we consider vital to an agreement. It lays the groundwork for refusing to sign a treaty in Kyoto, if we are unable to secure agreement on flexibility or developing country provisions.

Overall economic impacts of this option could be significant (although GDP impacts could be transitory). Dislocation in some sectors and regions (especially coal states) could be large. Environmental benefits (both climate and non-climate) could be significant. Some environmental groups would be pleased; others would complain of lack of U.S. leadership. Most business and labor groups would be opposed, although some might support if the policy were coupled with other features they find attractive. Without significant changes in the political landscape, the prospects for ratification by the Senate in the next several years would be poor.

Option 3: Call for "reducing emissions *growth* in the medium term, on the way to stabilization."

Comment: This is consistent with views of the Treasury Department. Economic costs would be relatively mild, as would opposition in the business and labor communities. Environmental benefits (both climate and non-climate) would be modest. Criticism from other countries and U.S. environmental groups would be very strong. Environmental groups would equate your performance in New York with George Bush's performance at the 1992 Rio Earth Summit.

start in terms of costs?

With this option, there is no chance of obtaining international agreement on our "flexibility" or "developing country participation" proposals. Emphasizing the importance of these proposals in the context of this option would lead to especially scathing criticism. However, there is a chance an option along these lines would be ratified by the U.S. Senate in the next several years without major political changes.

Option 4: Call for "strong action on climate change" and "agreement in Kyoto." Say that the United States is continuing to study the issue of emissions levels and will elaborate on its position at a later time.

Comment: This roughly repeats prior statements by you and other administration officials. It would be strongly criticized by environmental groups, who (here too) would equate your performance in New York with George Bush's performance at the 1992 Rio Earth Summit. ?

This formulation would allow additional refinement of economic modeling runs before our position is announced. We are currently in the middle of peer review of this modeling. More time would produce additional validation of interagency modeling work, although we do not anticipate significant changes in the results.

Material analyzing the environmental impacts of these options is attached as Appendix B. Material summarizing the projected economic impacts of Options 1, 2 and 3 is presented in Appendix C. Additional background material on climate change (including a discussion of domestic policy options) is attached as Appendix D.

Not correct. Reviewers have been very critical of our models and assumptions.

Add possibility of smaller unilateral actions to signal seriousness of intent.

TALKING POINTS: JF 6/1/97
CEA POSITION ON GLOBAL CLIMATE CHANGE

[Here we assume that political constraints must be confronted. E.g., option 3 of the 6/2 Decision Memorandum would simultaneously be rejected by the environmentalists/European negotiators as much too weak environmentally – implicitly "blowing up" the negotiations – while *also* being rejected by business/domestic constituencies as a case of the US (and other Annex I countries) bearing the burden while a free ride is given to the LDCs, the source of most of the future growth in carbon emissions. Once each of the four listed options is rejected as politically undesirable, what is left?...]

We propose:
Option 2 "Stabilize emissions in the medium term and reduce thereafter"

BUT with a rigorous insistence on the various "flexibility" and "developing country" provisions referenced at the bottom of the page below Option 4. Specifically, we would require in the Kyoto negotiations:

- International trading
- Serious participation by the LDCs, meaning participation *beyond* "Joint Implementation"; we would require LDC commitment to "evolution," that is, eventual accession to emission limits similar to the Annex I countries[1].
- Multiple multi-year budget windows
- Banking and borrowing

We are aware the likely outcome would be failure to agree on a treaty at Kyoto. [But, "no treaty is better than a bad treaty" or than an un-ratifiable treaty.]

We would further propose, in the event that there would then be no agreement in Kyoto, that the U.S. offer some more modest steps that it is prepared to take unilaterally, as a good-faith gesture.
These might include some of the steps mentioned as part of Option 4:

- supporting a worldwide end to fossil fuel subsidies (beginning at home)
- imposing a very small measure to raise the price of gasoline
- expanding the existing SO2 trading program among utilities to CO2
- increasing investment in technologies

JF

Very moderate option on GCC

- Emission levels should peak by 2010, and begin to decrease thereafter.
- Emission levels should return to 1990 levels in the longer term [e.g., 2030], and continue to decrease thereafter.
- The U.S. is prepared to support some moderate measures immediately, such as a ban on energy subsidies.

Additional talking points

- **Wishful thinking.**

  - The assumed rate of (non-price induced) **autonomous** technological change (-1.25% and -1.75% drop in energy-to-GDP) is **too fast** relative to historical records. The historical rate of autonomous technological change is between -0.1 and -0.5% drop in E/GDP per year. Note that the historical **total rate** of change (price-induced and non-price induced) ranges between +0.2 to -2.9% drop in E/GDP per year. Most of this rate is price-driven around the time of the two oil crises in the 1970s. Some researchers have explained all the variation in the E/GDP ratio by price and input substitution, implying that the autonomous rate is near zero.

  - **CEA and Treasury** have argue from the beginning that these autonomous rates are too large; and do not match up with historical rates. These high autonomous rates push a larger fraction of the economy into more energy-efficiency **for free** than we should expect given historical evidence. Therefore, when we introduce a carbon policy, the shock to the economic system is watered down artificially. EPA has started to rationalize this autonomous rate as a "change due to expected price increases." If that is the case, the models are double counting the price effect--once with the expected-price-autonomous change and once with the actual price effect. They cannot have it both ways. (*see Section 6 in your briefing book*).

  - **Overestimation of costs**. Some proponents of a tight emissions budget will claim that economists always overestimate the costs of compliance (e.g., the SO2 market where current permit prices ($120) are considerably less than predicted prices ($750-500)). While it is the case that predicted costs of tighter environmental protection have been high relative to actual costs, usually this is due to a combination of factors including changing market fundamentals (e.g., lower energy prices), changes in the actual design of the program. And while control costs may not be as high as predicated, these people ignore the fact that environmental regulation has still been a significant drag on the US economy (about 0.2% annual decline).

  - **Innovation Offsets**. Some will argue that the costs of carbon policy will not be significant because tighter environmental regulations will induce innovative technological silver bullets that will reduce overall costs. But these innovative offsets do not cover the costs of the extra compliance. While case studies can be found to support the innovation offset argument, the real question is whether there is a ubiquitous free lunch across the smorgasbord of US firms? The evidence suggests the answer is "no." US firms and the federal government currently spend at least $100 billion on pollution abatement and control. The magnitude of the cost offsets, as measured by the Commerce Department's Bureau of Economic

Analysis, is about $2 billion, less than 2 percent of estimated environmental expenditures. Even if the cost offsets are doubled, tripled, or quadrupled to account for unreported benefits, *net annual spending* on environmental protection is still about $100 billion (in 1992). Another counter to the claim is that technological solutions are also exaggerated. *Recall the days of nuclear power when the slogan was that with nuclear power electricity would be "too cheap to meter."*

- **President's comments in June.** There is no real need for the President to stray from the general principles stated in the December 1996 U.S. position paper:

(1) The need to examine an international greenhouse gas emissions trading system among annex I (OECD plus former Soviet block) countries.

(2) Joint implementation (projects that reduce emissions below baseline in host country which are credited to the target of the partner country) between annex I and the rest of the world.

(3) The need for a concerted global effort that eventually would imply targets for all countries.

(4) Support for multi-year, rather than single year, targets.

(5) Urge consideration of a right to bank and borrow permits.

- **Why are we demanding serious participation by developing nations? Carbon leakage**. The US position seems to be taking a "deep, then broad" perspective by first establishing a narrow coalition of developed nations and then reaching out to the developing countries to join later ("evolution" in treaty protocol language). This approach begins with a narrow participation by a limited set of countries (Annex I) in a relatively ambitious agreement that involves considerable costs and hence requires fairly sophisticated policy instruments.

  This approach, however, runs the risk that the developing countries will not join later because the costs of doing so will be too high. By increasing the relative costs of carbon in the narrow coalition, carbon-intensive industries will move to developing countries, thereby making these economies even more carbon-dependent as they try to grow their way past the real health problems they face now. Their addiction to carbon-based growth increases the costs of "evolving" into the treaty. The suppliers of carbon-intensive energy will look for existing markets and will create new markets. A climate treaty without China or India probably will not work.

  A "broad, then deep" approach to climate policy might make more sense. Broad--bring in all the nations with a low cost agreement, then deep--the agreement can be made more ambitious (and costly) later.

- **Why are we demanding flexibility?** It is estimated that any agreement without the cost flexibility provided by trading or JI will at least double the US costs. The key is to distribute emissions internationally so as to minimize the costs of climate policy. But before alternative policies can be usefully evaluated, we need to know how the system would be designed. The US does not have a set position as to what either a domestic or international trading system would look like. EPA has argued for relatively high transaction costs that would limit the cost-savings of a trading system; CEA has argued for a flexible system that allows for banking and borrowing of permits. This is an area that is wide-open, and CEA could play an important role in the design of such a trading system. All this holds for joint implementation as well--vaguely defined but yet a potentially important tool to reduce the costs of climate policy.

- **The economic consequences of a delayed agreement**. What do we have to gain by rushing into a stringent emissions budget? The estimated US economic impacts of **NO treaty** are not that large--Nordhaus estimated that there would be a 1% drop in US GNP for a 3°C warming (or a doubling of CO2). This loss is so small because only 3% of US livelihoods are earned in agriculture and other climate-sensitive outdoor activities. Two other studies found similar magnitudes on the US economy. In fact, researchers at Yale estimated that agriculture and forestry might actually benefit from climate change. The impact on developing countries would be larger given that their economies are more dependent on agriculture. EPA's own estimate of the effects is *plus or minus* change of 2% GDP.

- **DELAY** the agreement for 12-18 months to:
  - Draw the developing nations into the treaty (broad, then deep)
  - Define an emission budget based on science (optimal reduction path)
  - Define the trading systems ex ante (a flexible system in place)

  In return for the delay, the US would commit to a significant domestic action
  - domestic carbon trading system
  - increased R&D expenditures
  - removal of fossil fuel subsidies
  - revisit the reinvent regulation

Questions on climate policy left unanswered by the IAT

- What are the costs and benefits at the world and US levels of different climate policies that consider concentrations, climate change, and economic welfare?
- What is the impact of different climate policies on international trade and capital flows?
- What is the likelihood and magnitude of carbon leakage if the non-annex I nations do not participate?
- What will it take from an economic perspective to draw China, India, and Brazil into a climate treaty?
- How will the international and domestic emission trading systems be designed and implemented?
- ?
- How exactly will Joint Implementation be implemented?

Notes for Climate Change briefing paper

Risks of Kyoto round:

1. Binding commitments enforced by command-and-control regulation at home. This would greatly increase the cost.

2. Binding commitments, enforced in the US through the courts, but not enforced in the EU.

3. Binding commitments without flexibility. To prevent this, and to prevent freelancing by the State Department, we should explicitly instruct the negotiators to reject commitments that do not include trading and joint implementation.

4. Binding commitments for Annex 1, with no commitments by the developing countries. This would saddle us with high costs while doing nothing for the climate. The Kyoto agenda does not seem to include commitments by the LDCs, so we may have to accept this outcome.

Beyond Kyoto. The Kyoto round may fail altogether. The parties are so far apart now that many have abandoned hope for an agreement in December, other than a symbolic one. What then?

We could move away from a target of the form "stabilize at 1990 levels by 2010." This target is based on no analysis; it has survived this long mostly because it is easy to remember. William Nordhaus of Yale calculates a benefit-cost ratio for a policy based on this target of 0.20; he and other economists have long advocated climate targets based on long-term concentrations, with attention to benefits and costs. Even adding trading and joint implementation does little to improve the attractiveness of the "stabilize at 1990 levels" policy. Adding international trading raises the benefit-cost ratio only to 0.22, in Nordhaus' calculation.

Other possible proposals include mandating no new coal-fired power plants after the year 2020. This policy would be much simpler to negotiate, as the 6 major coal producers account for the overwhelming share of the world's coal production and reserves. This policy alone would stabilize atmospheric concentrations at about 650 ppm.

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To Jason Shogren		Date 6/2	# of pages ▸ 2
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Costs of Greenhouse Control Programs.

The Interagency Analysis Team (IAT) calculates the cost of stabilizing U.S. emissions at 1990 levels in 2010 at 0.2% to 0.6% of GDP if international trading is not allowed, and at 0.1% to 0.4$ of GDP if trading is permitted within the OECD. Calculated costs fall farther into the future.

Results are sensitive to the models used, and to several modeling assumptions. For example, the IAT assumes that the Federal Reserve Board will allow expand the money supply over the entire 25-year modeling horizon, to keep interest rates down and encourage investment. Without this assumption, costs rise significantly. Also, the IAT assumes that the economy will rapidly grow more energy-efficient, in effect lowering the cost of meeting a limit on carbon emissions.

The IAT's results are roughly consistent with those of the more comprehensive and better-known Energy Modeling Forum (EMF) at Stanford. The EMF study included 10 models, of several designs, which calculated GDP losses of 0.2% to 0.7% in 2010 to stabilize carbon emissions at 1990 levels without international trading. As with the IAT, the lower estimates come from models that adopt optimistic assumptions about reducing energy intensity, or about the availability of low-cost substitutes.

The EMF models, however, all calculate that control costs will rise, not fall, as time goes on. On average, they calculated that to stabilize U.S. greenhouse emissions at about current levels over the next several decades, assuming this is done in the most efficient way (using tradable carbon rights or carbon emission taxes), would cost about 2% of the *growth rate* of GDP; this would reduce growth from, say 2.5% annually, to 2.45% annually. Thus, by the year 2020, GDP losses would be about one percent annually.

Both the IAT and EMF calculations are likely to be on the low side, for several reasons. First, all the models assume the most efficient possible climate control program, using carbon taxes or carbon emission permits; in reality, we now have only one market-based environmental control program, and it accounts for only a tiny fraction of compliance efforts. Second, the models implicitly assume that the control program is announced early, and maintained at that level indefinitely. In reality, the government is not likely to maintain consistent control measures over decades. Third, the models used by EMF focus on long-run equilibrium; none includes short-term adjustment costs, such as we experienced following the two oil crises of the 1970s.

How much would these factors add to the calculated costs? Richard Schmalensee of MIT, long prominent in the economics of climate change, believes these factors would raise the EMF estimate by a factor of one to four. This would put the cost of stabilization in 2020 at one to four percent of GDP; that is, GDP in each year would reduced by one to four percent from the baseline. For comparison, the US now spends about two percent of GDP on all environmental programs combined.

Reducing emissions by 20% relative to 1990 levels would cost about twice as much as stabilizing at 1990 levels, according to EMF.

Global climate change

- Response to EPA overture? If we ever talk with the EPA it should only be after we talk with treasury.

- Tell Robert Gillingham to get Larry to call. Yes--or we should call them. What do we lose by us calling over there?

- Give Mark "moderate option" language. Mark needs something to guide him otherwise he will just keep getting overwhelmed by State and the EPA. For example, in the last decision memo it stated that the temp in Washington, dc will increase by 5-15 degrees in the near future. Now there is no way any modeler knows this because the climate models cannot predict down to this level of detail. This is the swarming nature of the EPA that Mark has to try to deflect. He probably has not been given anything by the economic agencies as a counter-option and he probably should have one.

- Prevent Sandalow et al. from blowing off the reviewers comments. We need to identify the non-academic (i.e., non-trivial) concerns that must be addressed, and then get the economic agencies to play a more active role in the IAT. More active and less passive because right now the IAT has really been run for State regardless if it was run in Commerce. I see this as a chance for treasury to demand the analysis they need and then volunteer some labor to get it done.

A few things to consider when thinking about climate policy

- **1990 @ 2010 as a focal point emissions budget**. This target was **not** derived from any scientific or economic analysis. From what I can tell it was selected because it was a "medium term" target. Some integrated modeling analyses show that this target is worse than doing nothing. Nordhaus, for example, has estimated that the benefit/cost ratio for this target equals b/c = 0.20. Even with international trading, the b/c = 0.22. A bad idea with trading is still a bad idea. The IAT modeling effort has focused completely on the costs of a carbon policy without considering the benefit side. And while some optimal carbon policy is probably unattainable, it provides a better focal point for discussions of US global climate change policy than does the ad hoc 1990@2010. Nordhaus and Jorgenson's reading of the evidence is that current assessments do not support the idea of focusing primarily on stabilizing emissions, especially when stabilization is limited to developed countries. The preferred strategy should be to decide what concentration level is acceptable, and then work backward from there to decide the most cost-effective path to achieve the concentration. Unlike the Clean Air Act, nothing says that a climate policy cannot be based on sound economics. Plus an optimal path will have lower carbon taxes that will prove more attractive to industry and Congress.

- **Carbon leakage**. The US position seems to be taking a "deep, then broad" perspective by first establishing a narrow coalition of developed nations and then reaching out to the developing countries to join later ("evolution" in treaty protocol language). This approach begins with a narrow participation by a limited set of countries (Annex I) in a relatively ambitious agreement that involves considerable costs and hence requires fairly sophisticated policy instruments.
  This approach, however, runs the risk that the developing countries will not join later because the costs of doing so will be too high. By increasing the relative costs of carbon in the narrow coalition, carbon-intensive industries will move to developing countries, thereby making these economies even more carbon-dependent as they try to grow their way past the real health problems they face now. Their addiction to carbon-based growth increases the costs of "evolving" into the treaty. The suppliers of carbon-intensive energy will look for existing markets and will create new markets. A climate treaty without China or India probably will not work.

  Economists argue that a "broad, then deep" approach to climate policy makes more sense (e.g., Schelling, Schmalensee, Stavins). Broad--bring in all the nations with a low cost agreement, then deep--the agreement can be made more ambitious (and costly) later.

- **Emissions trading, joint implementation, and transaction costs**. It is estimated that any agreement without the cost flexibility provided by trading or JI will at least double the US costs. The key is to distribute emissions internationally so as to minimize the costs of climate policy. But before alternative policies can be usefully evaluated, we need to know how the system would be designed. The US does not have a set position as to what either a domestic or international trading system would look like. EPA has argued for relatively high transaction costs that would limit the cost-savings of a trading system; CEA has argued for a flexible system that allows for banking and borrowing of permits. This is an area that is wide-open, and CEA could play an important role in the design of such a trading system. All this holds for joint implementation as well--vaguely defined but yet a potentially important tool to reduce the costs of climate policy.

- **Impact on international trade flows.** Given that substantial flows of rents will be created by an international or domestic trading system, we still no very little about the impact on international trade flows. In 1992, Manne and Richels estimated that the US might import $50 billion in permits from China--this would have major impacts on trade flows. None of the IAT models can address this issue (the SGM models energy use by region but not trade in goods and services).

- **Positions within the Administration.**

  Tight (option 1): EPA, State, Interior, CEQ

  Loose (option 3 or 4): Agriculture, Treasury, Commerce ?

  Don't know: SBA, Defense, Transportation, Labor, Justice,

  DOE's position: option 2 (1990@2010) with caveats (the shorter the budget period, the later the starting date; commitment to technology; and commitment to reexamine the reinvent regulations that have not been followed through)

  OSTP: with enough support for technology, OSTP would be willing to delay until 2020

  NEC: DT has wondered whether delaying a year might not be a bad idea

A proposal

- DELAY the agreement for 12-18 months to:
  - Draw the developing nations into the treaty (broad, then deep)
  - Define an emission budget based on science (optimal reduction path)
  - Define the trading systems ex ante (a flexible system in place)
- In return for the delay, the US would commit to a significant domestic action such as
  - domestic carbon trading system
  - increased R&D expenditures
  - removal of fossil fuel subsidies
  - revisit the reinvent regulation

PNGV Report Released

Differentiation

Glossary

Activities Implemented Jointly A pilot program to test the feasibility of joint implementation projects.

Annex C Gases A list of greenhouse gases, their global warming potential (GWP), and sources and sinks of those gases. (e.g. carbon dioxide, methane, nitrous oxide) This list will exclude those gases for which there is insufficient information on GWPs or monitoring and measurement methods do not exist.

Annex I Countries Nations listed in Annex I of the FCCC; includes countries who were members of the OECD in 1992, 11 countries in transition to a market economy, and the European Economic Community.

Australia	Austria	Belarus
Belgium	Bulgaria	Canada
Czechoslovakia	Denmark	European Economic Community
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 of Great Britain and Northern Ireland
United States of America

Autonomous Energy Efficiency Index (AEEI) Rate of technology progress independent of energy prices.

Budgets National budgets would determine total allowable emissions over a fixed multi-year period. Each nation would have an initial allocation which could be added to or subtracted from through emissions trading, joint implementation projects, or banking between budget periods.

Banking and Borrowing If a nation does not use all of its emissions permits in a budget period, they may be applied to the next budget period (saved). Alternatively, if a nation exceeds its budgeted amount, it must borrow emissions credits from its next budget allocation.

Carbon Emission Trading A program (international or domestic) to allow the trading of emissions credits between entities -- the tradeable unit would be a "tonne of carbon equivalent emissions allowed."

Climate Change Action Plan (CCAP) The US plan (announced Oct. 1993) to respond to climate change, coordinated through the EPA, DOE, etc.. Goal is to stabilize U.S. anthropogenic emissions at 1990 levels by 2000.

Early Credit When actions taken prior to the first budget period receive credit against obligations in that period.

Energy/GDP Ratio Energy intensity, the ratio of total domestic primary energy consumption or final energy consumption to GDP.

Evolution Process by which non-Annex I (developing) nations are brought into the formal binding portion of the regime.

Framework Convention on Climate Change UN convention to coordinate an international response to global climate change. Signed in Rio during the "Earth Summit," the convention entered into force in March 1994, and has been ratified by nearly 160 countries.

Global Warming Potential (GWP) The potential of a given greenhouse gas to cause global warming relative to a ton of carbon dioxide over a 100 year period.

Imputed Value of Carbon The implicit carbon tax.

Intergovernmental Panel on Climate Change (IPCC) An assessment group of international experts brought together by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to assess scientific information on climate change and the environmental and socio-economic impacts of climate change.

Joint Implementation (JI) A system for granting emissions credits to a country for implementing emissions reductions projects in other countries. This differs from emissions trading in that credits are generated through specific projects and can be carried out between parties with budgets and those without budgets. Activities Implemented Jointly (AIJ) is a current pilot test of such a system.

Paper Tons In a cap and trade system, nations whose annual emissions have gone down since the base year would have immediate surplus emissions credits. These credits are called paper tons.

When & Where Flexibility Refers to the choices nations will have to reduce emissions geographically (where) and temporally (when).

Revenue Recycling Using revenues generated through carbon taxes or permit programs to reduce the federal deficit, or business or personal taxes.

Sinks Processes, such as forest growth, that absorb greenhouse gases.

Acronyms

AIJ	Activities Implemented Jointly
AEEI	Autonomous Energy Efficiency Index
CCAP	Climate Change Action Plan
FCCC	Framework Convention on Climate Change
GHG	Greenhouse gases
GWP	Global Warming Potential
IPCC	Inter-Governmental Panel on Climate Change
IAT	Interagency Analysis Team
MMTCE	Million Metric Tonnes of Carbon Equivalent
PPM	Parts Per Million
TCE	Tonne of Carbon Equivalent
UCE	Units of Carbon Equivalent