THE WHITE HOUSE

WASHINGTON

STAFF SECRETARY

TODD STERN

April 30, 1998

MEMORANDUM FOR RECORDS MANAGEMENT

FROM: JONATHAN ADASHEK

The attached three boxes contain the following material relating to climate change:

Box 1: UNFCCC - COP - 3 Briefing Book; Agency Papers for Climate Change-Analysis Workshop (6/27); Congressional Information Notebook; PCAST Report Release, 11/5/97; Five Labs Study Information; The March of the Jolly; Global Warming (The Complete Briefing); WHCA East Room Remarks (Audio); Microcassettes of White House Conference;

Box 2: President's Advisory Committee - USTR Briefing Book (9/25/97); Administration Documents on Climate Change; October 22 Cabinet Briefing Materials; Draft- Climate Change Report; PCAST Report (11/5/97); Global Competitiveness Report- 1997; U.S. Submission Under UNFCCC- 1997; Argone Report; White House Conference Transcript;

Box 3: Talking Points- Stern; Stern Speeches; Meetings- Todd; Todd's Speech-10/14/97; Research; Talking Points- Q & A; White House Conference Materials; International Utility; Climate Change Background; National Security; Oversight/ Working Group; International Actions; Congressional Record (10/22-23/97); Asphalt Nation; Kyoto: Diplomatic Reports, Press, Vice President, State Department Policy Papers, Miscellaneous.

Box 1 - 11461 - NARA 8854

Box 2 - 11462 - 8855

Box 3 - 11463 - 8856

ENCLOSURES FILED OVERSIZE ATTACHMENTS

3 boxes filed 5/4/98 OR

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White House Climate Change Task Force

734 Jackson Place, N.W. • Washington, DC 20503

Prepared for Todd Stern

AGENCY PAPERS FOR CLIMATE CHANGE ANALYSIS WORKSHOP

Drafts as of June 27, 1997

I. Executive Summary

II. Scientific Basis for Action

III. Policy Options for Controlling Emissions

IV. Economic Effects of Global Climate Change Policies

V. Sector Emissions and Opportunities for Mitigation Under a Climate Change Mitigation Strategy

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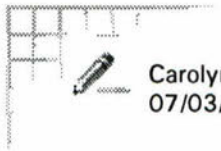

Carolyn E. Cleveland
07/03/97 05:19:56 PM

Record Type: Record

To: Todd Stern/WHO/EOP

cc:
Subject: Climate Change Meetings

The following meetings are set up (however, I will be confirming on Monday):

Tueday, July 8
Global Climate Coalition - 3:30 p.m.

Wednesday, July 9
International Climate Change Partnership - 11:00 a.m.
Business Council for Sustainable Energy Future - 2:00 p.m.
AFL-CIO - 4:00 p.m.

Message left with Alden Myers for the Environmental Groups.

Are these okay with you? It do not have the attendees yet for any of the meetings but will get them on Monday when I confirm the appointments.

C

MESSAGE CONFIRMATION

JUL-01-97 16:04

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PAGE : 07

ELAPSED TIME : 03'56"

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THE WHITE HOUSE
WASHINGTON

OFFICE OF THE STAFF SECRETARY

Fax Transmittal Sheet

TO: Leslie Dach

Fax Number: 898-0392 **Phone Number:** 371-0200

FROM: Todd Stern

SUBJECT: Climate Change

DATE: 7-1-97

NUMBER OF PAGES (including cover sheet): 7

MESSAGE:

If all pages are not received, please call 202/456-2702

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Executive Summary

- Fossil fuel use and land-use changes have raised atmospheric concentrations of carbon dioxide and other greenhouse gases by roughly 30% since the beginning of the Industrial Revolution. Global emissions are currently growing by more than 1% per year, and concentrations are rising by roughly half a percent per year.

- In the absence of a proactive response, emissions will continue to grow, and will more than double atmospheric concentrations by the end of the next century. The Intergovernmental Panel on Climate Change stated that such an increase in concentrations will lead to a rate of warming that "will probably be greater than any seen in the last 10,000 years."

- The changes in climate associated with higher concentrations are likely to have significant impacts on human health, water availability, agriculture, natural ecosystems and sea levels. Increased climate variability could lead to greater frequency of large storms and other catastrophic events.

- Emission controls would not only reduce the likelihood of climate change but would also provide ancillary benefits, including reduced conventional pollution from fossil fuel combustion and enhanced energy security from reduced fossil fuel imports.

- The developed countries are responsible for the bulk of historical emissions and have relatively high per capita emissions, particularly the United States. In contrast, the developing countries will be responsible for the bulk of future emissions, but their per capita emissions and their share of cumulative emissions will remain below that of the developed countries for many years to come. As a result, attempts to limit global emissions will inevitably involve controversy over how to share the burdens of control.

- Policy options for controlling emissions domestically include policies that reduce barriers to the adoption of existing energy-efficient technologies; policies that impose standards or market incentives (such as the acid rain emissions trading program); and research, development and diffusion programs that target energy efficiency and non-carbon technologies.

- A permit system allowing emissions trading is considered a particularly promising efficient mechanism for controlling emissions. A permit system would involve the issuance or sale of tradable greenhouse gas emission permits. Permits could be bought and sold on a commodities market, allowing the greatest degree of flexibility in where emissions are reduced.

- During the past year-and-a-half, the Interagency Analysis Team has analyzed the potential costs of permit trading systems to achieve a variety of emissions targets over time. For example, a permit system to stabilize U.S. carbon emissions at 1990 levels

from 2010 to 2020 would involve the annual sale or distribution of a quantity of permits equivalent to 1990 U.S. emissions.

- In its "central case" estimate of the costs of a stabilization policy, the IAT analysis suggests that permit prices would range between $80 and $150 per ton of carbon in 2010 and between $105 and $150 in 2020 (in 1995 dollars). The overall impact on the economy would be highly dependent on whether permits were directly allocated or auctioned, and on how revenues from a permit auction were recycled through the economy. In any event, overall GDP effects are relatively small, with a maximum decline of about 1% from base a few years after the policy is initially introduced. Direct compliance costs (the outlays by households and businesses to reduce greenhouse gas emissions) would range from $12-18 billion per year in 2010.

- Economic impacts would vary by industry and region. Fossil fuel producers would face a decline in output under any scenario. Energy-intensive industries would face higher energy costs. Such a policy would somewhat accelerate the U.S. economy's ongoing shift away from energy-intensive manufacturing toward information technology, services, and other activities. The central regions of the U.S. would be more stongly affects, while the east and west would experience more modest impacts. International trade impacts and emissions "leakage" – increases in other countries emissions that simply offset reductions in the U.S. – would be fairly modest, since most energy use is associated with activities that cannot be exported.

- Any emissions reduction policy adopted by the U.S. would be coordinated with similar policies in other developed countries and perhaps with policies implemented in the developing countries. International permit trading – particularly trading among the Annex I countries – would significantly reduce the overall cost of achieving any emissions reduction goal.

Todd--Here is an annotated presentation I give to agency heads on the science of climate change. Hope it's helpful; I'd be happy to take you through it!.
Rosina Bierbaum, OSTP 6-6077

There is a strong scientific consensus that human activities are affecting the global climate system as stated by the Intergovernmental Panel on Climate Change (IPCC). This represents more than 2000 scientists from more than 50 countries.

Figure 1: Greenhouse effect
There is a natural greenhouse effect that keeps world 33^{0}C or 60^0 F warmer than it would be. Without this, life would not be possible. Water vapor, CO2, methane, nitrous oxide and other trace gases trap heat as it is re-radiated out to space.

Figure 2: Changes in 4 greenhouse gases over time
Since pre-industrial times, humans have added to the natural greenhouse effect by releasing additional GHG to the atmosphere. Burning of fossils fuel--coal, oil and gas for energy is primary cause of emissions (about 6 Billion metric tons of carbon/yr); changing land-use patterns through agriculture and deforestation also contribute another 1-2 billion metric tons per yr.

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Of course that will change--that's where 90% of the population growth will take place. And energy use--which averages about 1/15-1/20th of our "per person" use will increase if it can (e.g., there is only 1 car per 3000 people in China.

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Under business as usual, we expect emissions from the developing countries to rapidly increase--equal those of Annex 1 (US, OECD, Former Soviet Union and E. Europe) by about 2035 and continue to climb.

Figure 5: Global temp and CO2 since 1750 projected to 2100
What's happened to date? Over the last century, the global mean surface temperature increased by about 0.5^0 C (almost 1.0^0 F). The surface temperature this century is as warm or warmer than any century since at least 1400 AD. The last few decades have been the warmest this century, the ten warmest years this century have all occurred since 1980, and 1995 was the warmest on record.

And where are we headed? To another 2-6^0 F by 2100.

Figure 6: US Precipitation and drought trends over the last 100 years,
What does warming do?--**a warmer earth essentially speeds up the planet's hydrological cycle or water cycle**--There is more evaporation meaning there is more water in the atmosphere that will come down as rain or snow. The increased evaporation will also lead to drying in some areas, so we expect both more soil drying and more precipitation

Figure 7: We're beginning to see changes along these lines in the US. This map show that while, overall, US rainfall has increased about 6% over the last century, we are also seeing an increase in dryness in some areas (light blue). The type of rainfall is also changing. We are getting more of our rainfall in extreme downpours that promote flooding--not the 'gentle rains from heaven' so conducive to agricultural growth. The frequency and intensity of floods and droughts will change. In the United States, the Great Basin, California, Missouri, Arkansas, Texas Gulf, Rio Grande, and Lower Colorado River Basins are likely to be most vulnerable.

Figure 8: Florida/or graph by region of sealevel rise
Warming the ocean causes **Sealevel to rise**--mostly from thermal expansion of the water, some from melting of seaice and glaciers. Here I show you (thanks to USGS) what a 1 m. rise in sealevel will do to Florida. Expected sea level rise over the next century could inundate 9000 square miles of lands. The Atlantic and Gulf Coasts are particularly vulnerable.

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Figure 12: VP's favorite chart (CO2 and temp over the last 170,000 years as measure in ice cores)
Where will "Business as usual" take atmospheric concentrations? In 100 years, through 720 ppm--approaching 3x preindustrial levels ---levels not seen in the last 50 millions years of the planet, certainly faster than natural systems have been exposed to, and all in a geologic blink of an eye.

Figure 13: Emissions as usual versus stabilization paths
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This map centered over the US show how average temperature increases for a 2x and 4 x CO2 world--2 to 6° F for a doubling, but 15 to 20 degrees F for quadrupling.

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In the growing season, soil moisture deficits would approach 30-50% for quadrupling , as opposed to 10 - 30 % for a doubling.

We clearly wish to avoid these impacts. Mitigation actions are urgently needed.

(I also attach 2 pages of the IPCC findings)

Policy Options for Controlling Emissions

Ideally, a domestic program for controlling emissions would ensure that specified emission goals are achieved, while granting the private sector the flexibility to invest in response strategies that achieve emission reductions at the least cost. In addition, a response strategy should exploit the vast market on the horizon for advanced technologies -- be they for energy efficiency, renewables, natural gas, or other low greenhouse gas technologies. And finally, a control program should be fair, minimizing adverse effects on workers while ensuring a viable economic future for any worker losing employment because of the changes brought about by the action taken to mitigate climate change. This chapter analyzes the following:

- An Emissions Trading Program for Greenhouse Gas Emissions: This program involves the creation of emission permits for those emitting greenhouse gases. These permits would be allocated to emission sources either by formulae or through an auction. Once allocated, they could be traded in the marketplace. An important characteristic of emission trading is that no matter what the initial permit allocation, the final allocation after trading will be the one that minimizes the cost of reducing emissions. In addition to emission trading, other government interventions, such as energy efficiency standards that overcome other market failures, may be appropriate.

- Technology Research and Development (RD&D) and Diffusion. RD&D can reduce costs in all periods. However, it is particularly important in the long term, since controlling warming ultimately requires adopting an energy system that does not rely primarily on fossil fuels. This would involve stepping up and refocusing the federal government's R&D program and reversing the long-term trend of declining government and private R&D expenditures.

- Economic Transition Programs. A successful greenhouse gas control policy could have important implications for the level and pattern of energy usage in the economy. Usage of high carbon fossil fuels (e.g. coal) will decline, while the demand for other energy sources (e.g. natural gas or renewables) will grow in importance. A transition program would reduce the costs to individuals and communities associated with this environmental policy. Transition assistance can help facilitate community and worker adjustments via retraining, job search assistance, and infrastructure development for new business in the community.

Greenhouse Gas Emissions Trading Programs

Emissions trading involves allocating or auctioning emissions allowances, and allowing the trading of allowances in a market with sufficient mechanisms to ensure compliance with targeted levels and the integrity of the trading system. Emission trading creates new, marketable assets that can have substantial value, so distributional issues will be an important component of program design. Allocation designs or auction revenues can be used to address these distributional issues.

Emission trading systems offer both static and dynamic efficiency advantages over more traditional forms of regulation. Emitters face different abatement costs, so emissions trading

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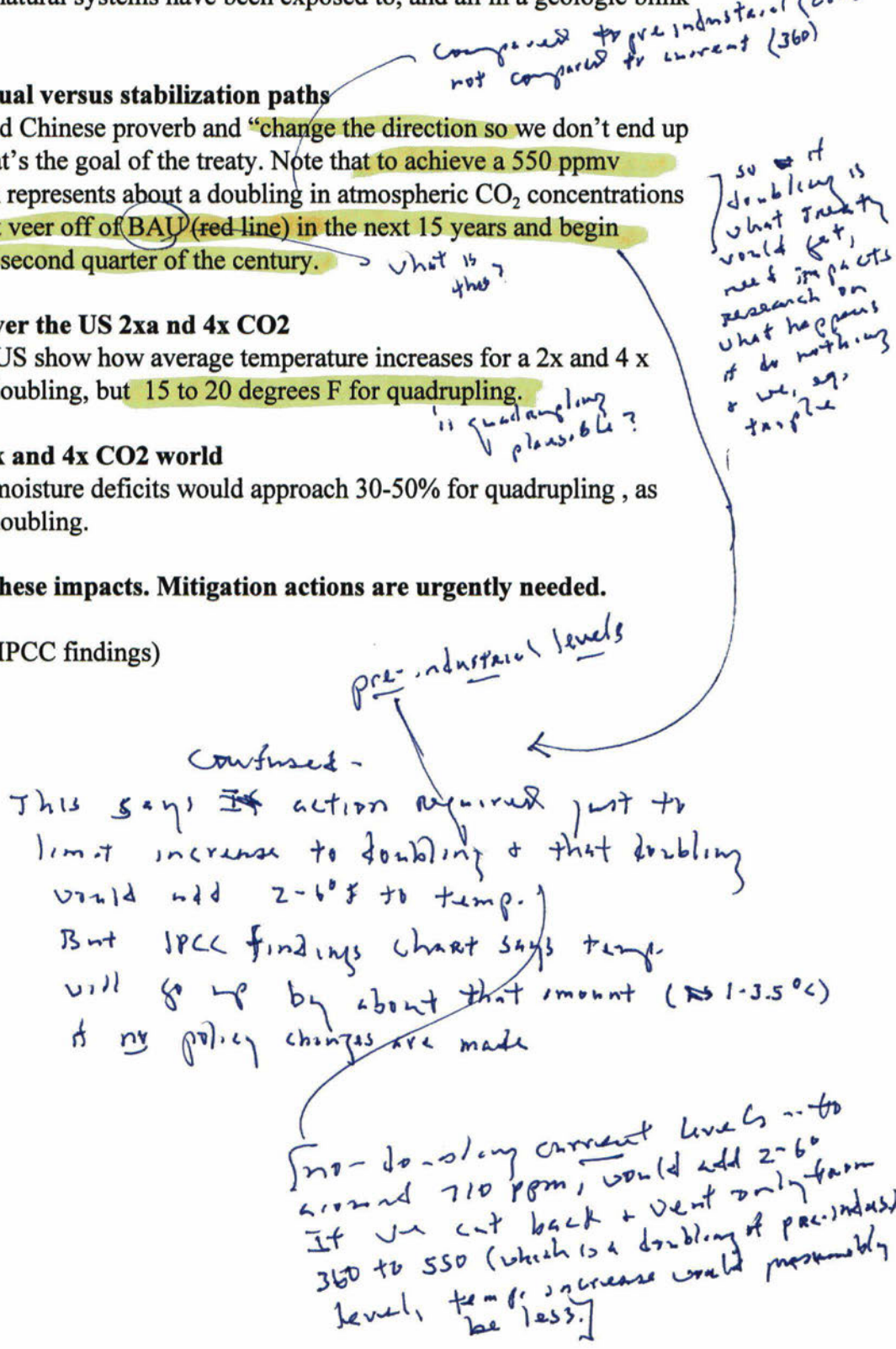
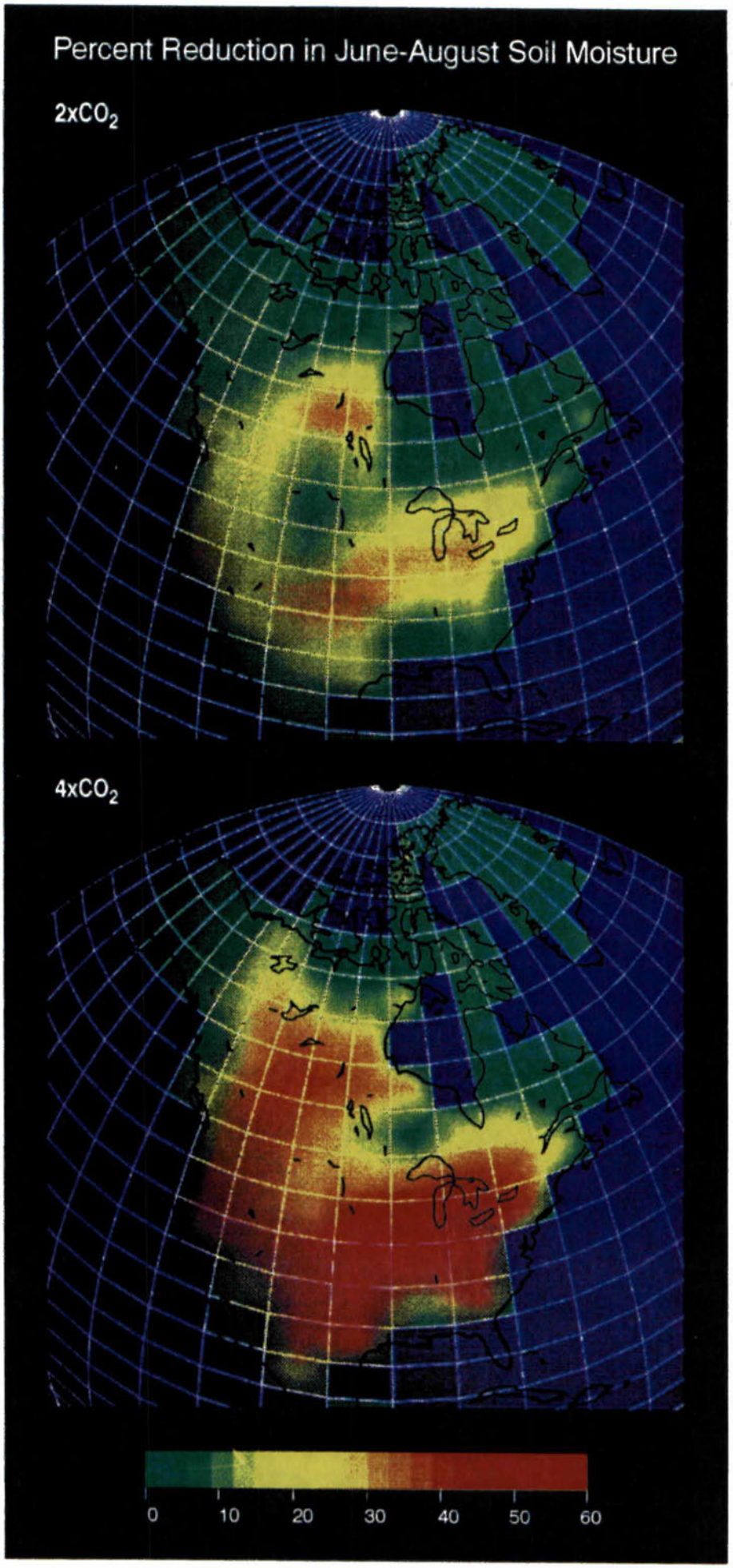
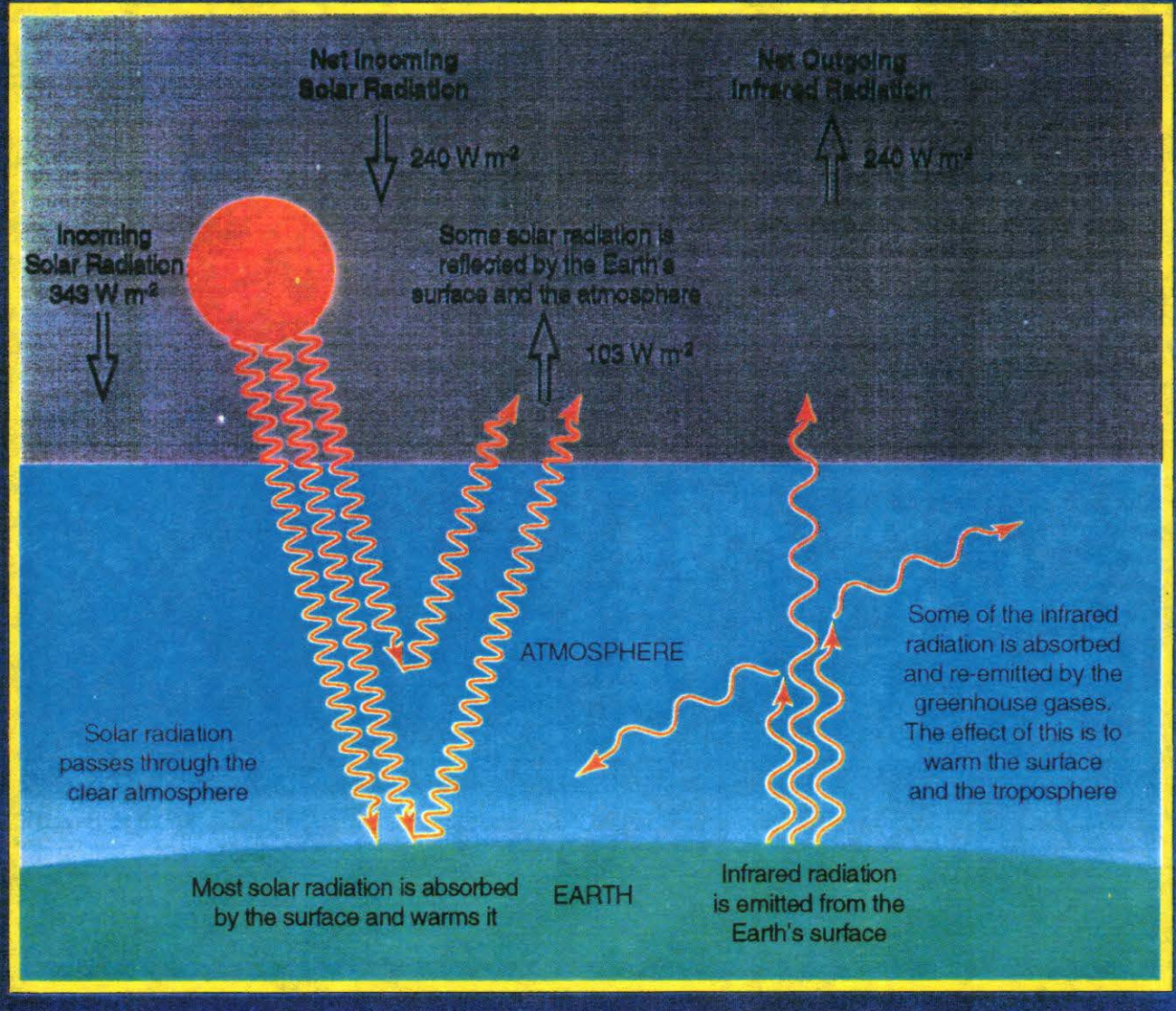
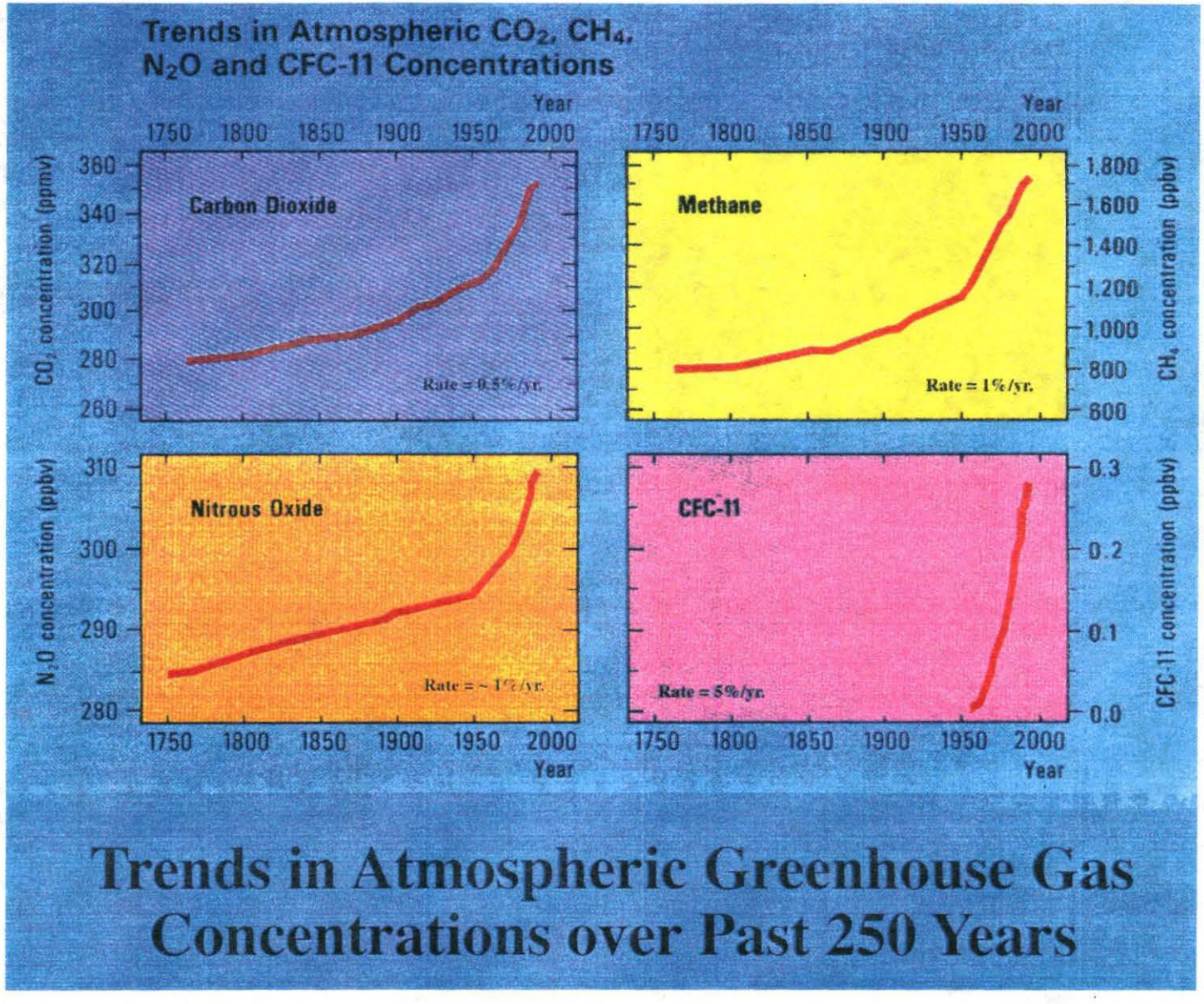



Percent Reduction in June-August Soil Moisture
2xCO2
4xCO2
0
10
20
30
40
50
60

The Greenhouse Effect

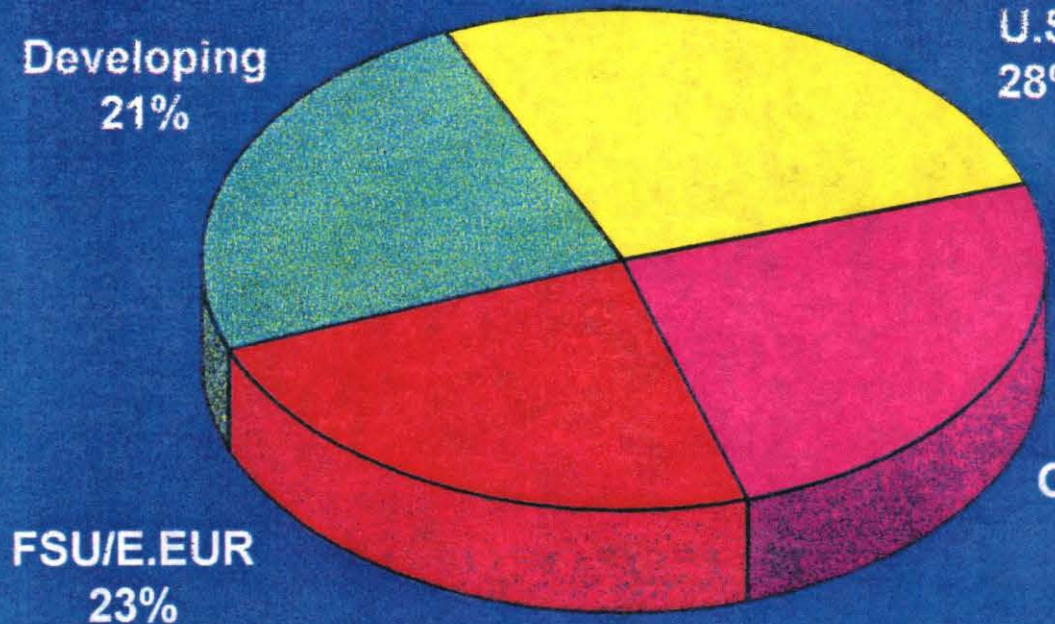




Trends in Atmospheric Greenhouse Gas Concentrations over Past 250 Years

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

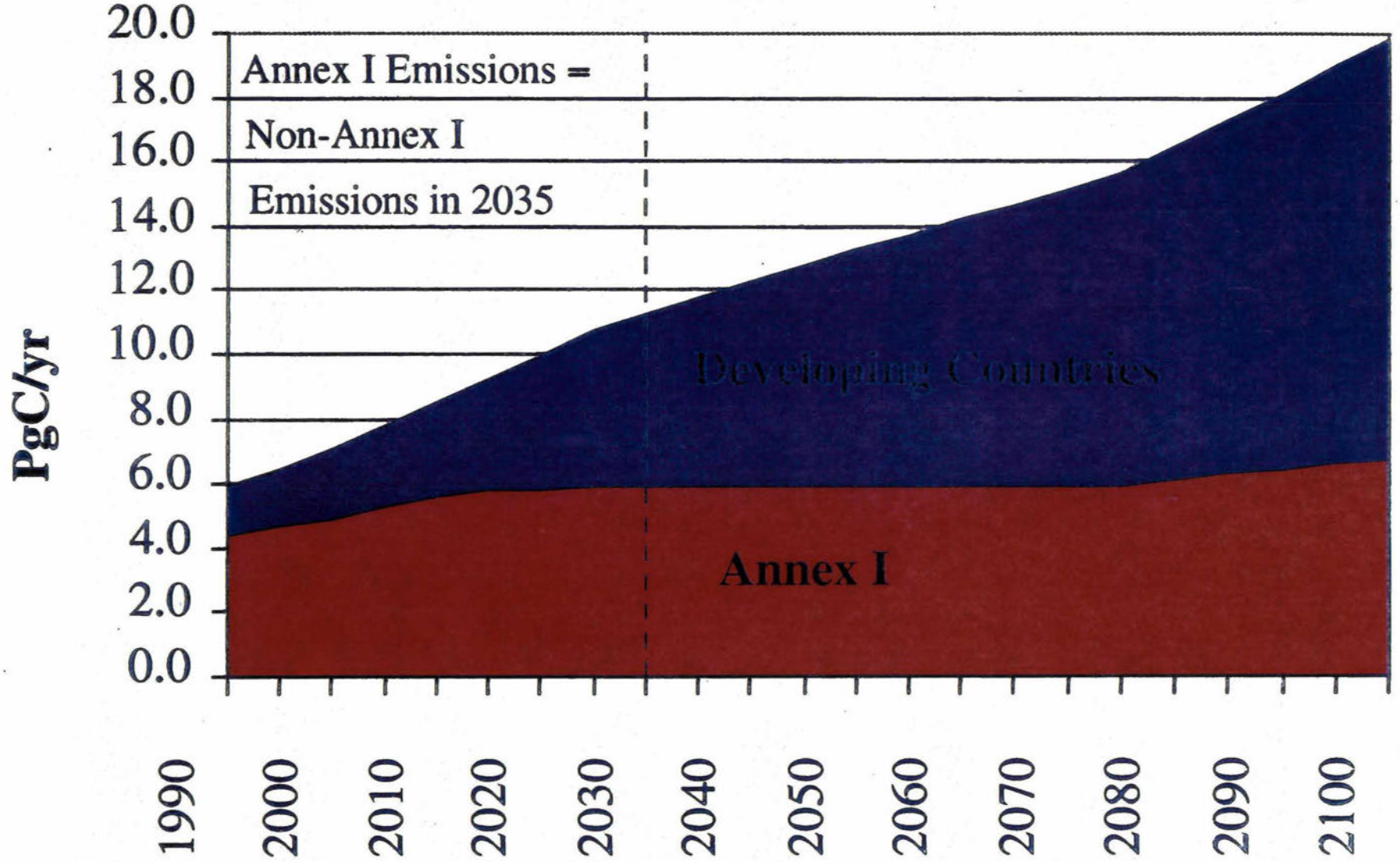
Global Total: 583 Billion Tonnes CO_2

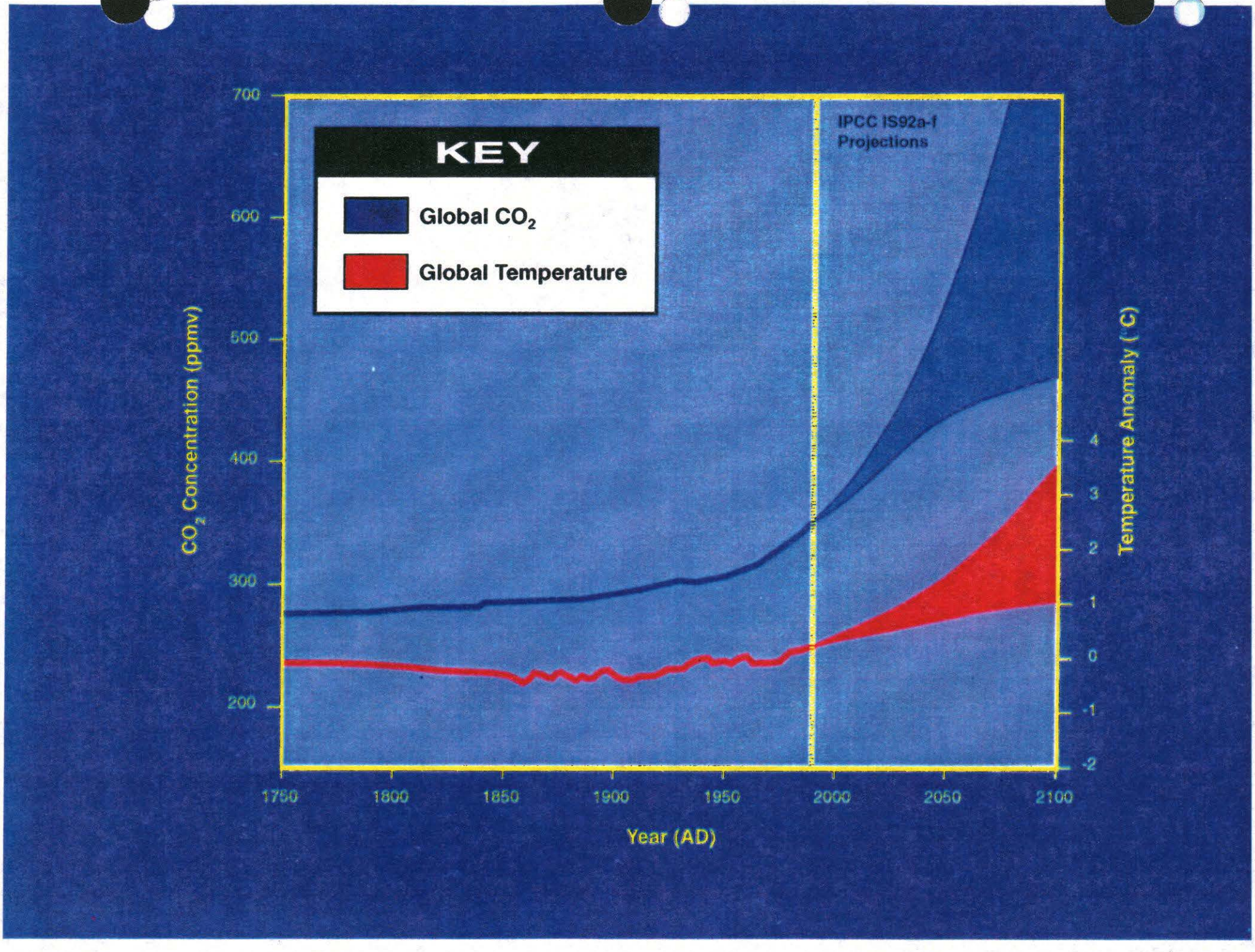


Source: Marland *et al* (1995)

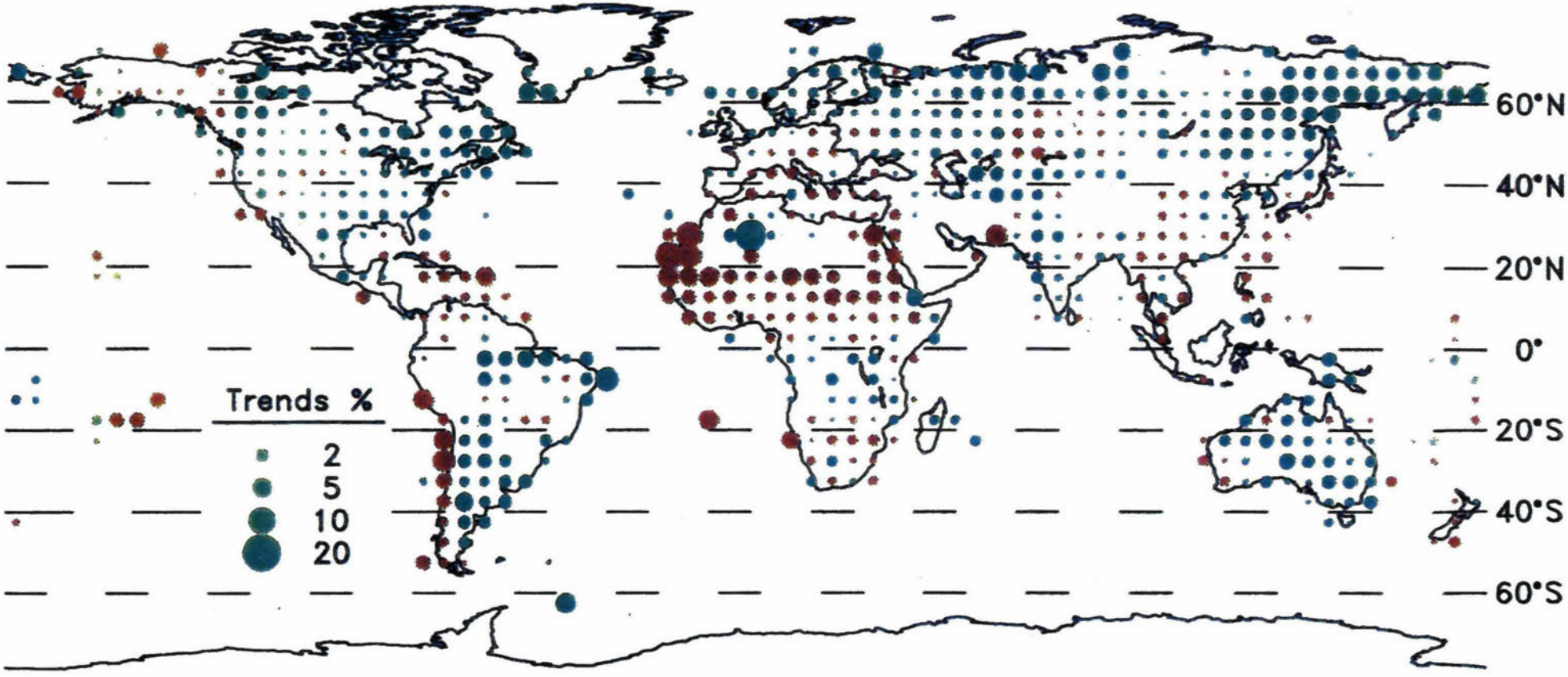
EPA

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

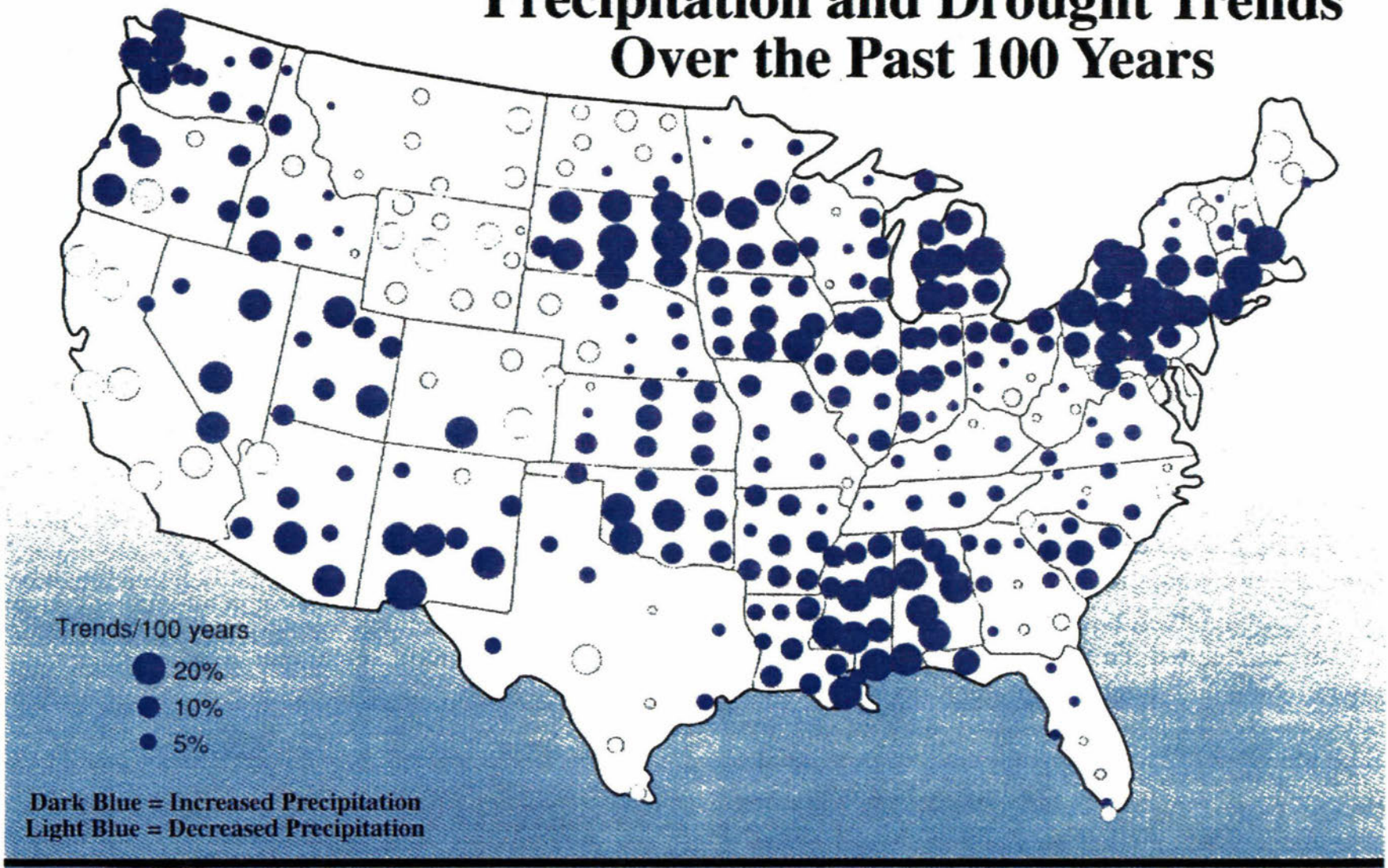



KEY
Global CO_2
Global Temperature
IPCC IS92a-f
Projections
CO_2 Concentration (ppmv)
700
600
500
400
300
200
Temperature Anomaly (°C)
4
3
2
1
0
-1
-2
1750
1800
1850
1900
1950
2000
2050
2100
Year (AD)

Precipitation Trends (%) per Decade (1900-1994)
green, increasing; brown, decreasing

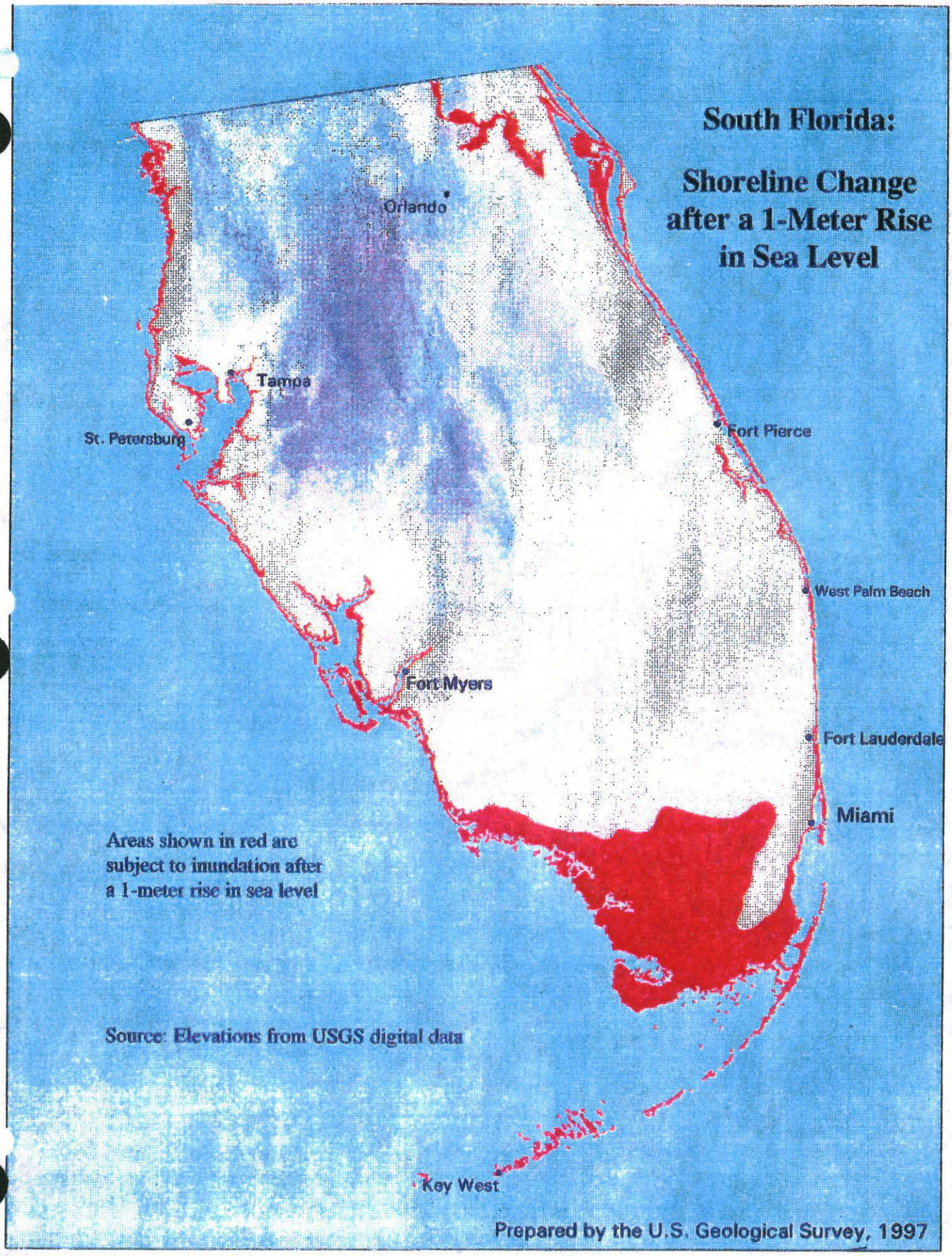


Precipitation and Drought Trends Over the Past 100 Years

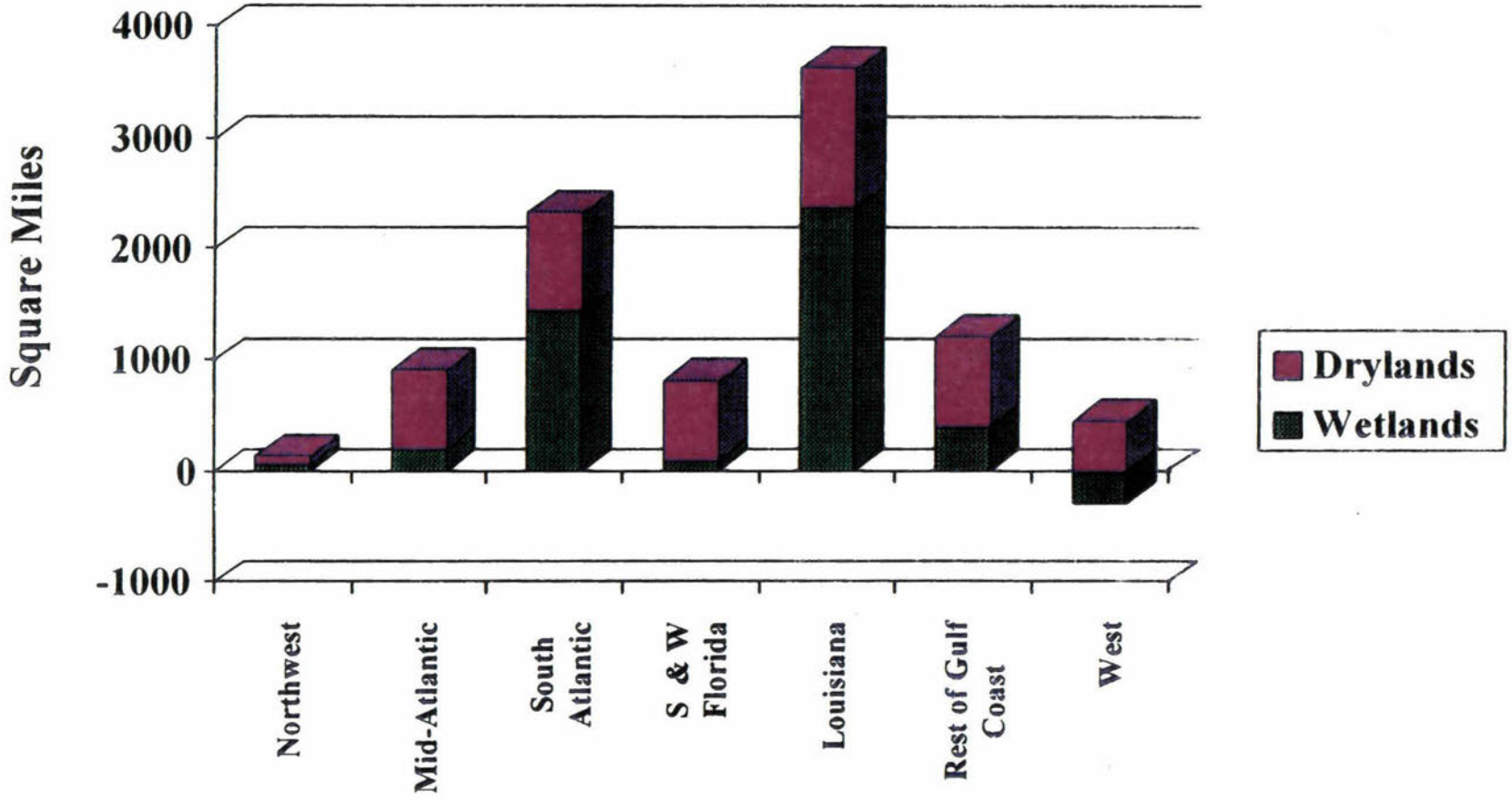


Detailed analysis of these data suggest that "since about 1970 precipitation has tended to remain above the twentieth century mean, averaging about 5% higher than the previous 70 years. Such an increase hints at a change in climate."

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

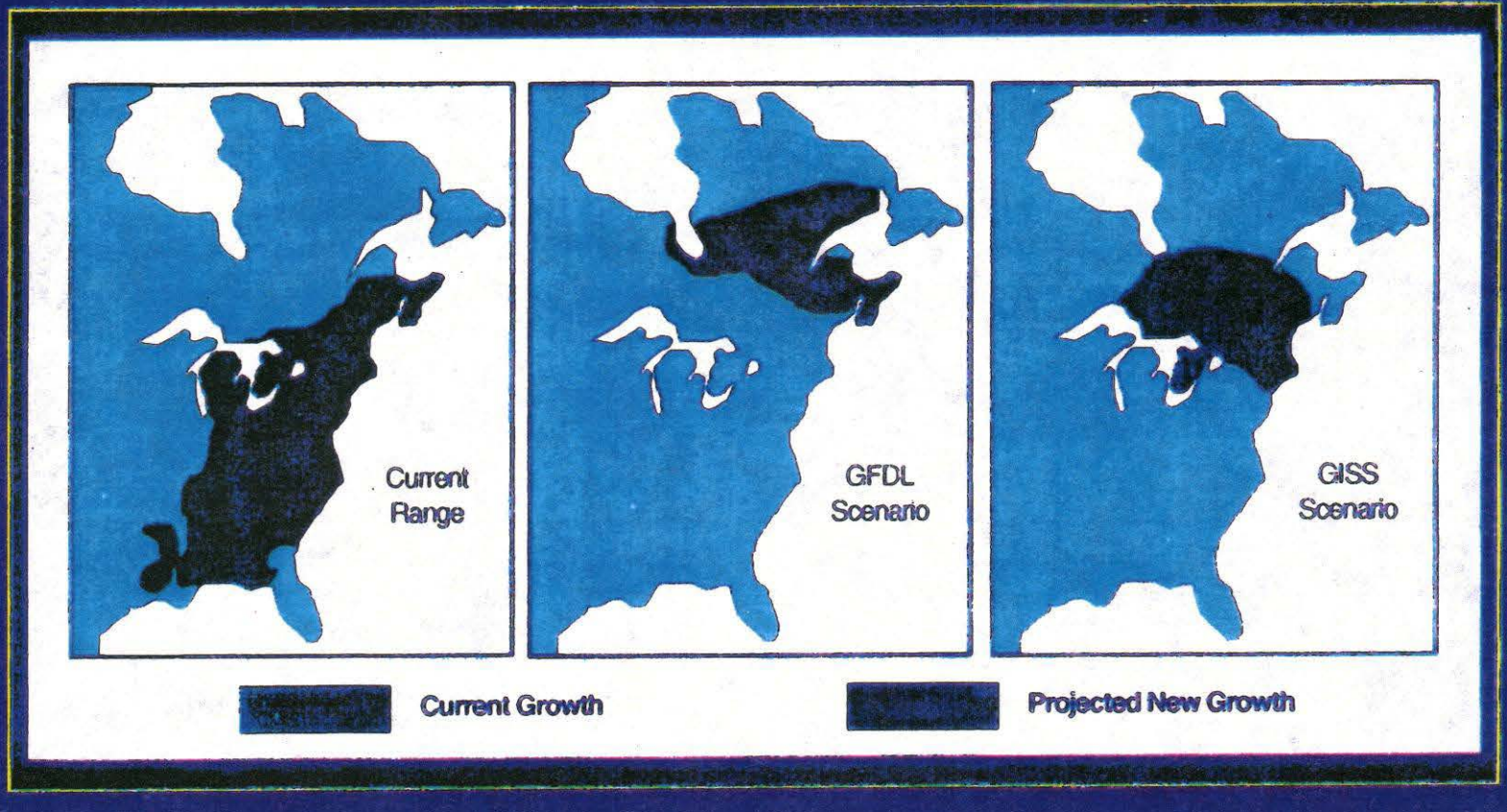

South Florida:
Shoreline Change after a 1-Meter Rise in Sea Level
Orlando
Tampa
St. Petersburg
Fort Pierce
West Palm Beach
Fort Myers
Fort Lauderdale
Miami
Key West
Areas shown in red are subject to inundation after a 1-meter rise in sea level
Source: Elevations from USGS digital data
Prepared by the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

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

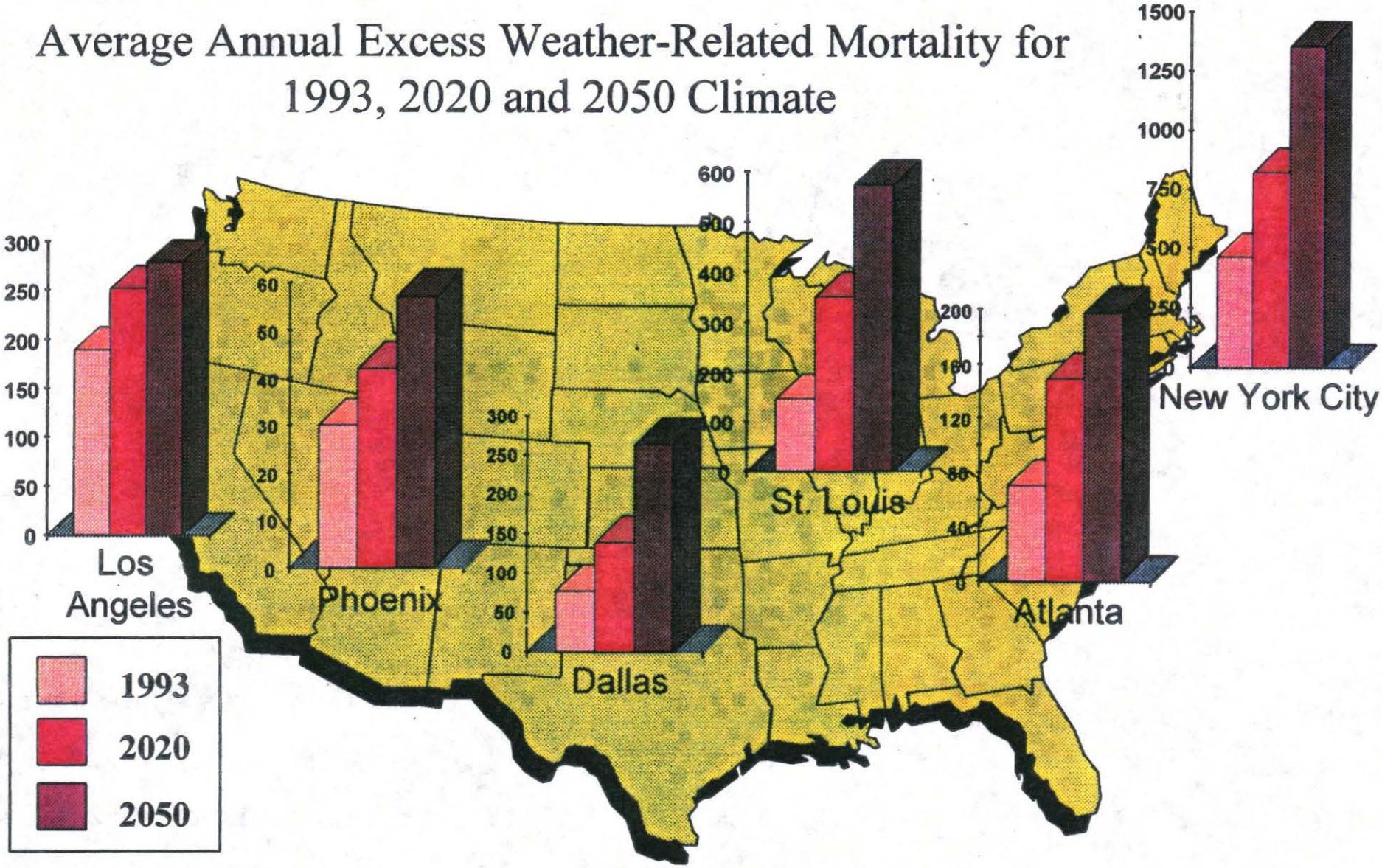


Source: U.S. EPA (1989)

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)

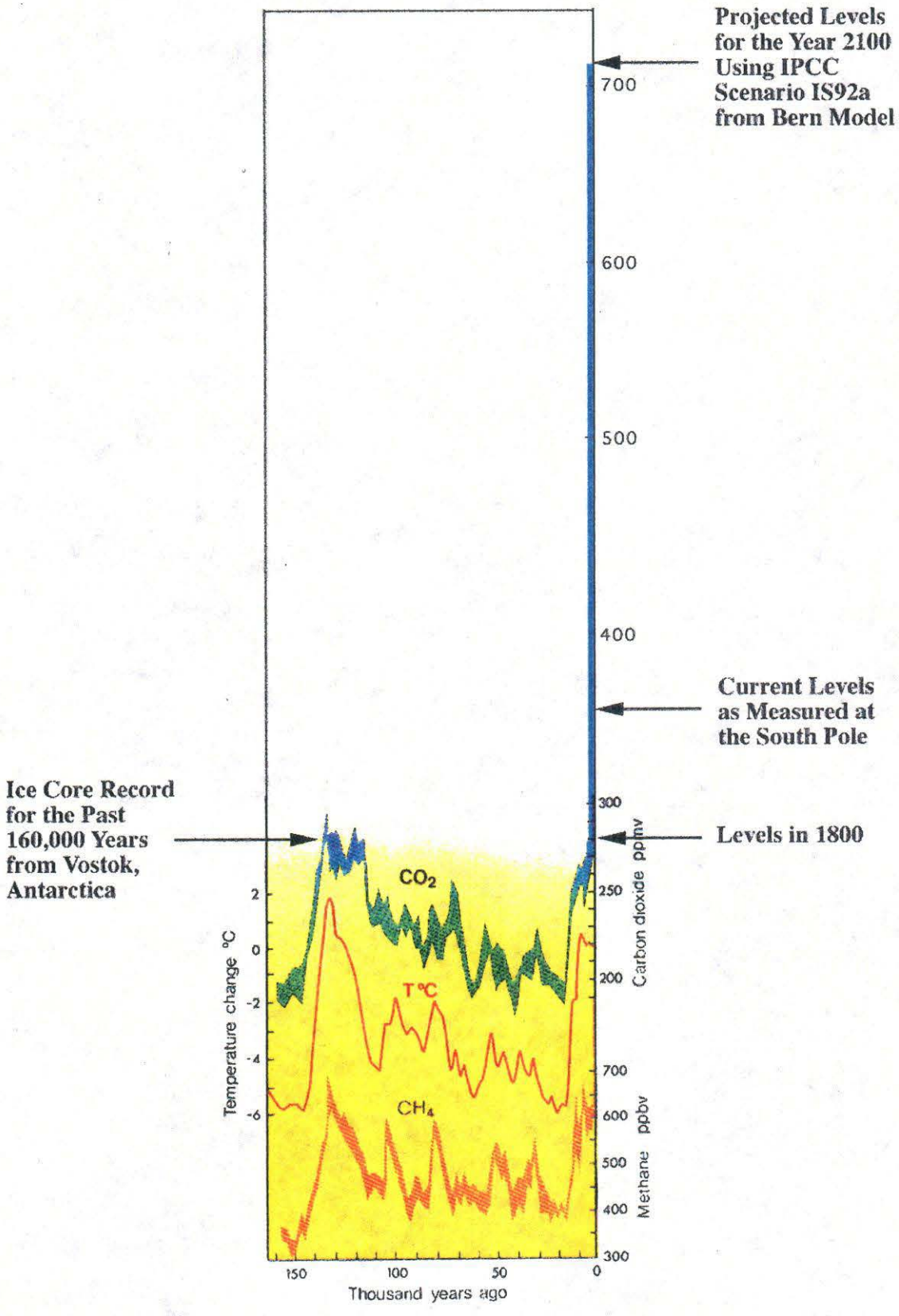
GFDL89 Climate Change Scenario

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

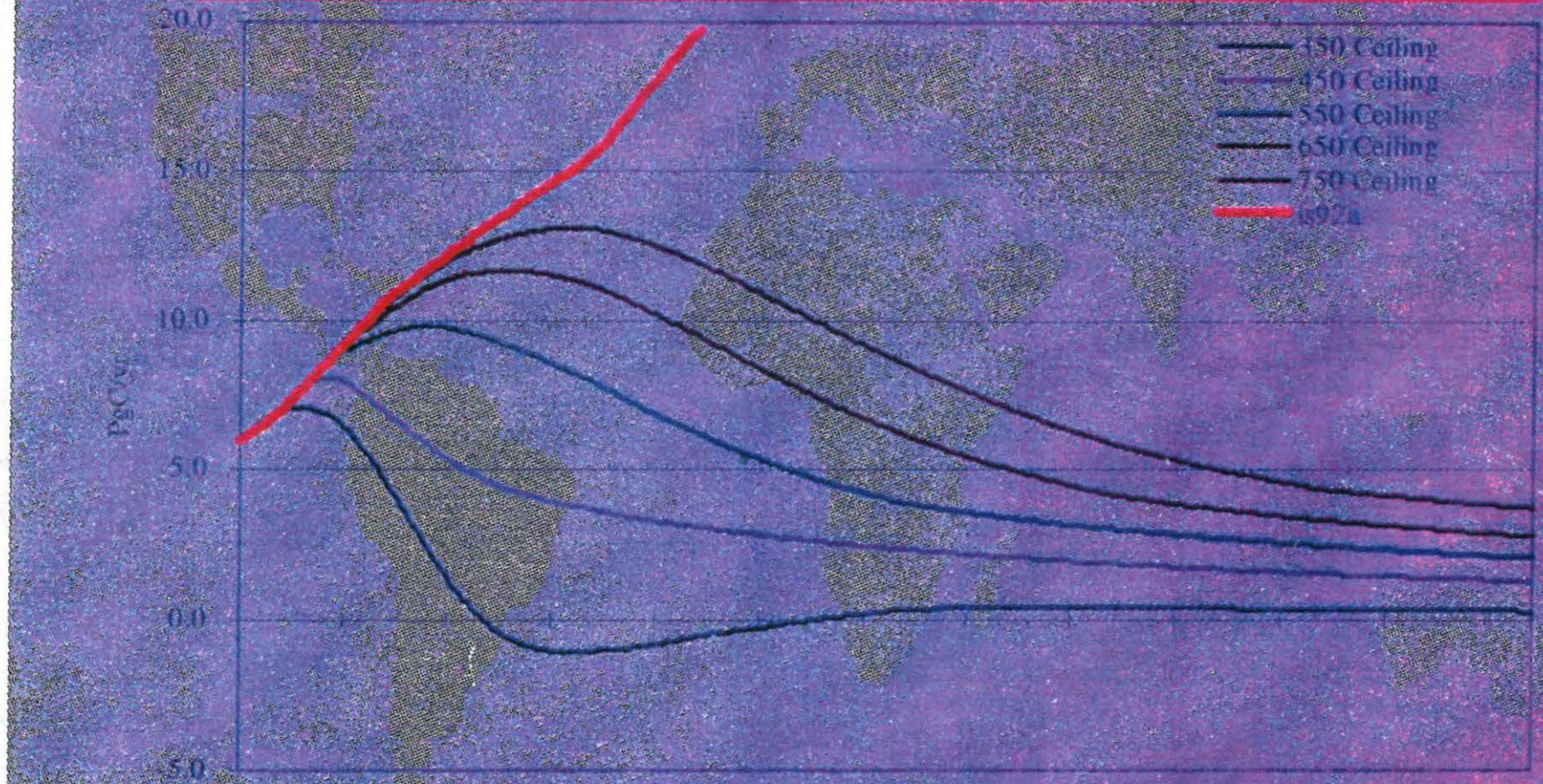
Atmospheric Carbon Dioxide Concentrations

-- Comparing Past Interglacial Ice Core Records with IPCC Projections for the Next 100 Years --

Source: "Radiative Forcing of Climate Change" Climate Change 1994, IPCC Record, Cambridge University Press, 1995

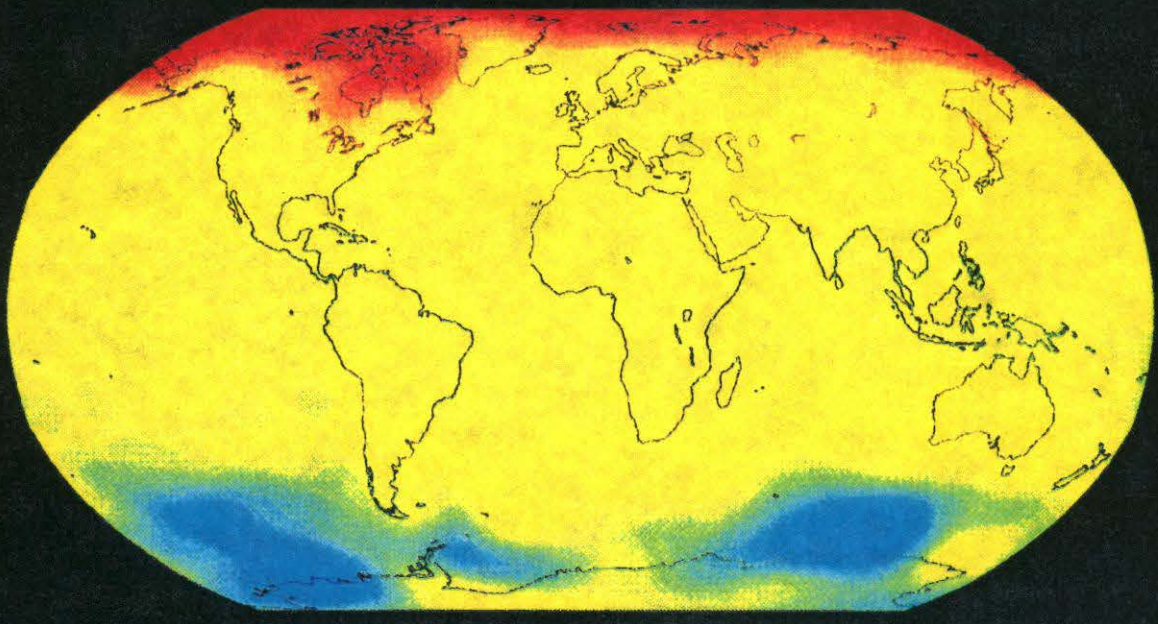


ATMOSPHERIC STABILIZATION EMISSIONS PATHS

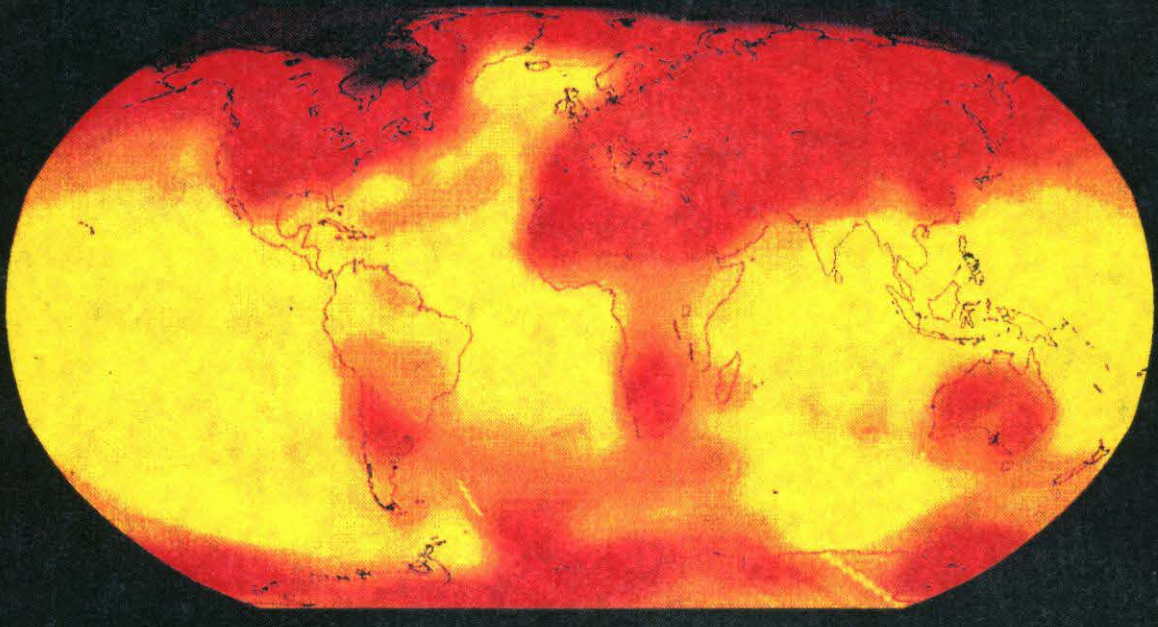


Surface Air Warming (°F)

$2 \times CO_2$



$4 \times CO_2$



Source: GFDL R15 Climate Model; CO_2 transient experiments, years 401–500.

Our Changing Planet

Major Categories of Impacts Identified by the IPCC

Human Health:

Potential for the spread of vector-borne diseases and heat-related health conditions;

Food Security:

Threats to some regions of the world, especially in the tropics and subtropics where many of the world's poorest people live;

Water Resources:

Likely to be increasingly stressed, leading to substantial economic, social, and environmental costs;

Human Habitat Loss:

Sea level rise likely to lead to impacts on small islands, across coastal plains, and in river areas; and

Natural Ecosystems:

Likely to shift as individual species respond to changes in climate. This may lead to reductions in biological diversity and in goods and services.

A Few of the Central IPCC Findings - 1996

The Earth's average surface temperature, assuming no major policy changes internationally, is projected by the IPCC scientific assessment to increase about 2° C above present by 2100 (with a range of 1° C to 3.5° C depending on scenario and uncertainty). This is a rate faster than for any similar period during the last 10,000 years.

Sea level is projected, by the IPCC, to rise by about 50 cm by 2100 (with a range from 15 to 95 cm) and to continue to rise significantly thereafter, even if greenhouse gas concentrations are stabilized.

Models are accounting, with greater accuracy, for the observed increases in the composition of the atmosphere and can simulate the recent history of observed changes in surface and vertical distributions of temperature. However, the ability to predict details of regional patterns and consequences of climate and global change remains relatively imprecise.

The IPCC concludes that "the balance of evidence suggests that there is a discernible human influence on global climate".

DRAFT SCIENCE PAPER

I. THE CLIMATE SYSTEM AND THE GREENHOUSE EFFECT

(DRAFT - NOT FOR QUOTATION OR ATTRIBUTION)

A natural greenhouse effect keeps the Earth about 60°F warmer than it otherwise would be. Without this greenhouse effect, life as we know it would not be possible. Water vapor, carbon dioxide (CO_2) and other trace gases, such as methane, nitrous oxide, and hydrofluorocarbons (HFCs), trap heat as it is re-radiated from the Earth back to space. Since pre-industrial times, human activities have added to the natural greenhouse effect by releasing greenhouse gases into the atmosphere. These emissions have led to a steady increase in the concentrations of greenhouse gases in the atmosphere (figure 1).

- The atmospheric concentration of carbon dioxide (CO_2) has increased by about 30%.
- Methane concentration has more than doubled.
- Nitrous oxide concentration has risen by 15%.

The burning of fossil fuels (coal, oil, and gas) for energy is the primary source of CO_2 emissions, accounting for about 85% of US annual totals; changing land-use patterns through agriculture and deforestation also contribute a significant share.

On a global scale, burning of fossil fuels releases about 6 billion metric tons of carbon into the atmosphere each year. Changing land use patterns from forestry and agriculture contribute about another 1-2 billion metric tons per year. Emissions of other greenhouses gases from a variety of industrial and agricultural processes effectively add about 20% to these totals.

Without intervention, the level of emissions and concentrations of greenhouse gases will continue to increase, resulting in a variety of global, regional and local effects. Global average temperature will rise, although there will be considerable variation of temperature increases on the regional scale. The Earth's water cycle will intensify, with an overall increase in evaporation and transpiration (water loss from plants), as well as precipitation -- both rain and snow. More precipitation will occur in "extreme" downpours, where large amounts of rain fall in a short period. Some areas will be threatened by increased flooding, while others will suffer through an increased incidence of drought as the interior of continents warms and dries. Sea level will rise, due primarily to the thermal expansion of the oceans and the melting and retreating of glaciers.

The Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) describes a series of changes that have already been observed:

- Over the last century, the global mean (average) surface temperature increased by about 0.5° - 1.0°F.
- Over the same period, global mean sea level has already risen 4 to 10 inches.
- Mountain glaciers have retreated world-wide this century.
- The surface temperature this century is as warm or warmer than any century since at least 1400 AD.

- The last few decades have been the warmest in this century, the ten warmest years this century have all occurred since 1980, and 1995 was the warmest on record.

A paper published in the April 17, 1997 issue of *Nature* (Mynemi, et al) presented compelling evidence of significant regional ecosystem response to warming experienced during the period 1981-1991:

- Over that 10 year period, high latitudes (between 45° and 70° North) sustained a longer growing season, and an advance of up to seven days in "greening" in spring and summer,
- These latitudes appear to be experiencing an increase of approximately 10% in photosynthetic activity, possibly due to the longer growing season and increased CO_2 fertilization.

Precipitation trends over the last century show that global precipitation has increased. Change can also be seen in United States precipitation trends. In the May 1997 issue of *Scientific American*, Tom Karl reviews the records of total rainfall and extreme rainfall for the United States over the last century:

- Total precipitation has increased by about 6 percent since the beginning of the century, as has the frequency of heavy downpours.
- Since the beginning of this century, these intense precipitation events have increased by about 20%. Such events lead to flooding, soil erosion and even loss of life.

Global warming, the global intensification of the water cycle, and the rise in sea level observed over the past century are all consistent with predictions from global climate change models. Estimates of future changes include: — i.e. absent policy changes, right?

- Global surface temperature is projected to increase an average of another 2-6° F by 2100, with significant variation by region. Temperature change of this magnitude would be faster than any observed changes in the last 10,000 years.
- Global mean sea level is projected to rise another 6 to 28 inches by the end of the next century.
- The rate of evaporation is expected to increase as the climate warms, leading to an increase in average global precipitation as well as frequency of intense rainfall and floods in some regions. In some regions, the soil moisture will decrease, leading to increased frequency and intensity of droughts.

Most of the climate impacts have been evaluated for a world at equilibrium after a doubling of greenhouse gases. But a doubled greenhouse gas world is one in which intervention has occurred. A continuation of business as usual implies a world with far higher concentrations and far greater effects. The Geophysical Fluid Dynamics Laboratory at Princeton has recently modeled the effects of doubling and quadrupling the level of greenhouse gases and compared the results:

but is this fantasy or plausible?

- A quadrupling of such concentrations is likely to increase temperatures in North America by 15 to 20° F, as opposed to the 2 - 6° F expected from doubling.
- In the growing season, soil moisture deficits would approach 30 - 50%, as opposed to 10 - 30 % for a doubling.

II. GLOBAL EMISSIONS & ATMOSPHERIC CONCENTRATIONS

(DRAFT - NOT FOR QUOTATION OR ATTRIBUTION)

Models have been used to project future emissions and atmospheric concentrations of CO_2 and other greenhouse gases. These models incorporate assumptions about future population growth, per capita energy demand, and changes in technology. In the most widely reviewed of these activities, the Intergovernmental Panel on Climate Change (IPCC) defined a "business-as-usual" case which assumed that technology continues to improve at historical rates. The IPCC business as usual simulations show that current annual emissions of 6 billion metric tons of carbon could grow to 15 billion tons per year by 2050 and 20 billion tons per year by the end of the next century. Carbon Dioxide is clearly the most important greenhouse gas.

Over the same period, human-related emissions of other greenhouse gases is also likely to increase. Despite the fact that their emissions are lower, these other gases play a significant role in greenhouse warming, adding about 20% to the effect of CO_2 alone. Methane has a much shorter atmospheric lifetime than CO_2, but is estimated to be 21 times more effective at trapping heat in the atmosphere over a 100-year period. Nitrous oxide is 320 times more powerful than CO_2 over a 100-year period. Some of the hydrofluorocarbons are thousands of times more powerful, and once emitted, effectively reside in the atmosphere permanently.

These large increases in emissions would lead to an increase in the atmospheric concentration of CO_2 and other greenhouse gases, and increase the radiative forcing (or warming potential) of the atmosphere. The IPCC business as usual scenario indicates that even with continued technological improvement, unless policies to control emissions greenhouse gases are implemented, the atmospheric concentrations of these gases will be much higher by 2100 (Figure 2):

- CO_2 concentrations would reach about 710 parts per million by volume (ppmv). i.e. doubling current levels absent policy changes
- Other gases will add at least 20% to this total on a carbon equivalent basis.
- For context, pre-industrial levels of CO_2 were about 280 ppmv, and have increased to the current level of about 360 ppmv.

Even if it were possible to freeze global emissions today, concentrations would nonetheless continue to rise throughout the next century and beyond, eventually exceeding a doubling of pre-industrial CO_2 levels. Freezing emissions, which continues to add greenhouse gases to the atmosphere at a constant rate, will not lead to a stabilization of atmospheric concentrations (Figure 3). ✓

Since the IPCC Second Assessment report was published in 1996, the relationship between annual emissions and stabilization of greenhouses gas concentrations in the atmosphere has been examined. Figure 3 shows the results of one analysis that tried to outline the optimal economic pathways (Wigley, Richels, Edmonds, *Science*, 1996) to meet atmospheric carbon concentration targets of 450 to 750 ppmv (for CO_2 only).

- Each target requires significant reductions in projected global carbon emissions; and all of them require dramatic reductions in annual emissions rates sometime during the next century .
- To achieve a 450 ppmv target – which represents a two-thirds increase in atmospheric concentrations over pre-industrial levels – reductions in the growth rate of worldwide annual emissions must begin by 2007, and emissions must fall to about half of current levels by 2100.
- To achieve a 550 ppmv target – which represents about a doubling in atmospheric CO_2 concentrations – reductions in the growth rate of worldwide annual emissions must begin by 2013, and overall emissions must begin declining steeply during the second quarter of the century.

If we look at emissions on a global scale:

- Of the 6 billion tons of carbon currently emitted each year, approximately 65% come from developed countries, and 35% from developing countries.
- The U.S. is currently the largest emitter of carbon dioxide, with China the second largest source.
- If current trends continue, developing countries will account for 50% of total global emissions by 2035, and China will have become the largest emitter (Figure 4).
- Because of the long-lived nature of these gases, the atmospheric reservoir of carbon in 2100 will remain dominated by decades of emissions from the developed world .

If emissions are examined on a per capita basis, there is a dramatic difference between the developed countries and the developing world. Despite substantial growth in total emissions from developing countries, per capita differences between Annex I and non-Annex I countries would remain large under a business as usual scenario.

- On a per person basis, the U.S. currently emits about 5 tons of carbon per person, compared to an average of approximately 3 tons per person in Japan and Western Europe, and 0.4 tons per person in developing countries.
- If current trends continue, in the year 2100 developing countries would be emitting slightly more than 1 ton of carbon dioxide per person each year whereas the developed world would be emitting close to 5 tons per year for each individual.
- If the world wanted to keep CO_2 from exceeding a doubling, per capita emissions would have to approach .5 tons per person per year.

III. VULNERABILITIES TO AND IMPACTS OF CLIMATE CHANGE

Although there is scientific uncertainty about exactly how and when the Earth's climate will respond to increased concentrations of greenhouse gases in the future, observations clearly show that detectable changes are underway and that ecological systems are responding to these changes. Numerous efforts are underway to assess the vulnerability of ecological, social and economic systems to future changes by defining plausible future scenarios of climate change and using model simulations to evaluate sensitivities to various levels and types of change.

An extensive body of research suggests that human health and ecological systems are vulnerable to climate change. The human-induced climate changes that are expected will add important new stresses on ecological and socio-economic systems that are already affected by pollution, increasing resource extraction, and non-sustainable management practices. The magnitude of climate change impacts will be determined by the degree of vulnerability, and the amount and rate of change that is experienced in addition to existing stresses.

Most estimates of the effects of climate change are those associated with a doubling of the pre-industrial concentration of carbon dioxide to approximately 550 ppmv, or an increase in all greenhouse gas concentrations that together would have an equivalent capacity to trap heat. These analyses also assume that the sensitivity of the climate system itself to this change falls in the middle of the range outlined by the IPCC. If the actual sensitivity is lower than projected, impacts will be less; if it is higher, impacts will be more severe than described here.

The climatic changes that would result from an equivalent doubling of carbon dioxide would have pervasive effects, some of them irreversible, on ecological systems, human health, and socio-economic sectors. A lower atmospheric concentration could result in less severe impacts, while a higher concentration would likely have more severe impacts. The following sections describe a range of climate change vulnerabilities and predicted impacts of a doubling of the atmospheric concentrations of greenhouse gases.

of pre-industrial ?

Health Effects

According to the World Health Organization, the vulnerability of human populations to climate change varies across populations depending on environmental circumstances, social resources, and preexisting health status. In general, developing countries are more vulnerable to climate change than developed countries because of their limited capital and their greater dependence on natural resources. The elderly and children are the most vulnerable segments of the population. Climate change increases the risk of heat-related mortality and the potential for the spread of vector-borne diseases, such as malaria, dengue and yellow fever, and encephalitis, and non-vector borne diseases such as cholera and salmonellosis. The incidence of infectious diseases, which are still the world's leading cause of fatalities, may also increase .

- A study of deaths associated with summer time heat stress and winter time illnesses in 44 US cities estimated that climate change could double the number of weather related deaths (See Figure 6). The elderly are at greatest risk in the US and urban populations in developing countries are also especially vulnerable to heat stress.
- Climate change is likely to extend the geographic ranges of disease-carrying vectors such as mosquitoes, which can increase the populations exposed to diseases such as malaria, dengue and yellow fever. Globally, the population potentially exposed to malaria could increase by one-third, with a possibility of 50-80 million additional malaria cases per year.
- Climate change can reduce air quality and increase levels of air borne pollen and spores which exacerbate respiratory disease, asthma, and allergic disorders.

Water Resources

Among the most fundamental effects of climate change is an intensification of the hydrological cycle. Changes in precipitation, and increased evaporation and transpiration due to higher temperatures, can be expected to reduce water runoff, affecting the quantity and quality of water supplies for domestic and industrial uses, irrigation, hydropower generation, navigation, stream ecosystems and water based recreation. These affects will vary region by region. Increased variability in the hydrologic cycle is expected to result in more severe droughts and/or floods in some places but less severe in others. Impacts and mitigation expenses for such events are significant; damage estimates from the Mississippi flood of 1993 range from $10 billion to $20 billion. Areas of greatest vulnerability are those where water supplies and quality are already problems, such as arid and semi-arid regions of the world and some low lying coastal areas, deltas and small islands.

- Climate change would likely add to the stress in several US river basins, such as the Great Basin, California, Missouri, Arkansas, Texas Gulf, Rio Grande, and Lower Colorado.
- The Colorado River Basin would suffer decreased summer runoff, coinciding with peak demand for irrigation, unless precipitation also increases substantially. Reductions in runoff of up to 25 percent in the basin are projected under some scenarios of doubled CO_2 equivalent climate change.
- Runoff losses of this magnitude in water short regions such as the Colorado River basin are likely to adversely affect water deliveries, exacerbate salinity problems, reduce hydropower generation, and reduce water storage in reservoirs.
- Water scarcity in Middle Eastern and African countries also is likely to be exacerbated by climate change. Countries which are highly dependent on water originating in areas outside their borders include Syria, Sudan, Egypt and Iraq.

Forests

One-third of the Earth's forests would undergo a major change in the type of vegetation that could be supported as a result of an equivalent doubling of CO_2. In northern forests, which are the forests most vulnerable to climate change, two-thirds of the currently forested area may undergo a change in vegetation type. Climate change can dramatically alter the geographic distributions of individual tree species and of forest and vegetation types (Figure 7). Mountain-top species and isolated populations are particularly vulnerable (Figure 8)

Over the next century, the ideal range for some North American forest species will shift by as much as 300 miles to the north, exceeding the ability of forests and other ecological communities to migrate. In some instances, a change in vegetation type will result in a loss of forest area as the land converts to grassland or shrubland (Figure 8).

- Globally, forested areas may decline 10 percent after forests reach a new equilibrium under a new doubled CO_2 climate.
- In the United States, western conifer forests could decrease in area and be replaced by broadleaf forests; eastern hardwood forests may be replaced by grasslands along their western boundary because of mid-continental drying. Forest damage from fire and diebacks driven by drought, insects and disease could increase.

Other Natural Areas

Natural ecosystems are highly vulnerable to degradation from climate change. Federally protected natural areas have become a repository for the Nation's rarest species and are critical for the conservation of biological diversity. Nearly $3 billion is spent annually to manage, maintain, restore, and protect these lands. Climate change may threaten this substantial national investment. The composition, geographic distribution, and productivity of many ecosystems will shift as individual species respond to changes in climate. This will likely lead to reductions in biological diversity and in the goods and services ecosystems provide for society, such as clean water and recreation. Freshwater wetlands are particularly at risk from climate change. IPCC findings show that:

- Precipitation changes and salt water intrusion from sea level rise could adversely affect the ecological communities of the Florida Everglades and degrade the habitat for many species of wading birds.
- The wetlands of the prairie pothole region of North America, which support half the waterfowl population of this continent, could diminish in area and change dramatically in character in response to climate change.

Coastal Areas

Even if concentrations of greenhouse gases are stabilized in the future, sea level would continue to rise long after, perhaps for several centuries, and reach levels much higher than projected for the next 100 years. For example, after an equivalent doubling of CO_2, the IPCC expects sea level to rise by 15 - 95 cm over the next century, with a "best estimate" of 50 cm, but the equilibrium sea level rise several centuries in the future is estimated to be at least 2 meters. Rising sea level erodes beaches and coastal wetlands, causes the gradual inundation of low lying areas, leading to human habitat loss and increasing the vulnerability of coastal areas to flooding from storm surges and intense rainfall. The IPCC estimates that 50 cm of sea level rise would double the population at risk from storm surges, from roughly 45 million at present to over 90 million world-wide. A one meter rise would triple the number of people exposed. Increases in coastal area populations are likely to further increase the number of people at risk.

- Along US coasts, a 50 cm rise could inundate more than 5000 square miles of dry land, and an additional 4000 square miles of wetlands if not protective measures are taken. A 1 meter rise would have greater impact. Figure 9 illustrates the effect of a 1 meter rise on Florida.
- Internationally, low-lying areas, such as parts of the Maldives and Bangladesh, would be completely inundated by a 1 meter sea level rise, creating large numbers of environmental refugees which put stress on governments and social structures.
- A 1 meter sea level rise would affect 72 million people in China, assuming existing levels of coastal development.

what protective measures? don't best measure over a danger if there's an easy answer [eg. inundate unless build barriers]

Agriculture and Food Supply

Agriculture is highly dependent on a number of variables that are likely to be affected by climate change, including weather patterns, longer term patterns of climate variability, and, most importantly, water availability. Climate strongly affects crop yields. Doubling of equivalent CO_2 are likely to lead to increased crop yields in many areas, but decreased yields in others, even for the same crop. The magnitude of these changes can exceed +/- 30 or 40 percent for some crops and locations.

Despite these potentially large changes in yields, average global food production is not expected to change substantially. This is because farming practices are considered to be highly adaptable to different climates, because production of important food crops can shift to new locations in response to changes in climate, and because CO_2 has beneficial effects for plant photosynthesis and water use efficiency that can offset some deleterious effects of changes in climate. Impacts are likely to vary considerably across regions and some regions may suffer substantial reductions in agricultural production.

- Large reductions in soil moisture could significantly reduce flexibility in crop distribution and increase demands on water resources infrastructure.

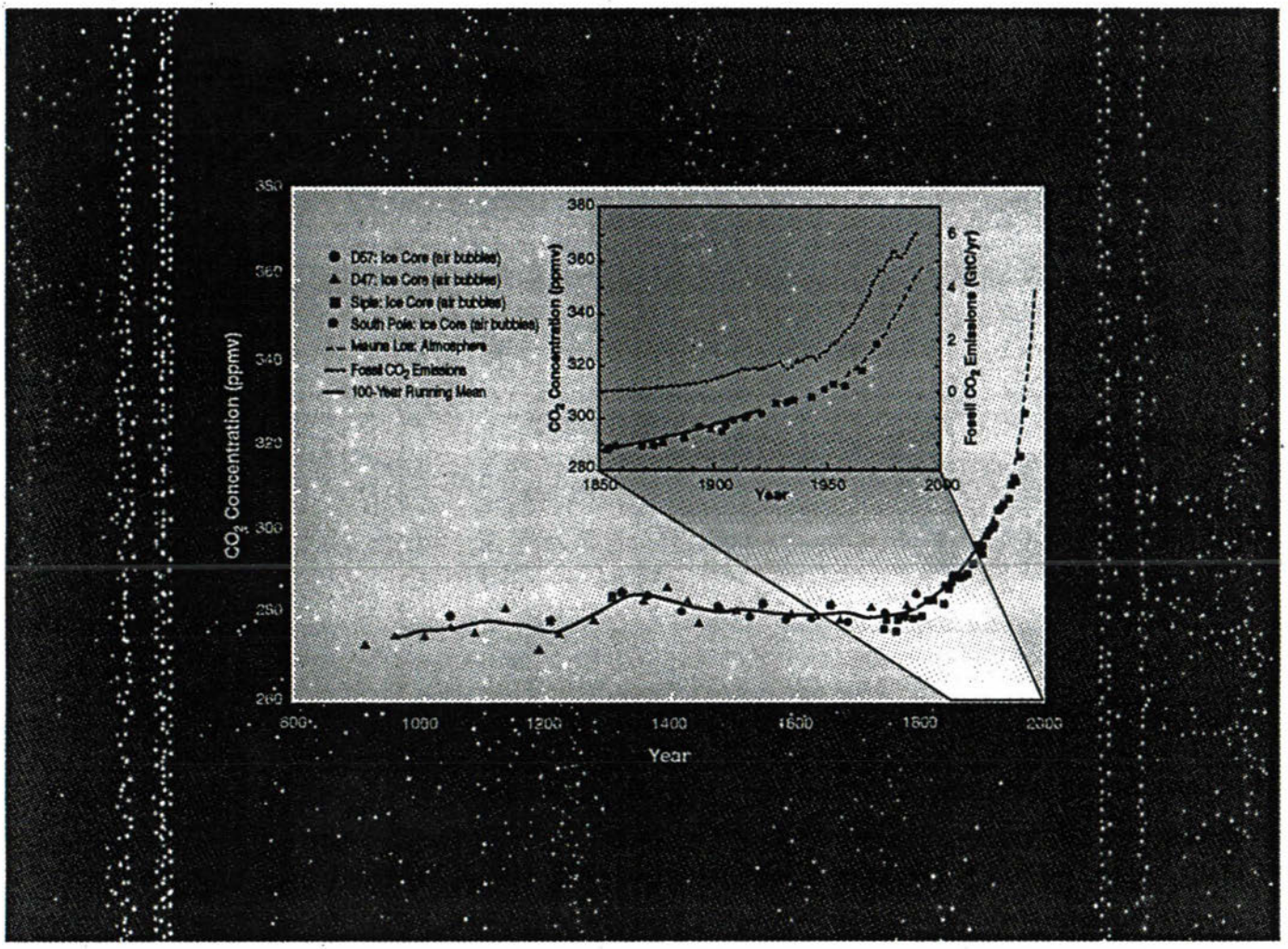
- Increases in the range of pest habitat could increase vulnerabilities to pests and demand for, and use of, pesticides.
- In the United States, large areas of the eastern and central regions of the country face moderate to severe drying. Drought could become more frequent, particularly in the great plains.
- Developing countries are more vulnerable to losses than are developed countries (See Figure 10).

Conclusion

The ultimate aim of the Framework Convention on Climate Change is "... stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to: (i) allow ecosystems to adapt naturally to climate change; (ii) ensure that food production is not threatened; and (iii) enable economic development to proceed in a sustainable manner."

The rates of change already imposed on the climate system are the faster than any experienced during 10,000 years, during which modern civilization has developed. Current emissions trajectories, if not altered, could take us to an atmospheric concentration of CO_2 not seen on this planet during the last 50 million years. While much work remains to be done to improve the precision of impacts estimates, the increasingly apparent risk of the rapidly changing atmosphere argues that mitigation and adaptation measures are warranted.

Rising Concentrations of Carbon Dioxide in the Atmosphere



Global CO_2 Emissions and Concentrations (placeholder figure)

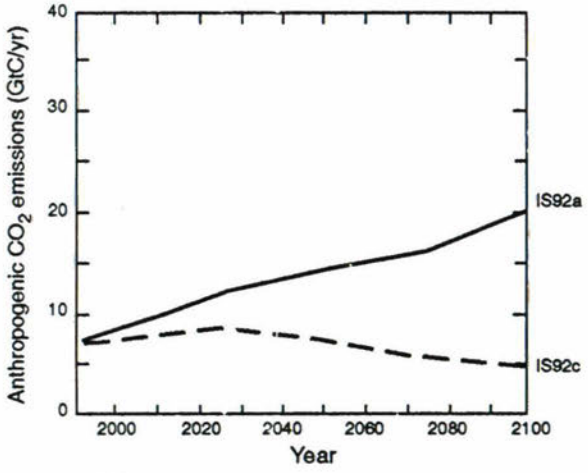


Figure 1

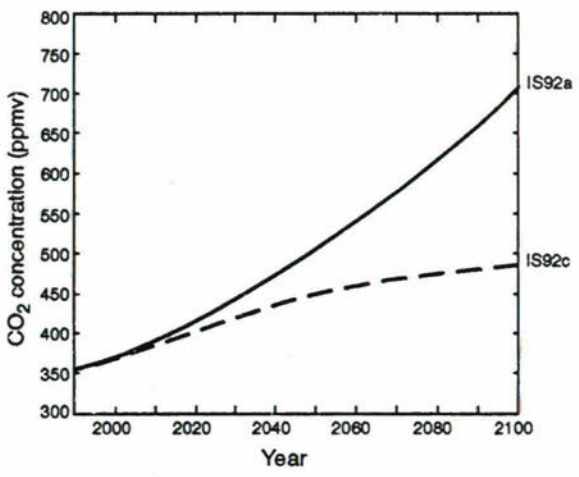


Figure 2

Energy emission pathways and stabilization concentrations

Steady-State Concentration →	450 ppm	550 ppm	650 ppm	750 ppm
Deflection Date BAU [a]	2007	2013	2018	2023
Maximum Emission Date	2011	2033	2049	2062
Maximum Emission [b]	8.0	9.7	11.4	12.5

[a] The deflection date is the year in which emissions in the emissions stabilization trajectory first fall below BAU emissions by more than 0.1 PgC/yr.

[b] MaximumPgC/yr fossil fuel carbon emissions. If other greenhouse gases are included, emissions would be effectively 20% higher; thus, reductions would have to occur sooner than the deflection date noted to achieve a given concentration.

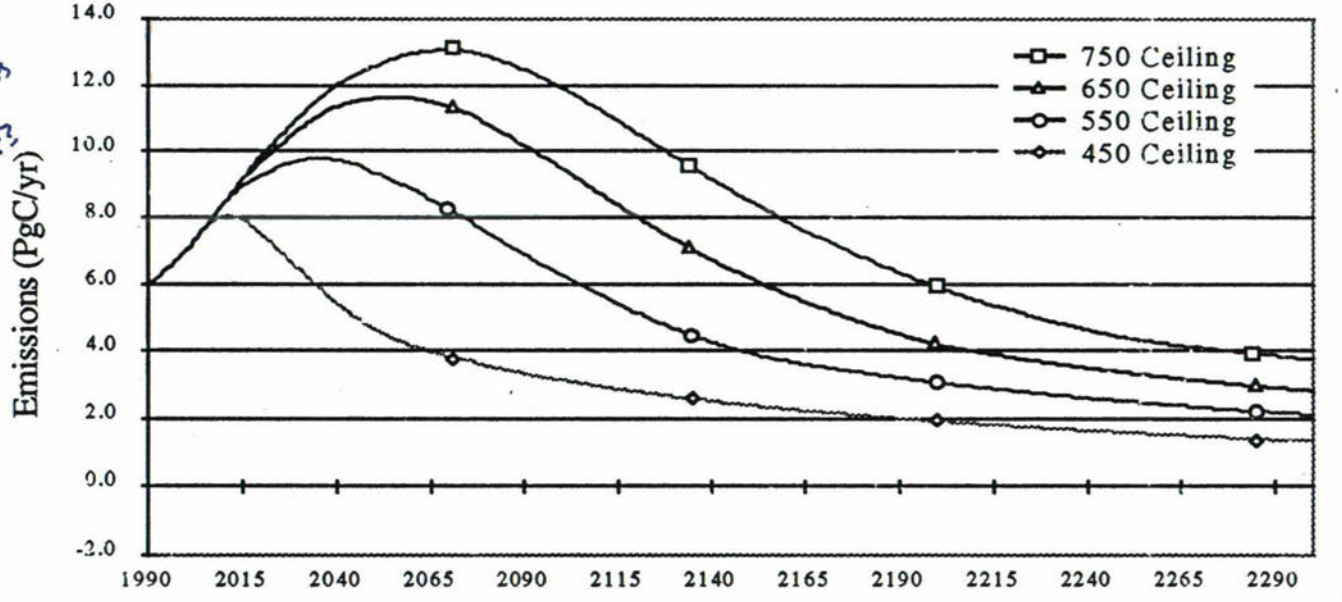


Figure 3

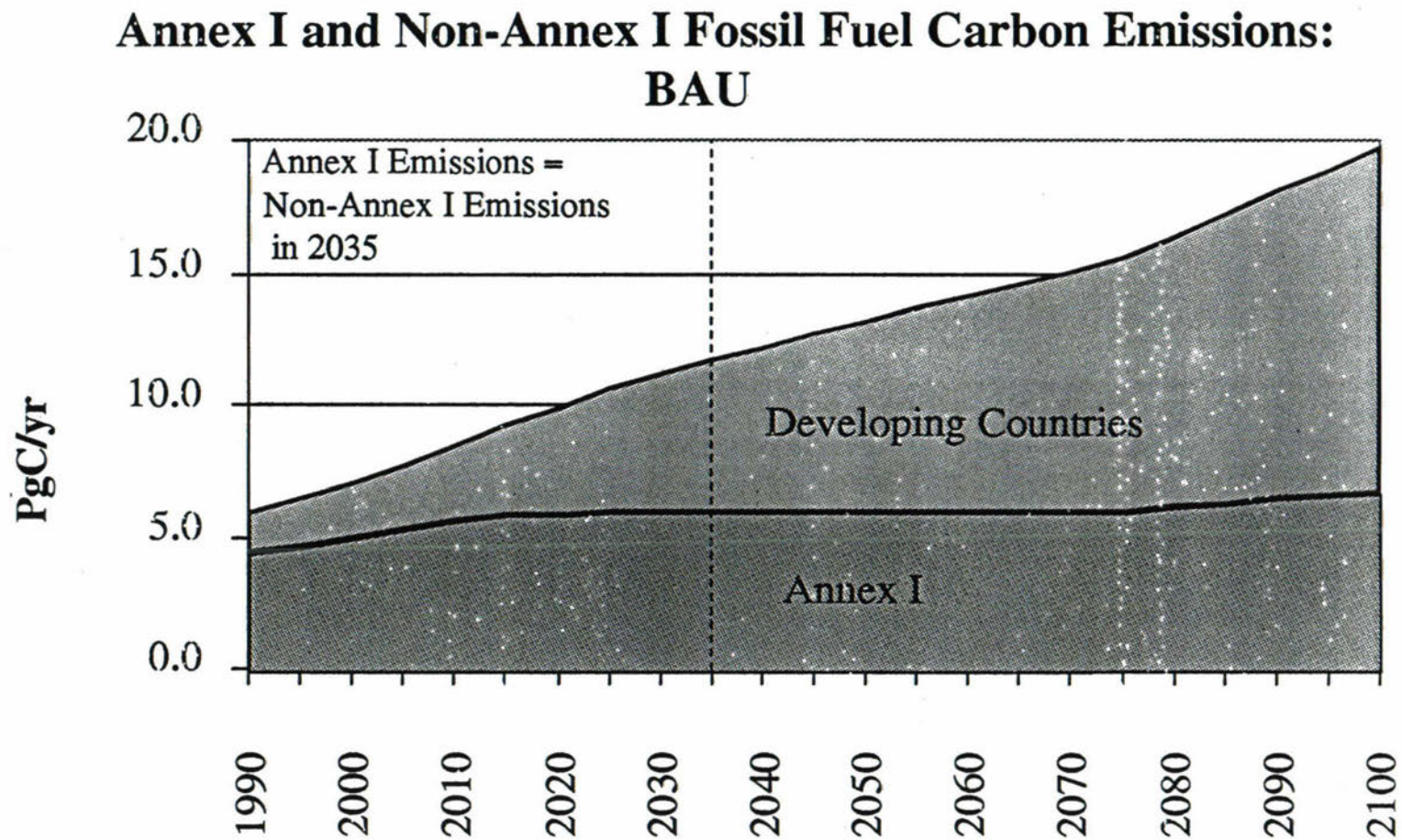

Annex I and Non-Annex I Fossil Fuel Carbon Emissions:
BAU
PgC/yr
20.0
15.0
10.0
5.0
0.0
Annex I Emissions =
Non-Annex I Emissions
in 2035
Developing Countries
Annex I
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

Figure 4

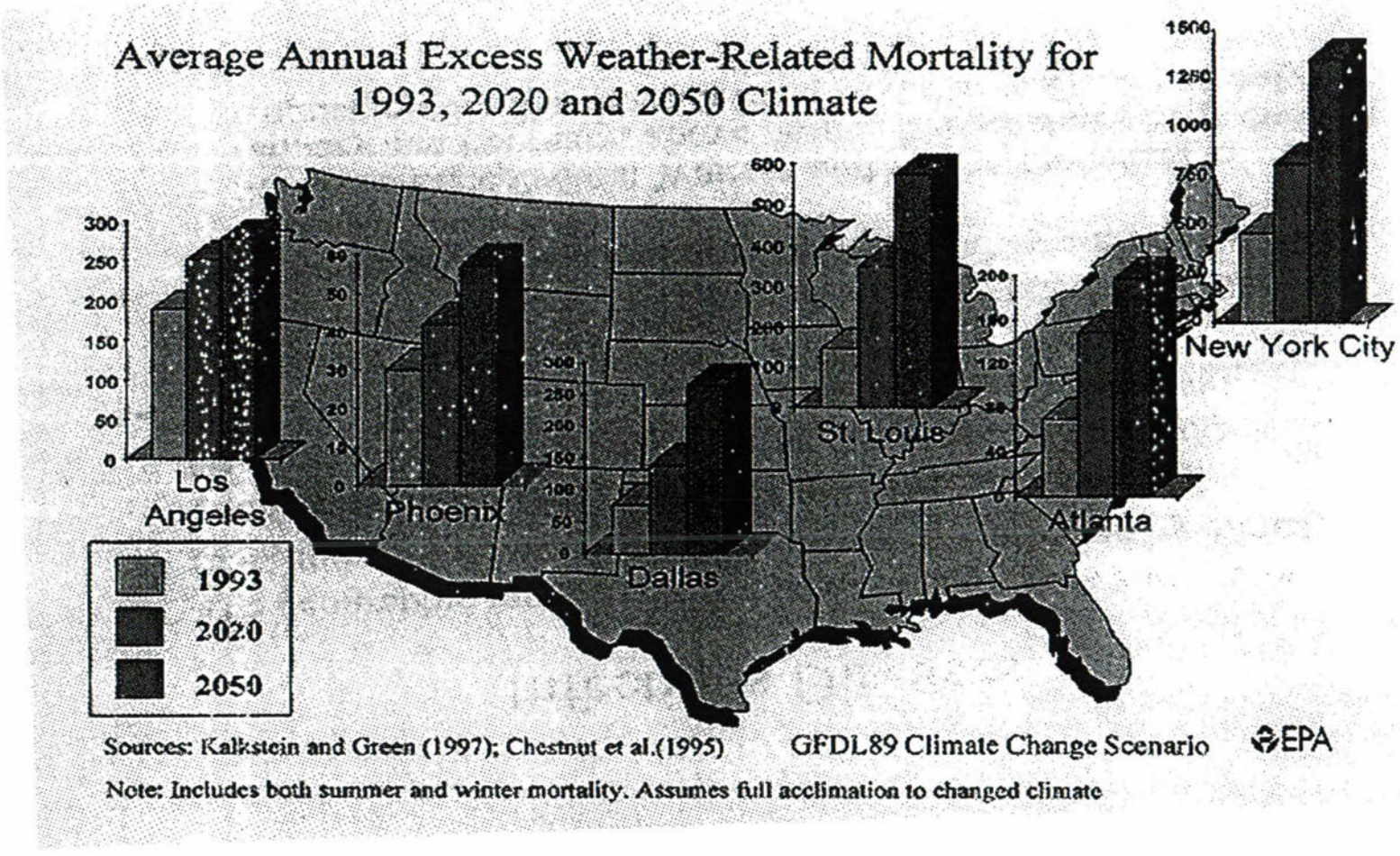

Average Annual Excess Weather-Related Mortality for
1993, 2020 and 2050 Climate
Los Angeles
Phoenix
Dallas
St. Louis
Atlanta
New York City
1993
2020
2050
Sources: Kalkstein and Green (1997); Chestnut et al.(1995)
GFDL89 Climate Change Scenario
EPA
Note: Includes both summer and winter mortality. Assumes full acclimation to changed climate

Figure 5

Projected Shifts of Sugar Maple Range

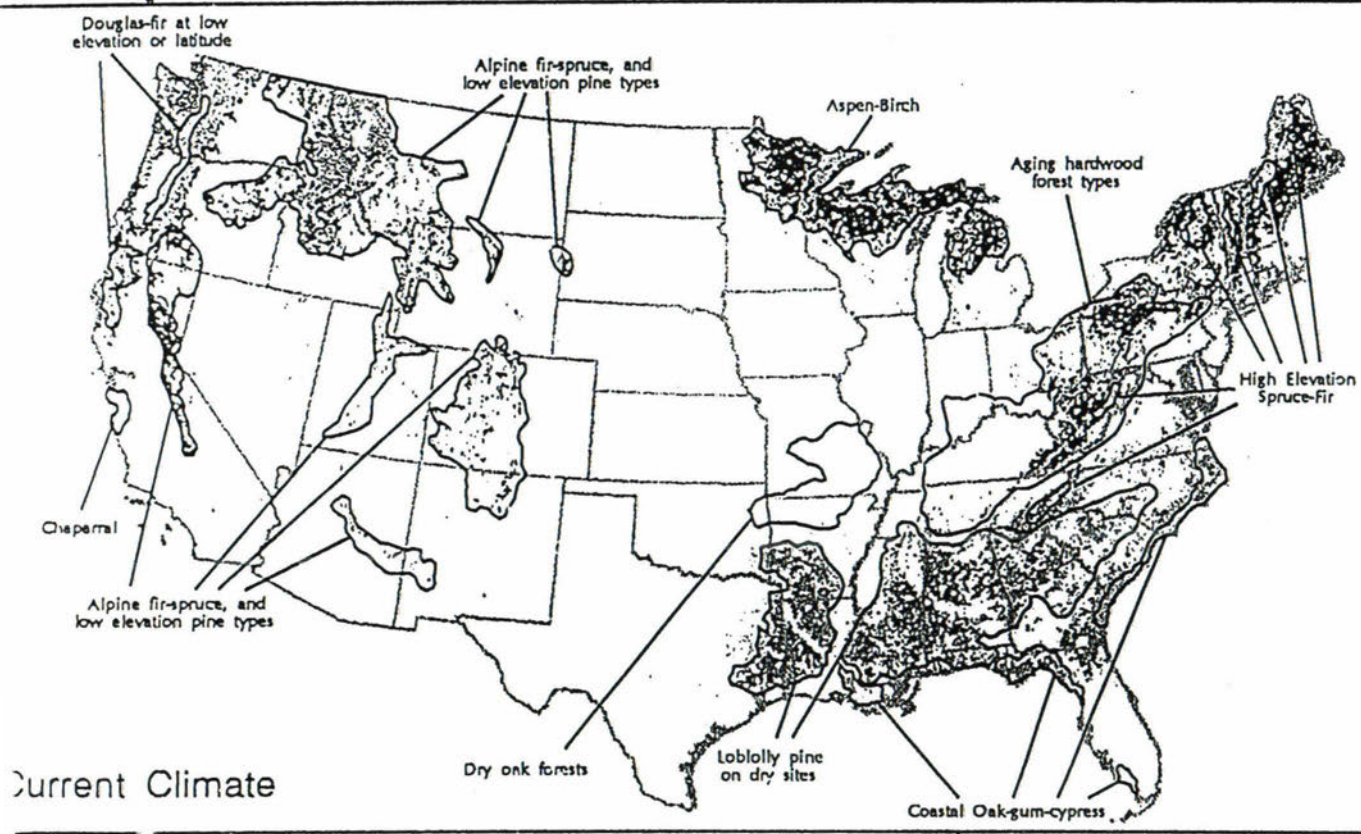
Present and future geographical range for sugar maple. A: Present range (from Fowells, 1965). B: 2XCO2 climate-space in 2090 A.D. under the GISS scenario. Black area is the predicted species range; stippled area is potential range. C: 2XCO2 climate-space in 2090 A.D. under the GFDL scenario. Black area is the predicted species range, stippled area is potential range.

Source: USEPA, 1989

Figure 6

Figure 7

Examples of Forest Types that are Vulnerable to Climate Change



Current Climate

MAPSS Forest Cover

Eastern Forests
- Spruce-fir
- NE Mixed Forest
- NE Mixed Woodland
- Oak-Hickory Forest
- SE Mixed Forest
- SE Mixed Woodland

Tropical Forests
- Dry Tropical Forest
- Moist Tropical Forest

Western Forests
- Douglas Fir & Larch
- Coastal Moist Forest
- Western Pines
- Western Hardwoods
- Western Fir-Spruce

Only parts of the forest within each selected area are vulnerable. In the climate change scenario, forest is not allowed to migrate into current nonforest areas. Base maps from Neilson (1997). Overlay graphics by Birdsey and Holt (USDA Forest Service).

FIGURE 5

Potential South Florida Inundation from 1 meter Rise in Sea level

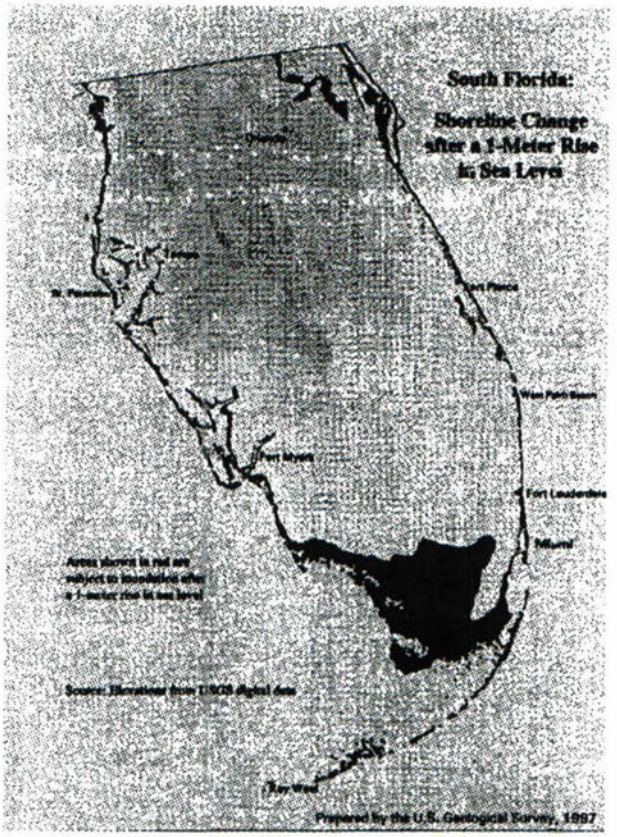


Figure 8

Regional Variation of Estimated Changes in Average Wheat Yields in GISS Doubled CO_2 Scenario

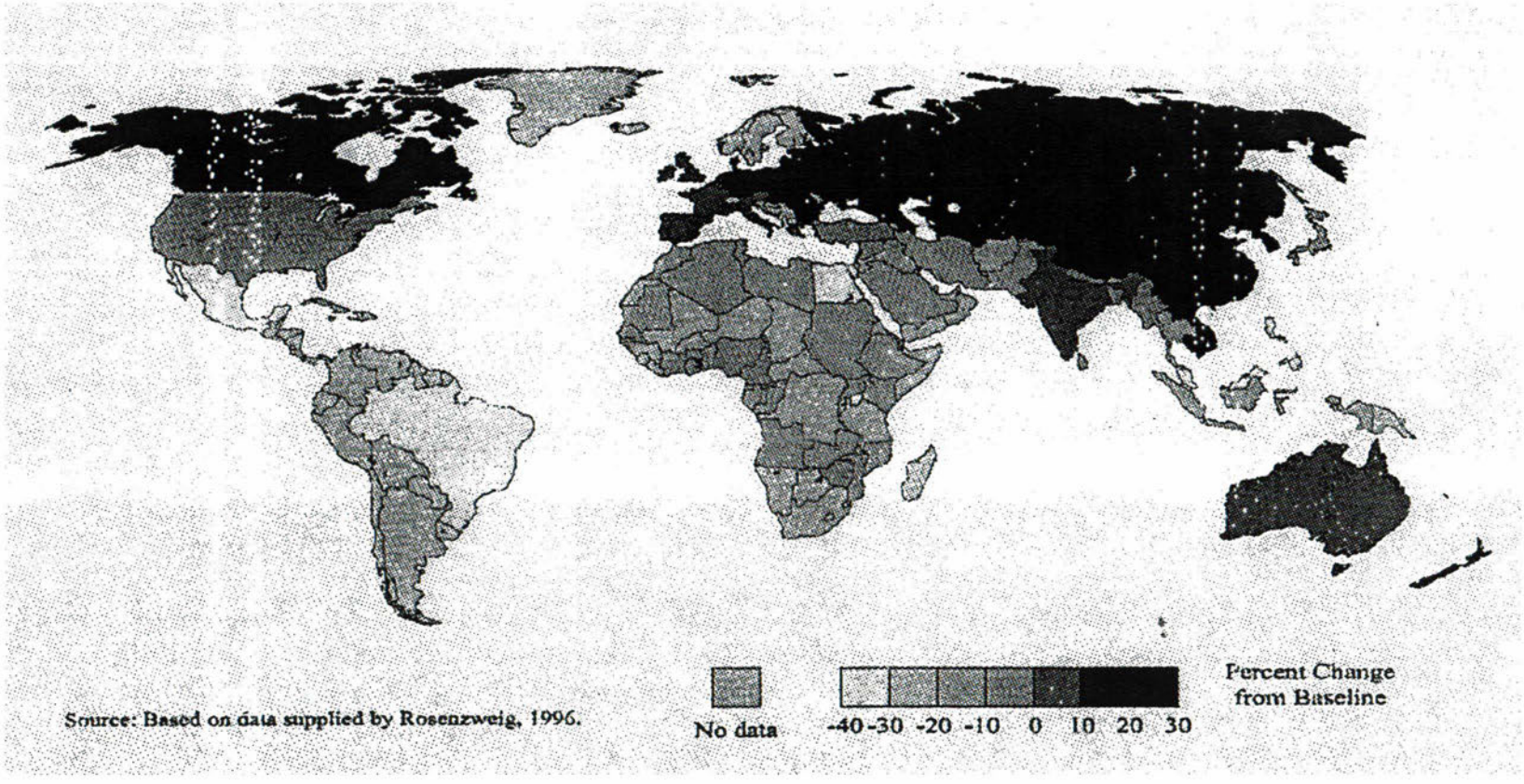


Figure 9

Clinton Presidential Records
Digital Records Marker

This is not a presidential record. This is used as an administrative marker by the William J. Clinton Presidential Library Staff.

This marker identifies the place of a tabbed divider. Given our digitization capabilities, we are sometimes unable to adequately scan such dividers. The title from the original document is indicated below.

Divider Title: **III. Policy**

Policy Options for Controlling Emissions

Ideally, a domestic program for controlling emissions would ensure that specified emission goals are achieved, while granting the private sector the flexibility to invest in response strategies that achieve emission reductions at the least cost. In addition, a response strategy should exploit the vast market on the horizon for advanced technologies -- be they for energy efficiency, renewables, natural gas, or other low greenhouse gas technologies. And finally, a control program should be fair, minimizing adverse effects on workers while ensuring a viable economic future for any worker losing employment because of the changes brought about by the action taken to mitigate climate change. This chapter analyzes the following:

- An Emissions Trading Program for Greenhouse Gas Emissions: This program involves the creation of emission permits for those emitting greenhouse gases. These permits would be allocated to emission sources either by formulae or through an auction. Once allocated, they could be traded in the marketplace. An important characteristic of emission trading is that no matter what the initial permit allocation, the final allocation after trading will be the one that minimizes the cost of reducing emissions. In addition to emission trading, other government interventions, such as energy efficiency standards that overcome other market failures, may be appropriate.

- Technology Research and Development (RD&D) and Diffusion. RD&D can reduce costs in all periods. However, it is particularly important in the long term, since controlling warming ultimately requires adopting an energy system that does not rely primarily on fossil fuels. This would involve stepping up and refocusing the federal government's R&D program and reversing the long-term trend of declining government and private R&D expenditures.

- Economic Transition Programs. A successful greenhouse gas control policy could have important implications for the level and pattern of energy usage in the economy. Usage of high carbon fossil fuels (e.g. coal) will decline, while the demand for other energy sources (e.g. natural gas or renewables) will grow in importance. A transition program would reduce the costs to individuals and communities associated with this environmental policy. Transition assistance can help facilitate community and worker adjustments via retraining, job search assistance, and infrastructure development for new business in the community.

Greenhouse Gas Emissions Trading Programs

Emissions trading involves allocating or auctioning emissions allowances, and allowing the trading of allowances in a market with sufficient mechanisms to ensure compliance with targeted levels and the integrity of the trading system. Emission trading creates new, marketable assets that can have substantial value, so distributional issues will be an important component of program design. Allocation designs or auction revenues can be used to address these distributional issues.

Emission trading systems offer both static and dynamic efficiency advantages over more traditional forms of regulation. Emitters face different abatement costs, so emissions trading

allows those with high abatement costs to purchase allowances from those whose costs are lower. Total costs will therefore be lower than through traditional regulations which require all polluters to comply with a specific standard. Nevertheless, emissions trading still involves people and firms adjusting to higher energy prices.

Under traditional regulation, firms have little incentive to investigate ways of abating pollution by more than the minimum required to comply with regulatory requirements. As a result, firms under-invest in pollution control R&D. Emissions trading offers dynamic efficiency gains because it creates incentives to continuously improve pollution abatement technologies in order to create "surplus" allowances for sale.

An emissions trading-based policy can capture the same efficiency benefits as a system of emission taxes (an alternative the Administration is not considering), with two further advantages. First, by setting overall quantity targets, emissions trading programs offer greater certainty that national emission targets will be achieved. Under an emissions tax system, total emissions would be the net result of decisions by individual polluters in response to the tax, and would not necessarily stay within a U.S. emissions cap1. Second, under an allowance system, the government has greater flexibility in deciding whether to collect revenues. It can auction permits, allocate them based on historical emissions, or undertake some combination of the two. This flexibility can affect the public acceptance of the mitigation program. Emission tax systems always involve revenues accruing to the government (although they can be rebated).

US Experience with Emissions Trading

The US has had more experience with emissions trading than any other country in the world. Specific programs include:

- *Sulfur Dioxide (SO_2) Allowance Trading:* The Clean Air Act Amendments of 1990 required a 50% reduction in SO_2 emissions from electric utility boilers. To accomplish this goal, a fixed number of emission allowances were allocated to electric utilities based on a formula reflecting historical emissions. In addition, a small portion of allowances are auctioned every year to facilitate price discovery and new entrants. Allowances are specifically excluded from being defined as rights to pollute, may be traded to any party anywhere, and may be "banked" for use in future years. Participants need to conduct regular monitoring of emissions and make an annual accounting of their emissions. Penalties are imposed if emissions exceed the number of allowances held by a source.

  A functioning market in SO_2 allowances now exists, involving both bilateral exchanges between companies, and brokered exchanges through third parties. This market, along with other factors,2 has helped to dramatically reduce the cost of the abatement program.

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1 In principle, if the entire cost structure is known, any quantity target attained by a tradable permit system could also be attained by an appropriately calculated tax. In so far as forecasting in practice is difficult, however, the resulting level of emissions can be greater or less than the level targeted when the tax rate is set.

2 These include the fact that the target that was actually adopted was not as onerous as many in industry had feared, the low price and widespread availability of low sulfur coal, the awarding of "bonus allowances," the postponement of capital investments, and lower than expected transportation costs.

Initially, forecasters claimed that a 50% reduction (10 million tons) in SO2 would correspond to allowance prices in the range of $400 to $1000.3 However, prices for allowances that would be needed in the next decade to achieve this level of emission reduction currently range between $100 to $120. In addition, 1995 emissions were actually 40% below the legally required levels for that year.

- *Water Effluent Trading:* The US generally has regulated surface water quality through a system of discharge limits for large sources of water pollution. In addition, states have standards for ambient water quality which are often not attained even after large dischargers apply "best technology." The reason is that small ("nonpoint") sources (such as runoff from farms) contribute significantly to water pollution. A number of state and local governments are employing trading systems for watersheds that either permit trading among large dischargers, or allow large dischargers to fulfill their requirements by controlling nonpoint sources. These include the Fox River in Wisconsin, the Dillon Reservoir in Colorado, and the Tar-Pamlico River in North Carolina. The latter two programs are designed to manage future economic growth. Thus, the quantity of effluent allowances allocated exceeds current discharge levels. Once growth consumes this excess, trading is expected to reduce compliance costs.

- *Inter-refinery Lead Trading:* EPA operated a lead trading program from 1983 to 1987 as it phased out lead from gasoline. Lead trading allowed refiners and importers to trade lead reduction credits in order to meet limits for the lead content of gasoline. The quantity of allowances to which a firm was entitled was determined by the amount of leaded fuel produced by the firm and the contemporaneous EPA standard. Those who bettered the standard could sell their credits to others. Some 10 billion grams of lead were traded during the course of the program at prices ranging from 0.75 to 5 cents per gram. Allowing the trading of lead credits reduced the costs of the program by approximately 20 percent.

- *Criteria Air Pollutant Trading:* EPA first began incorporating aspects of emissions trading in its air program in 1974, when it allowed a modified source to use "credits" earned by another source within the same plant to avoid additional regulatory requirements. Since then, emission trading has substantially expanded. Trades have numbered in the thousands and have been estimated by Hahn and Hester (1986) to have achieved savings between $525 million and $12 billion.

- *Market Mechanisms for Chlorofluorocarbon (CFC) Phaseout:* Under the 1987 Montreal Protocol to limit stratospheric ozone depletion, the U.S. required the phase out of the production of CFCs by 1996. As part of its program, the U.S. adopted a tradeable permit regime covering CFC manufacturers and importers. These allowances were allocated based on each firm's 1986 market share. As the market for CFCs declined, the system allowed firms to allocate production among different facilities according to the least-cost pattern of supply. It also gave CFC users the flexibility to switch between different CFC compounds, within the overall limit on allowances. This program helped reduce the costs of the phaseout. In 1988, EPA estimated that the cost to *halve* CFC use would be $3.55 per kilogram. By

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3 Hahn, Robert W., and Carol May, "The Behavior of the Allowance Market: Theory and Evidence," The Electricity Journal, March, 1994.

1993, it became clear that all uses could be *eliminated* by 1996 at a cost of $2.45 per kilogram.

Emission Trading of Greenhouse Gases

An emissions trading program, like any program designed to limit greenhouse gases, must contain certain elements. First, an agreed upon emissions budget, and any rules governing provision for the project-specific crediting of reductions made in activities not explicitly covered by the budget, must be established. A central authority must be given the domestic responsibility for verifying compliance and the integrity of the allowances, and must be provided sufficient information to do so. Finally, noncompliance with allowance limitations or reporting requirements must generate real consequences, such as penalties or subtraction of allowances.

A program would have to establish permit lifetimes, monitoring and enforcement provisions, as well as rules for permit banking, borrowing, and trading. Consideration should also be given to transaction costs, which should be kept as low as possible. However, particularly difficult issues involve determining what types of activities require a permit and how permits should be allocated.

What types of Activities Should Require a Permit

Sources of greenhouse gases include not only those emitting carbon dioxide, but other gases such as methane, nitrous oxides, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). Gases differ both in their atmospheric lifetimes and in their ability to trap heat in the atmosphere. In addition, carbon is not only emitted through the combustion of fossil fuels, but is also absorbed by "sinks" such as trees and soils.

The decision for determining permit holders should consider the following:

- *Coverage:* While it may not be necessary to ensure that every ton of greenhouse gas is accounted for within an emission trading regime, the scope of coverage of the trading program should be sufficient to ensure compliance with targets set in accordance with an international agreement.
- *Administrative and compliance feasibility:* The number of sources involved in the trading program should be small enough to be administratively feasible and large enough to ensure market competition. In addition, monitoring and verification of permit compliance must be possible for those included in the program.
- *Potential to Diffuse Low Greenhouse Gas Technologies:* Alternative points of intervention should be evaluated for their ability to provide incentives for research, development, adoption and diffusion of low greenhouse gas technologies.
- *Market Impacts:* The permit program will have economic impacts on firms that vary depending on program design. For example, exempting certain sizes or categories of sources from permit requirements because of administrative or equity concerns (e.g., small boilers or home heating oil) has competitive implications within the energy market.

- *Public Acceptance:* The program must consider the ease or difficulty with which various allocation approaches would be accepted by the public.
- *Consistency with the international trading system:* The domestic program should be consistent with any international prescriptions concerning the coverage of sources and gases.

Carbon Sources

Carbon dioxide currently accounts for about 85% of U.S. greenhouse gas emissions and number in the hundreds of millions since they include sources such as automobiles and residential gas water heaters. Since virtually all of the carbon contained in fossil fuel extracted from the ground is eventually released to the atmosphere (with the possible exception of carbon in certain feedstocks), a trading program need not focus uniquely on direct emitters, but can be implemented through other points in the energy market. These include fuel imports, fuel extraction, processing, refining, distribution, and secondary conversion (e.g., coal to electricity). In addition, these points could vary by sector. For example, an emission trading program could focus on the point of final combustion for coal, but on refining for oil, or distribution for natural gas. Given the wide variety of options available for including energy sources in a trading program, a few alternative programs are described below for illustration:

A Program Targeting Primary Fuel Producers

The primary fuel producing sector – extraction, processing, refining, and distribution – has many levels where a permit program could be implemented. One option would be to require permits at the point of first sale (a permit is surrendered with the first inter- or intra- company transaction). Such a system would include transactions between a coal company and an electric utility, between a natural gas producer and its marketing arm, between a natural gas producer and a broker, or between an oil extraction company and its refinery operations. Fuel importers would also require permits to import fuel. This would capture the carbon from fuel consumed in the refining process. The number of market actors under this program design would be under 5000 and virtually all carbon in the energy sector would be included in the program.

A Program of Emission Trading at the Sectoral Level

An emissions trading program could also be applied at the point of combustion, allowing trading among affected sources. This system would be most comparable to the current SO_2 emission allowance trading system.

Targeting the six largest industrial CO_2 emitting sectors (electric utilities, cement, primary metals, pulp and paper, petroleum refining and chemicals) in a sectoral trading program could encompass as many as 20,000 market participants and 90 percent of industrial CO_2 emissions. Mobile source emissions could be indirectly included in the system by allocating transportation equipment manufacturers permits for emissions associated with their automobile fleets or by including refiners in the program. Residential and commercial emissions could be similarly addressed by focusing upstream in the energy system. For the electric generating sector, this

sectoral approach has the administrative benefit of using an existing monitoring and reporting infrastructure.

Other Greenhouse Gases and Sinks

Other gases account for the remaining 15% of greenhouse gas emissions (on a carbon-equivalent basis). Most important among these is methane, which accounts for 11% of national emissions. Since gases differ in their lifetimes and in their potential to trap heat in the atmosphere, an "exchange rate" or trading ratio must be established to convert all gases into common units for inclusion in a trading program. Such ratios have been developed by climate researchers and could be applied here. These should be consistent with the rules established in the international protocol.

Several, although not all, of the many sources of non-carbon greenhouse gases could likely be included in a trading system. For example, methane emitting coal mines, landfills, livestock manure management facilities and potentially natural gas distribution systems may meet the criteria described above for inclusion in a greenhouse gas trading program. These sources account for 7% of national greenhouse gas emissions. Similarly, emissions of some sources of other gases could potentially be included (e.g., magnesium production).

Forests in the United States currently remove an amount of carbon equal to 8% of national emissions from the atmosphere. Their inclusion in the trading program would theoretically enhance the system's flexibility. Translating the potential of sinks into monitorable, verifiable, and cost effective emission reductions would require the development of a comprehensive national accounting system for sinks. Such a system is needed to ensure that the planting of trees and preservation of forests in a given area would not result in offsetting losses elsewhere. Nonetheless, the decision on whether to include sinks in the trading system will be influenced by the outcome of the international negotiations.

Distributing Emission Permits

In an emission trading system, some mechanism must be provided for distributing emission permits to sources. Permits can be given to existing emitters on the basis of baseline/historical emissions or other formulae, given to consumers or others (who can then sell them to emitters), auctioned (where revenues accrue to the government), or some combination of the foregoing. The value of these assets could be large depending on the permit price, which is determined by the emissions target and the costs of substitutes.

Alternatively, permit allocation formulae could take into account the market impacts of the mitigation program. "Set asides" could be made available to those industries, workers, or consumers who experience a grossly disproportional share of the costs of control. A set aside could also be auctioned, with the revenues used to redress gross inequities in the distribution of control costs.

Allocation Based On Baseline/Historical Emissions

Under this approach, sources are given a number of permits based on baseline fuel production or emissions and an allocation formula. Various allocation formulae can be devised, weighted to greater or lesser degrees in favor of sources with high historical emissions. Emissions allowances are endowed to facility operators for no cost and would be transferable.

Those receiving permits thus obtain assets of potentially large value from the government at no cost.

Such an allocation mechanism could create entry barriers. In a capital intensive sector like primary fuel production, where entry barriers are already substantial, new entrants would be further disadvantaged if they had to purchase permits – especially if existing holders hoard permits. This problem could be mitigated by setting aside a number of permits for purchase by new entrants or by auctioning a portion on the open market. Such an auction would also facilitate price discovery in a new market. Although new firms will still be disadvantaged (as they will pay for all of their permits), they would be able to enter the market. The pool of permits would need to be withheld from existing sources to ensure compliance with budgeted national emission levels.

It may be desirable to design an allocation that would allow credit for early emissions reductions (those achieved prior to the start of the program, but after the baseline period) -- in particular for those that reduced greenhouse gas emissions as part of government sponsored voluntary programs. If credits for past actions are given, the total credits allowed would need to be deducted from the overall permit allocation for the first budget period in order not to exceed the national greenhouse gas emissions target. In addition, mechanisms may be necessary to ensure verification of these credits.

Auction

Alternatively, an auction could be used to allocate permits. The price permit holders pay would depend in part on the auction design or method used. Auctions ensure that permits cannot be hoarded (a concern often expressed regarding allocation approaches), are available for trade, and would serve to inform potential traders about current price levels. Auctions would put new entrants on the same footing as existing emitters. As discussed earlier, since an auction could produce substantial revenues, some decision would have to be made with respect to what to do with the proceeds.

Given that an auction could produce substantial revenues, some decision would have to be made with respect to what to do with the proceeds. They could be used exclusively to reduce taxes or the deficit. Alternatively, as discussed below, a portion of the revenues could be used to address inequities in the distribution of control costs and to fund R&D for less carbon intensive energy sources and end uses.

Supporting Technological Progress and Program Transitions

The allocation of permits, or the use of auction revenue, could be used to promote more rapid diffusion of existing climate-friendly technologies and accelerated R&D for new technologies. For example, a reserve of allowances could be set aside to encourage more rapid development and diffusion of low greenhouse gas emitting technologies. Manufacturers of energy consuming equipment could compete for the set aside based on the degree to which they produce equipment more efficient than the average in use or than required by current mandatory efficiency standards. Such a program could yield reductions in energy demand and help buffer the consumer from the impact of higher energy costs. Similar results could be achieved with the use of auction revenue.

Permit allocation formulae could take into account the market impacts of the mitigation program. "Set asides" could be made available to those industries, workers, or consumers who experience a grossly disproportional share of the costs of control. Auction revenues could also used for this purpose.

Other Policy Interventions

In addition to an Emissions Trading Program, there could be other interventions to improve the functioning of markets. These could include standards for energy efficiency and/or direct limits on greenhouse gases. For example, methane from larger landfills is already controlled due to limits on emissions of volatile organic compounds. Historically, government efforts for energy efficiency standard have targeted appliances and other residential and commercial equipment, as well as personal transportation (i.e., the Corporate Average Fuel Economy (CAFE) program). DOE estimates that the federal appliance standards implemented to date will reduce carbon emissions by 14 million tons in the year 2000. Further development of standards could result in additional reductions.

Emissions of greenhouse gases from the transportation sector account for about one-third of total U.S. GHG emissions and are expected to grow by about 25% by 2010. The overall in-use fuel economy of the combined new light vehicle fleet (i.e., cars and light trucks such as minivans, sport utility vehicles, and pickup trucks) has begun to *decline*. In 1994, President Clinton convened a Federal Advisory Committee Policy Dialogue to assist in the development of measures to significantly reduce greenhouse gas emissions from personal motor vehicles ("CarTalk"). Although CarTalk ended without consensus among members of the Committee, the process did result in a number of proposed policies that could be pursued.

In addition to the standards it sets, government indirectly affects the levels of greenhouse gas emissions through its policies towards transportation and energy market regulation. These also offer opportunities to generate reductions in greenhouse gas emissions. Most prominent among these are:

Electricity Restructuring: States are currently adopting retail competition for the electricity industry. This trend could be accelerated with federal legislation. Retail competition is expected to lower the price of electricity by as much as 20-25% in certain regions and change the fuel mix of generation. Preliminary EPA and DOE analysis indicates that utility greenhouse gas emissions could rise by as much as 2-6% as a result. To mitigate the environmental impacts of competition and maintain the environmental benefits of current state level renewable and demand side management programs, a number of options have been adopted at the state level (for states that have already adopted competition) or are under consideration federally. These include:

- A "portfolio standard" for renewable energy or greenhouse gas emissions: This would require that all generators meet a specified level of renewable generation or greenhouse gas emission reduction either by undertaking such projects themselves or purchasing "credits" from others who have.

- A social benefit fund: Revenues from a charge on transmission service are used to fund energy efficiency projects, renewables, R&D, or low income consumers. California has adopted this approach.

- Information disclosure requirements: Generators could be required to disclose the emission profiles of their generation, facilitating the marketing of "green" electricity.

- Additional air pollutant requirements: Many states are hesitant to adopt retail competition because they perceive that differing regional environmental requirements put their electric industry at a competitive disadvantage and (in the case of certain conventional pollutants) will result in more pollution being transported into their states. Thus, additional environmental provisions to "level the competitive playing field" – which could include greenhouse gas emission reductions – are currently being debated.

The Intermodal Surface Transportation Efficiency Act (ISTEA): This Act establishes the rules for federal transportation funding to the states. In 1991, ISTEA authorized $140 billion in transportation projects over six years. The Act expires in 1997 and Congress is now considering options for its reauthorization. These could include provisions that would indirectly reduce greenhouse gas emissions. Examples include the following:

- Congestion Mitigation and Air Quality Improvement Program: Additional funds could be targeted to transportation projects that reduce air emissions and energy consumption on a long-term sustainable basis.

- Brownfields Restoration: Successful redevelopment of brownfields can help revive inner city areas and reduce sprawl, thereby reducing vehicle miles traveled. More funds could be made available for these projects.

The Role of Technology Policies in Limiting Greenhouse Gas Emissions

"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 long run."

-- The Economists' Statement on Climate Change, Feb. 13, 1997 (signed by more than 2,400 economists, including eight Nobel Laureates)

A strategy to accelerate diffusion of existing technologies and research, development and deployment of more advanced technologies is a critical component of any U.S. policy to stabilize greenhouse gas emissions. Without such a technology strategy, any emissions control program

would result in greater economic costs and higher prices for carbon allowances than would otherwise be the case. Analysis suggests than an accelerated technology effort has a large potential for bringing down the cost to the economy and this price.

In addition to major studies in the early 1990s[4], forthcoming analysis by five leading National Laboratories finds that a large potential remains for reducing U.S. energy consumption and greenhouse gas emissions while meeting the full energy needs of U.S. businesses and families. In the long term, reducing emissions sufficiently to stabilize greenhouse gas concentrations at even twice pre-industrial levels, which will likely still have severe national and global environmental impact, poses an unprecedented challenge that can only be met with superior technology brought about by aggressive diffusion and significantly higher levels of R&D.

Two types of technology provide significant opportunities to reduce greenhouse gas emissions in the near- to mid-termwhile providing our full energy needs. First, energy-efficient technologies are currently underutilized in all sectors of the economy. These technologies allow us to do more while consuming less energy and reducing pollution. Through increased energy efficiency, we can maintain GDP growth while cutting energy usage and associated greenhouse gas and other air pollution. Second, a variety of low- and zero-carbon technologies, such as solar, wind and biomass power, advanced industrial processes and highly efficient fuel cells, are becoming increasingly competitive. These technologies can supply energy or produce energy services with little or no carbon emissions, allowing us to further sever the link between GDP and greenhouse gas emissions and other air pollution. Working together, energy efficiency and low-to-zero carbon technologies provide the means of sustaining economic growth while meeting medium- and long-term limits on greenhouse gas emissions.

In the longer term, greater technology opportunities exist - including a variety of advanced low-to-zero carbon technologies and carbon sequestration. In addition to reducing greenhouse gas emissions, these technologies provide other benefits to the nation that have long been the basis of national policy, including: achieving major reductions in criteria air pollutants, decreasing dependence on foreign oil, increasing productivity of domestic industries, and promoting U.S. leadership in the large and growing international market for advanced technologies. Greater penetration of today's energy-efficient technologies can also enhance economic productivity through more efficient use of our energy resources. Shifting capital from energy expenditures to new investments elsewhere in the economy will help drive economic growth, employment and consumer income.

A clear policy on limiting U.S. greenhouse gas emissions would help to focus attention on energy consumption and will provide important incentives for the diffusion of existing technologies and the development of even more advanced technologies. The technological response to past environmental policies, such as acid rain controls and the ban on CFCs, has been dramatic. In both cases, the actual cost of control has been substantially less than early projections.

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[4]See National Academy of Sciences, Policy Implications of Greenhouse Warming (1991) and Office of Technology Assessment, Changing by Degrees: Steps to Reduce Greenhouse Gases (1991).

Unfortunately, even with a clearer market signal, the technology response to a greenhouse gas policy will continue to be restrained. A host of market barriers contribute to today's large energy efficiency gap — the significant underutilization of existing, cost-effective, energy-efficient technologies. Many federal programs, many of which were launched in the President's Climate Change Action Plan, are successfully overcoming market barriers to key energy-efficient technologies through partnerships with the private sector. These programs need to be fully supported, and additional initiatives need to be put in place to target the remaining barriers to the use of energy efficiency and low-to-zero carbon technologies.

Additional barriers lead to systematic under investment in important research and development of new technologies. To achieve a sustainable emissions pathway through the year 2010 and beyond, there is an unavoidable need for advances in low-to-zero carbon energy technologies. As global population and energy demand continue to rise, technological advances provide the key to stabilizing global concentrations of greenhouse gases at safe levels without jeopardizing our quality of life. In order to stabilize greenhouse gas concentrations at safe levels, new technologies will have to reduce emissions by more than a factor of ten during the next few decades and be competitive enough to achieve deployment throughout the world. This need for major and continual advancements can only be met through a strong commitment to Federal RD&D.

Existing Technologies Offer Significant Potential to Control Emissions

There is clear evidence that the full potential of existing, profitable technologies is not being realized. Many of these energy-efficient technologies have relatively small market shares and low rates of technology diffusion. Their penetration is restrained because of a number of institutional, organizational, and other barriers that work against the diffusion of existing, energy-efficient technologies and the development of advanced technologies. Consumers and decision makers in business are often not aware of the availability of reliable, energy efficient equipment, nor the significant cost savings this equipment can offer. Even if they are aware, they may lack the information needed to make important investment decisions, or access to reasonable finance terms.

A number of federal, voluntary programs are currently enhancing markets by overcoming the barriers to energy efficiency. The Administration's Climate Change Action Plan (CCAP) launched over 40 initiatives in 1993. Building on other DOE and EPA programs, the CCAP's goal was to return U.S. greenhouse gas emissions to 1990 levels by the year 2000. Despite large Congressional funding cuts,[5] the CCAP programs are successfully overcoming market barriers and are currently expected to deliver approximately 70% of the emissions reductions originally projected. With continued support beyond the year 2000, these programs will significantly restrain growth in U.S. greenhouse gases through 2010 and beyond. Even at current funding levels, Administration projections indicate that these programs will eliminate 1/4 of total emissions growth through the year 2010, resulting in annual energy bill savings of approximately

[5] Total expenditures on CCAP programs in 1997 is $183 million, 40% million below the President's requested budget of $305 million.

$30 billion (in 1995 dollars). A sustained commitment to these programs beyond the year 2000 is needed to achieve these results, and restored full funding of CCAP programs will further cut the growth in greenhouse gas emissions. Some examples of CCAP programs include:

- DOE's Rebuild America program and EPA's Green Lights and ENERGY STAR Buildings programs are demonstrating that many of the barriers to energy efficiency in the commercial buildings sector can be overcome. By providing valuable information (no subsidies are provided), these programs have formed over 2500 partnerships to improve energy efficiency in buildings. Partners can reduce their energy use by up to 40% through technology investments with annual rates of return of 20-50%. This potential is significant because total greenhouse gas emissions from energy use in commercial and industrial buildings is equal to all emissions from U.S. light duty vehicles. Program partners have already invested over $1 billion dollars in energy efficiency improvements, and partners are saving over $280 million per year on their energy bills.

- EPA and DOE's ENERGY STAR Consumer Labeling programs are removing barriers that consumers have faced in purchasing energy-efficient home products, such as heating and cooling equipment and appliances. The programs have already transformed a number of markets, including cutting the energy used by computers, monitors, and printers by 50% at virtually no incremental cost to the customer. Other energy-efficient technologies, such as heating and cooling equipment, do have higher initial price tags. The programs are providing important information to consumers through a national education campaign on the highly profitable opportunities that efficient equipment offers when energy bills are considered. Manufacturers of home products are partnering with the federal government and labeling their more efficient products with the Energy Star logo. Through 1996, this program has seen thousands of products labeled and billions of dollars invested in ENERGY STAR products. Consumers are savings over $500 million per year on their energy bills.

Because the CCAP's focus on the year 2000 limited the options that were implemented, a longer term goal provides significant new opportunities to overcome remaining market barriers and develop key technologies.

No need to visit on this stuff is there

Research, Development, and Deployment of Clean Technologies

A strategy of continued diffusion of energy efficient and low-carbon technologies and accelerated development of key new low-carbon technologies during the next decade sets the stage for development and diffusion of a number of longer term low-to-zero carbon technologies that may begin to see limited penetration by 2010, but will have substantial impacts after 2010. The accelerated technology development effort must focus on four strategic thrusts: (1) clean power generation, (2) energy efficiency, (3) carbon sequestration accompanying a transition to a hydrogen-based economy, and (4) basic and very advanced research. Responding to the climate problem may require breakthroughs in all of these areas, and in any case the high-risk nature of R&D requires the pursuit of multiple pathways.

Increasing the probability of achieving these desirable outcomes will require expanding the government's current R&D spending in these areas, which is roughly $1.3 billion per year. Also, the policies described in the previous section, including partnerships with industry, market pull deployment initiatives, and improved regulatory processes, will be required to ensure technological success and accelerated market penetration. The benefits could be enormous. A 1997 study by Pacific Northwest Laboratory found that developing and deploying advanced technologies over the next 15 to 30 years could substantially lower the cost to the U.S. and global economy of achieving major reductions in emissions of greenhouse gases.

Clean Power Generation

Natural gas technologies now set the benchmark for low cost, cleaner power generation. Further advances in natural gas turbines could yield overall energy conversion efficiencies of 60% or more in the next decade, double conventional plants. High temperature fuel-cells, such as molten carbonate and solid oxide, may have significant application in power generation with further R&D, promising high efficiency and low emissions. Molten carbonate fuel cells could eventually cut greenhouse gas emissions by as much as 50%. Continued advances in high efficiency coal power plants, such as integrated gasification combined cycle, could approach 50%, allowing some continued use of abundant U.S. coal even in a greenhouse gas constrained world while helping the U.S. realize domestic and global market opportunities for these superior technologies.

While electricity from fossil fuels continue to become cleaner and cheaper, expanded R&D and deployment could make a number of renewable technologies competitive on purely economic grounds in the next two decades: wind power, photovoltaic (PV), biomass power, solar thermal, and geothermal. In a greenhouse-gas constrained world, these zero-carbon emitting sources of power would be even more competitive. Royal/Dutch Shell projects these technologies to be the dominant global source of energy by the middle of the next century.

Renewable technologies are becoming more competitive over time. Both wind and PV are experiencing a 20% cost reduction for every doubling of cumulative production. PV cells, which convert sunlight into electricity, have dropped from 90 cents per kilowatt-hour in 1980 to under 20 cents today while wind power has dropped from 25 cents per kWh to 5 cents. These cost reductions will continue to occur not just because of R&D, such as advances in thin film PV, but also through economies of scale and improvements in manufacturing that come with increased production. A number of different PV technologies are being pursued, providing multiple opportunities for breakthroughs. Accelerated RD&D for wind could potentially have an impact on CO_2 emissions in 2010.

How much can these do & how much is ensured Raising price (via permits) & ∴ cutting demand of fossil fuels?

Finally, life extension of nuclear power plants could provide substantial carbon reductions, so technology R&D to provide safe and economic extension of at least some nuclear plants is a vital component of the technology strategy.

Energy Efficiency

Technology R&D in transportation is essential because the sector produces one third of U.S. CO_2, and large reductions are unlikely without major regulatory changes or substantial technology advances. Also, two other major national problems — urban air pollution and dependence on foreign oil — stem largely from the transportation sector. The current federal strategy is to develop cars and trucks that are highly fuel-efficient as well as ones that run on fuels other than petroleum, including natural gas, electricity, and biofuels (ethanol). An aggressive RD&D strategy could result in significant penetration of much more efficient vehicles and biofuels in the next two decades.

The Partnership for a New Generation of Vehicle (PNGV) with the U.S. auto industry is pursuing multiple technology pathways for both advanced engines and energy storage. These vehicles could be commercially available just prior to 2010 and be 3 times more efficient than today's - providing large potential to reduce greenhouse gas emissions. In the slightly longer term, vehicles powered by proton exchange membrane (PEM) fuel cells have perhaps the greatest long-term potential for reducing transportation CO_2. To ensure that the R&D leads to commercially viable vehicles, a number of programs are needed to guarantee that the infrastructure is available to support vehicles that run on non-traditional fuels.

Federal RD&D into buildings technologies has been remarkably successful. Consider just five technologies developed or advanced by the national laboratories in the past two decades at a cost of roughly $40 million — building design software and advanced lighting, windows, oil burners, and refrigerator compressors. These have provided cumulative net savings of more than $28 billion to consumers and businesses, exceeding the $8 billion spent on all energy efficiency R&D since 1978. They now provide 16 million metric tons of annual CO_2 savings.

Continued RD&D in the buildings sector is likely to prove just as cost-effective. Key near-term technologies include improvements in lighting, superwindows, advanced design software, high-efficiency appliances, heat-pump water heaters, gas heat pumps, improved insulation and duct systems, more efficient cooling including gas cooling. Longer term R&D could result in electrochromic glazings for windows, building-integrated PV systems, and building fuel cells, all of which could see some market share before 2010 and make a large impact in the following decade. The Industries of the Future visions and technology roadmaps identify the best R&D opportunities for increasing energy efficiency and reducing emissions in the industrial sector while increasing productivity. These include advanced materials development, separation technology, catalysis, bioprocessing, renewable feedstocks, sensors and controls, and industrial cogeneration. All of these industries hope to dramatically improve their environmental performance while increasing their competitiveness. The pulp and paper industry, for example, sees the possibility of becoming a no-net-CO_2 industry, through a combination of efficient use of energy and biomass cogeneration.

Carbon Sequestration

In addition to the portfolio of R&D options related to less CO_2 intensive technologies for energy supply and use, capture and disposal of CO_2 offers an additional a lternative for reducing atmospheric concentrations of CO_2. If major reductions in CO_2 emissions are necessary, and global reliance on fossil fuels continues beyond the middle of the next

century, then some form of CO_2 sequestration will almost certainly be needed. A long-term R&D strategy would include demonstration of a number of sequestration options and research into their possible environmental impacts; converting CO_2 into an industrial chemical feedstocks; other novel sequestration options, such as CO_2 fixation by micro-algae; selectively permeable membranes for CO_2 capture; processes for converting fossil fuels and biomass into CO_2 and hydrogen; development of hydrogen infrastructure technology, including transportation and storage; and PEM fuel cells.

Basic and Advanced Research

A number of areas of basic research could prove crucial to responding to climate change, including biotechnology, fermentation microbiology, combustion research, polymer and ceramic science, process engineering, supercritical CO_2, new materials synthesis, and nanotechnology. We need to better understand the underlying biochemistry of the bioconversion of carbon dioxide to methane or to other potential fuels and feedstocks. This new research includes the ability to sequence the genetic material of microorganisms and plants, to develop new molecular genetic engineering techniques, and to understand biophysical and biochemical pathways of photosynthesis.

New and Expanded Efforts to Accelerate Diffusion and the Development of Clean Technologies

New initiatives are currently being designed to take advantage of the many areas of opportunity. All initiatives described are very preliminary.

Residential/Commercial Sectors

- *Split Incentives* — An initiative to overcome the unique split incentive barriers of landlord/ tenant and builder/buyer relationships. In these cases, the people who make investment decisions (i.e., the builder of new buildings, or the landlord) do not pay the energy bills.

- *Energy Information* — An initiative to empower consumers and businesses by providing better information is their monthly energy bills, including benchmark comparisons to efficient homes.

- *Advanced Buildings Technology Development* -- Accelerated development of a portfolio of buildings technologies - such as fuel cells in buildings, reflective surfaces and materials, and advanced windows.

Industrial Sector

- *Acceleration of Industries of the Future* -- The Industries of the Future process for the seven most energy intensive industries will be accelerated, resulting in successful development of new technologies sooner. These investments will be targeted on those

elements of industry's Technology Road Maps which will have the greatest potential to reduce emissions.

- *Cogeneration and Biomass Gasification* -- The development of advanced industrial turbines and biomass gasification technologies will be accelerated to provide many industries with not only inexpensive electricity, but also a means to reduce fossil-based electricity generation.

- *Industrial Partnerships* -- The federal government will work more aggressively with other major industries to achieve significant emissions reductions by 2010.

Transportation

- *Accelerated PNGV Initiative* -- The PNGV initiative will be expanded to accelerate the vehicle development and decrease the costs -making these vehicles even more attractive to consumers.

- *Light Truck Diesel R&D* -- The light truck diesel R&D initiative will increase light truck fuel economy by 40% - cutting carbon emissions from the fast-growing sport-utility vehicles, light truck and minivans market, while simultaneously meeting stringent criteria pollutant emissions standards.

- *Increased Ethanol Fuel R&D* -- Increased ethanol R&D will accelerate commercial competitiveness of biofuels with significant greenhouse gas benefits by supporting greater feedstock work and accelerating completion of production facilities - bringing ethanol costs down faster than anticipated.

- *Consumer Information/Market Incentives* -- Increase consumer demand for low greenhouse gas-emitting vehicles (such as those resulting from PNGV) through improved consumer information and outreach, market incentives, fleet programs, and other measures.

Cross-Cutting Opportunities

- *Financing for Energy Efficiency Investments* — Programs to improve access to financing for energy efficiency investments.

- *"Set Aside" for Clean and Efficient Technologies* — A new U.S. climate change policy would provide unique opportunities to provide further incentives to improve the penetration and innovation of energy efficiency and renewable technologies. For example, under a domestic trading system with a cap on greenhouse gas emissions, a reserve of allowances or a portion of auction revenues could be set aside to spur new R&D investment and production and use of energy efficiency and low-to-zero carbon technologies.

- *Business Accounting Practices* — An initiative to work with businesses to develop new practices that more accurately reflect energy liabilities.

- *Government Procurement* -- An initiative to harness the combined purchasing power of all levels of government and provide large markets for efficient and clean technologies.

Electric Utility Sector

- *Biomass Co-firing with Coal* -- Biomass, particularly waste biomass, has been co-fired with coal for over 10 years. This initiative will continue technology development to allow greater fractions of biomass to be co-fired and sponsor technology demonstrations at coal plants and offer technical assistance to plant operators, suppliers, farmers and others.

- *Expanded Renewable Energy Technology Development and Deployment* -- This initiative will expand technology development efforts on key renewable energy technologies such as photovoltiacs, wind and biomass while aggressively working with power companies, States and communities to accelerate their use.

- *CO_2 Sequestration and Hydrogen Production* -- This initiative would include demonstration of a number of sequestration options and research into their possible environmental impacts; converting CO_2 into an industrial chemical feedstocks; and other novel sequestration options - such as converting fossil fuels and biomass into CO_2 and hydrogen.

Climate Change Policy and the Role of Worker and Community Transition Assistance

The adoption of a new agreement on global climate change will represent an effort on the part of the government to reduce greenhouse gas emissions under this and other future agreements. A successful policy could have important implications for the level and pattern of energy usage in the economy. Usage of high carbon fossil fuels (e.g. coal) will decline, while the demand for other energy sources (e.g. natural gas or renewables) will grow in importance. While the adoption of a technology program has the potential to reduce the aggregate costs to the economy, consumers and business will still need to alter their energy usage patterns if greenhouse gas emissions are to be significantly reduced.

The development of new low energy (carbon) technologies and shifts in the pattern and level of energy usage in the economy will undoubtably benefit some industries and regions of the country. The presence of these "economic winners" will help reduce the aggregate costs to the economy of this policy. Nonetheless, there will be workers and communities that will be adversely affected by a policy to reduce greenhouse emissions. Workers in energy intensive industries and those in energy extraction are some of the most likely groups to be adversely

affected. Given the geographic isolation of some of these industries, the surrounding communities are also likely to be adversely affected.

A transition program would reduce the costs to individuals and communities associated with this environmental policy. Transition assistance can help facilitate community and worker adjustments via retraining, job search assistance, and infrastructure development for new business in the community. Previous experience strongly suggests that these investments in workers and communities have positive economic payoffs. Further, the development of such a policy at the initial stages of the climate change debate will help assure the public that the government has actively considered not only the long run ecological benefits of a global warming but that it is committed to taking steps to ameliorate the costs. Explicit attention to the costs and design issues of a transition program and their interaction with the desired structure of the permit trading and technology programs would reduce the total costs of climate change policy. As previous experience with free trade, acid rain, military base closures, and the federal government's own work force restructuring has demonstrated, this can be vital to building public support for the policy.

As noted above the federal government has extensive experience with worker and community transition programs. Some of these programs are dedicated programs to ameliorate the cost of specific government actions, while others are programs designed to reduce the effects of general economic dislocation. Below is a brief review of some of the features of the federal programs that might serve as either models, or be augmented, to meet the needs posed by a climate change policy.

Survey of Worker Transition Programs

The Department of Labor (DOL) has been responsible for a number of retraining/reemployment assistance programs that also provide income support payments. While their primary focus has been reemployment, the income support component of these programs have generally been coordinated with the regular unemployment insurance (UI) program. Benefits have generally been paid only subsequent to the exhaustion of UI benefits. While some programs paid weekly benefits that were more generous than the UI benefit levels, and the duration and conditions for receipt of benefits have varied greatly, most current programs tend to set them at the UI benefit level. Newer programs have also made income support conditional upon participation in training. The Administration has strongly supported the consolidation of these programs, including current legislative activity, moving away from categorical dislocated worker programs. Some important examples of worker transition programs are:

Clean Air Employment Transition Assistance (CEATA) Program

The CEATA program was authorized by an amendment to the Job Training Partnership Act included in the Clean Air Act Amendments of 1990. Its purpose is to provide retraining and readjustment assistance to workers dislocated by a decision to reduce employment as a result of a firm's compliance with the requirements of the Clean Air Act. Grants are awarded by DOL to eligible grantees (e.g., states, sub-state grantees established under JTPA, employers, employer associations, and representatives of employees).

The program includes retraining services, readjustment services (including readjustment planning, labor market information, job search and placement, supportive services, relocation assistance) and needs related payments to participate in training or education. CAETA was funded from specially allocated funds for FY 1992 and 1993. Since then CAETA projects have been funded with JTPA National Reserve funds. Over half of terminees received some retraining, while the remainder have received basic readjustment services. The cost per participant, based on recent project requests has averaged about $20,000, including the cost of needs related payments.

Trade Adjustment Assistance (TAA) Program

The TAA program offers Trade Readjustment Allowances (TRA) and reemployment adjustment services to workers who lose their jobs due to import competition. Established in 1962, the program initially emphasized compensating workers for their lost income, and relatively few workers received training, job search assistance, or relocation allowances. Beginning in 1981, the program emphasis shifted to providing training. TRA benefits were targeted to the long-term unemployed, and more funds were made available for training. Eligibility is a two-step process. First, groups of workers from individual firms or plants file a petition for eligibility with the DOL, which determines whether the group is eligible ("certified"). Second, individual workers are eligible for TRA benefits if they worked for and were laid off from a certified firm during the certification period and they meet other conditions.

Workers are entitled to TRA benefits for up to 52 weeks, job search allowances, relocation allowances, and training assistance. Workers are also eligible for the second 26 weeks of TRA benefits if they are enrolled in approved training programs. Prior to 1981, TRA benefits were far more generous than regular UI benefits, replacing 70 percent of lost wages. Under the new NAFTA-TAA program, the conditions for receipt of income support has been tightened further than in the basic TAA program, making receipt of income support conditional upon being enrolled in training by the 16th week of benefit receipt. Although TAA and NAFTA-TAA are separate programs, they have been interrelated to the basic DOL dislocated worker program (Title III JTPA) in their efforts to provide retraining and readjustment services. In 1988, following the most recent legislative amendments, it was estimated that average TRA benefits were $2,732 per participants and total benefits per TAA recipient (i.e., UI benefits, TRA payments, and TAA job search allowances, relocation allowances and training) totaled $10,603, based on a nationally representative sample.

Redwood Employee Protection Program (REPP)

Legislation was enacted in 1978 to provide employment and benefits to employers laid off between May 31, 1977 and September 30, 1980, as a result of expansion of the Redwood National Park. The program was operated only in a portion of the state of California. Benefits were paid through 1989. To receive benefits workers needed to be laid off or retired from an "affected employer." They also had to meet state requirements for UI. They were not eligible if receiving Social Security retirement or disability benefit or if receiving a pension under a plan contributed to by an affected employer. There were three types of affected employers. "Affected

woods employers" had to harvest redwood timber and own at least three percent of the acres with in the expanded park. "Affected mill employers" generally had to obtain at least 15 percent of their raw material from affected woods employers in 1977. "Affected contract employers" had to have at least 15 percent of their employee hours worked during 1977 be within or directly related to the expansion area.

REPP weekly layoff benefits replaced the worker's full wages and salary and were generally available for up to four years. UI benefits were deducted from these layoff benefits, as were earnings, in whole or in part. Receipt of benefits was not conditional upon participation in training, and only 16 percent of layoff benefit recipients participated in training. The full range of REPP benefits included weekly layoff benefits, vacation replacement benefits, continuation of health and welfare benefits, accrual of pension rights and credits, retraining, job search assistance (JSA) allowances, relocation allowances, and severance payments. The cost of this program for the 2600 workers who received layoff and severance benefits, pension and health benefits, retraining, and relocation allowance was $142.0 million.

Survey of Community Transition Programs

The USDA has a broad menu of programs focused on worker and community transition. These programs are primarily focused on longer term economic development and adjustment. Many of them are useful in worker, community, and sector adjustment and transition efforts. All of these programs are well tested and currently are fully operational.

The **Business-Cooperative Extension Service (RBS)** provides a range of assistance to rural businesses and to entrepreneurs including Rural Business Enterprise Grants funded at $450 million and Business and Industry Programs funded at $700 million in FY 1996. RBS Rural Economic Development Grants were funded at $20 million in the same year. Through its **Rural Utility Service (RUS)**, USDA delivers infrastructure development programs. In FY 1996, Water and Waste Disposal grants and loans were funded at $1 billion, Rural Electrification loans were funded at $940 million, and Rural Telecommunications loans were funded at $490 million. The **Forest Service (FS) Economic Action Grants** were funded at $31 million, and payments to States for Schools and Roads were funded at $300 million in FY 1996. The **Rural Housing Service (RHS)** single and multi-family housing loan, loan guarantee, and other housing assistance programs were funded at $2.868 billion in FY 1996. Community Facilities loans were funded at $280 million in FY 1996.

Finally, the Extension activities of the **Cooperative State Research, Education, and Extension Service (CSREES)** are a long established and highly regarded nation-wide network of specialists providing assistance, primarily to rural Americans, on a wide range of subject matter, including economic development and adjustment to structural change. In FY 1996, the Extension activities were funded at $428 million at the Federal level, with additional state and local government funding in every state. For the most part, the USDA programs operate independently of each other. However, each USDA office provides coordination across its programs and information on program linkages to other Federal government programs. The

Extension Service provides broad information on the availability and access to a wide range of government programs.

At least four models of program coordination in economic development and adjustment in rural America can be identified. The first model is one of coordination among services delivered by an individual USDA Office or Service, with services delivered at a local community or individual recipient level. The second model is that of the Appalachian Regional Commission in which program actions and expenditures are the result of coordinated program planning and execution across a multi-state region and over an extended period.

The third model, is illustrated by the **Empowerment Zone/Enterprise Community Initiative (EZ/EC)** designed to empower high-poverty communities to strategically plan for sustainable development and to obtain assistance from various Federal, state, local, private and non-profit programs to accomplish their plans. Also, the **Rural Economic Area Partnership** (REAP) assists rural places in the Northern Great Plains to diversify their communities and to adjust to long-term out migration and employment and population decline.

A fourth model is represented by the **Northwest Economic Adjustment Initiative**, funded over a five year period, to assist businesses, workers, tribes, and communities injured by reductions in Federal timber harvests in California, Oregon, and Washington. This is a coordinated effort by several Federal Agencies to create, in partnership with state and local initiatives, a comprehensive approach to economic revitalization. The comprehensive, multi-year, and regional approach to economic transition in this model may make it particularly useful.

The Department of Defense (DoD) has been closing military bases and assisting defense-impacted communities for more than 35 years. Through its **Defense Economic Adjustment Program**, DoD has worked with over 500 communities to alleviate serious economic impacts resulting from changes in defense activities, such as the closing or realignment of a military base, or the termination of a defense contract. The Office of Economic Adjustment (OEA) provides impacted communities planning assistance through technical expertise and financial resources, and serves as a focal point for information on other relevant Federal assistance programs. Financial assistance is provided through federal grants for the purpose of developing a strategy action plan to identify and address the adverse economic impacts. The objectives of the defense economic adjustment program have focused on creation of new jobs, reuse of the military assets, minimizing the economic adjustment period, stabilizing and diversifying the local economy and increasing the local tax base.

Recent reductions in the defense budget have required the closure and realignment of more than 157 major military bases and the consolidation of defense firms struggling to adjust to DoD procurement cutbacks. Jobs have been and continue to be eliminated with many workers forced to seek new employment. Communities, in turn, have had to develop strategies to create new jobs to replace those lost in the defense sector. The impact of the defense draw down has been significant in terms of job loss. In 1987 DoD employed more than one million civilians. By September 1996, the employment level had been reduced about 28 percent - a loss of 320,000 positions. Another 92,000 civilian positions are scheduled to be cut by 2001. The private sector defense industry has also seen a sharp drop in employment due to DoD procurement cutbacks.

To adjust, some defense firms have chosen to diversify to commercial products, while others believe they can survive by selling off peripheral operations and protecting their market niche. The number of private sector jobs directly supported by DoD contracts has declined by 29 percent 1987 and 1994, from 3.9 million to about 2.8 million.

The largest impact of DoD downsizing has been in the private sector, where the ripple effects of DoD spending cuts are felt beyond the prime contractor. The impact extends to subcontractors and suppliers, as well as community retail and service companies. The severity of economic impact and the community's ability to respond depend on a variety of factors, such as the number of jobs lost, the size of the community, or the diversity of the community economic base. Metropolitan areas with a large and diverse local economy usually adjust more easily that smaller, heavily defense-dependent communities. However, smaller communities can survive quite well if job gains in other sectors of the labor market offset the defense job losses. Conversely, a metropolitan area can suffer substantially if the health of the local economy is weak and not diversified.

DoD's experience has shown that the primary responses to address the economic impacts must be community-based. The economic adjustment efforts begin and end with the community leaders, with support and coordination from State leaders and Federal officials. Effective decision making rests with those most impacted by the defense action - those who have the greatest stake in economic recovery. Although experience suggests that the task of rebuilding an economic foundation is never easy, a community can find that a closed military base is its single greatest asset. Facilities have been freed up with the potential to generate new jobs that can replace, or even exceed, the losses resulting from the closure, and expand a community's tax base. The transition period for a base closure community often takes three to five years, with complete base redevelopment sometimes taking up to 20 years. Nonetheless, almost 26,000 new jobs and more than 550 tenant businesses have already been created on bases closed since the BRAC process began in 1988. On average, around 60 percent of the civilian jobs lost are replaced a year after formal closure.

Finally, whenever there is a change in the work force at a defense nuclear facility, Section 3161 of the Defense Authorization Act of 1993, requires the Secretary of Energy to develop a plan for restructuring the work force. These plans include: adequate notice of the impending changes; minimizing involuntary separations; offering preference in hiring to the extent practicable; providing location assistance; providing retraining and educational and out placement assistance. The Restructuring Plans that are developed are different at each site but all Plans must demonstrate that a work force analysis has been conducted that identifies future work needs. Since FY 1992, the Department has separated 37,000 of its contractors through FY 1996. Of these, 78% have been voluntary, including early retirement, non-retirement-voluntary separations, and attrition.

The total estimated costs through FY 1996, for separating these 37,000 employees was $643 million or slightly under $17,400/employee. This compares favorably with DoD and private industry benchmarks and is substantially below $25,000 in benefits per worker. In general, separation costs include severance, early retirement with benefits, training and out placement service. Each community adjacent to a defense nuclear site under going work force

restructuring is eligible to form a **Community Reuse Organization (CRO)** and apply for funding to plan and implement programs to mitigate the social and economic impacts of restructuring. To date, 11 communities have planning underway and most of these communities have formed a CRO and have implemented programs and projects.

Factors that are used to evaluate the potential success of a project or program include: projected job creation for workers affected by downsizing (communities should seek to create at least one job for each $10-25,000 in federal funding received, leveraging those funds to attract other private and public funds); the ability to reduce the region's dependence on the Department; consistency with identified strengths of the region; past performance of the applicant, if any; local participation in the project; cooperation with regional or state economic development efforts; ability of the project to become self-sufficient; optimal use of site equipment or technologies; other factors such as matching funds. Since 1993, over $160 million has been provided to support the diversification of affected communities, including assistance to CROs, Department field organizations, and Management and Integration contractors.

Another model under the jurisdiction of the Department of the Interior is the **Alaska Native Claims Settlement Act of 1971**. The Act gave Alaskan natives (Eskimos, Indians and Aleuts) title to 44 million acres of public land and $962.5 million in cash as settlement of their aboriginal claim to land in Alaska ($462.5 million from the federal treasury and the rest from oil revenue-sharing). More than 200 village-level Native corporations, as well as 17 regional and urban corporations, and, were formed to manage the lands and cash payments. 80,000 Native Alaskans born on or before December 18, 1971, who could prove one-quarter blood Native ancestry, enrolled in local and regional corporations, obtaining shares in the corporations and additional rights to revenue from regional mineral and timber resources. Along with cash compensation, these corporations could also earn income from their investments.

Issues in the Design of Economic Transition programs for Climate Change

A number of issues would have to be addressed in designing an economic transition program for climate change. These include:

Sources of revenue

If a climate change control program is implemented through a system of marketable permits, the revenues from a permit auction could serve as the funding mechanism for an economic transition program. Current projection of revenues raised from these auctions suggest a potentially large funding stream that would be available for either a dedicated or categorical program to facilitate the transition to a less greenhouse gas intensive economy. An alternate mechanism for funding a categorical program might be for program beneficiaries to receive permits in lieu of other forms of assistance, the value of which would be determined in the marketplace.

Targeted Population

A program could narrowly focus on employees of and communities dependent on energy industries or industries that consume large quantities of energy. Alternatively, a broader set of beneficiaries could be targeted, such as those manufacturing energy consuming equipment or engaged in industries indirectly dependent on energy (e.g., road builders). While identification of a limited set of industries most likely to be affected may be straight forward, it would be difficult to determine all of the industries or firms that might respond to an increase in energy costs by reducing employment. This problems would be exacerbated by the fact that the effects of global climate policy will take place over a protracted period of time making certification of whether the dislocations were due to climate policy or general economic factors problematic.

Criteria for documenting eligibility

A dedicated economic transition program must establish criteria for determining eligibility. If a climate change mitigation program is implemented through a system of tradeable emission allowances, permit prices could provide useful information to trigger the availability of transition assistance. Such prices would reflect the additional cost to firms of the greenhouse gas control program.

Timing of benefits

It is likely that industries will begin to take action to reduce greenhouse gas emissions before a legally binding obligation officially takes effect. This is especially likely to be the case if firms are allowed to bank early emission reductions that they make before the program start date. For example, in the Acid Rain Program, actual sulfur dioxide emissions were 40% below allowable levels in 1995 -- largely due to emissions banking. In addition, industries will anticipate future greenhouse gas constraints as they make capital budgeting decisions and will likely begin replacing greenhouse gas intensive capital with less intensive alternatives soon after a control program is announced. This would affect the livelihood of workers and communities dependent on energy intensive industries and should be considered in determining the timing of the economic transition program.

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DRAFT --May 30, 1997

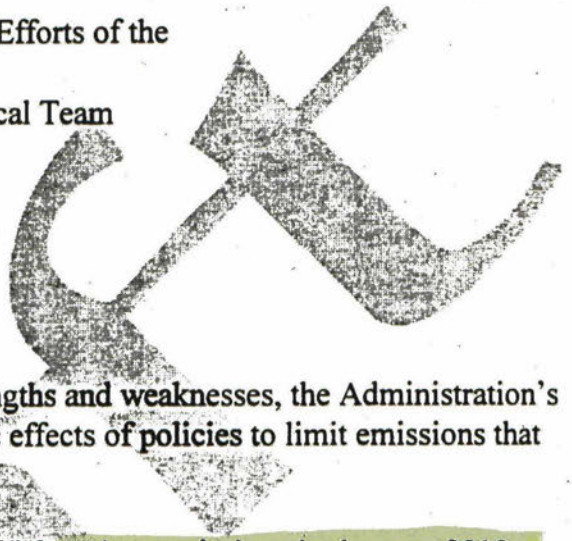
Economic Effects of

Global Climate Change Policies

Results of the Research Efforts of the

Interagency Analytical Team

June 1997



Executive Summary

Using a group of economic models with different strengths and weaknesses, the Administration's Interagency Analytic Team has analyzed the economic effects of policies to limit emissions that lead to changes in global climate.

The starting point for this analysis was a scenario in which carbon emissions in the year 2010 were reduced to their 1990 levels. This starting point was selected because it was presented in previous Administration analyses of the issue and because it has been the subject of numerous analyses by academic researchers. Cross-border trading of emissions rights (or permits) was then allowed to reduce transitional economic losses created by such a policy. This is particularly true in the short term. A dramatic acceleration of technological progress also has made the potential to reduce further economic losses, if it can be achieved, but over a longer time period. The economic losses are also reduced by policies that use any resulting revenues for the Federal budget deficit reduction or other policies, which favor investment and long-term growth.

The starting point scenario would raise the implicit price of carbon in the economy by about $100 per ton of carbon. (Actual household burdens would be somewhat offset by conservation and presumed subsequent efficiency improvements.) These higher energy costs would produce GDP losses, at peak, between 0.2 percent and 1.0 percent of GDP. The economy would thereafter bounce back, or in the worst case stabilize, so that it would soon reach its pre-policy growth path. Thus, the losses of economic output resulting from such a policy are real, but relatively small and transient. These losses are disproportionately greater for stricter targets and disproportionately smaller for more lenient ones. However, if international permit trading were established it would moderate the losses to GDP. The maximum effect on GDP under international permit trading is about half of that under no trading.

While the economy-wide losses are small, some sectors bear large burdens, particularly energy producers. Energy-intensive industries also face greater losses. But there is no evidence of a wholesale "capital flight" from the United States resulting from an emissions reduction policy. Moreover, some industries expand as the economy undergoes the adjustment to a world with fewer carbon emissions.

Introduction

In June 1996, the Department of Energy (DOE) and the Environmental Protection Agency (EPA) sponsored a joint workshop where more than 50 experts from inside and outside the government made presentations on technical issues associated with our emissions trends and capability to reduce emissions trends in the next century. As a part of that workshop, the Interagency Analytical Team (IAT) released what were then preliminary results on the economic effects of emissions reduction proposals.

Since that June 1996 workshop, the IAT has reviewed its work, selected new modeling instruments, improved its approach to old ones, and developed a new set of modeling runs that lead to a better understanding of the economic dimensions of the climate change policy problem. This paper describes those efforts. It first summarizes the IAT model selection process. Second, it discusses the (pre-policy) base case used to measure the effects of various policy options. Third, it discusses the IAT's core emissions reduction scenario. Finally, the bulk of this paper discusses the results of the IAT's analysis.

The modeling work performed for this analysis was done by economists at DOE and EPA. The IAT also included members from the Departments of Commerce, Treasury, Labor, and State, as well as members of the White House staff. The majority of the IAT members are still primarily from DOE and EPA --the agencies that have the primary responsibility for the Administration's energy and environmental policies.

Model Selection

The first task that the IAT confronted was to review the analytic "toolbox" to assure that it had all the tools necessary to specify the economic effects of a broad range of climate change proposals. At the time, the IAT relied primarily on the Data Resources, Inc. (DRI) macro model to measure economic effects. After this reevaluation of our modeling needs, it was apparent that the complexity of the analysis would require a broader range of analytical tools.

At a public meeting last November, the IAT announced the selection of three models for its analysis. It decided to continue to use the DRI model, but also included two additional models: the Second Generation Model (SGM) and the Markal-Macro model. Each of these three models met the criteria of being available in the public sphere; being well documented; having a track record of analysis in the climate change area; being widely understood within the energy-environment community; and bringing a unique capability to the IAT's work. Used separately, but in concert with each other, they provide the broad analytical capability needed to examine the many complex economic effects of potential global climate change policies.

The DRI model is a large disequilibrium model of the domestic economy that is particularly well suited to identify transition issues based on short-run behavior embedded into a long-run model. The DRI macroeconomic model is linked to energy, regional, and industry sub-models so that macroeconomic effects of policies are translated into the effects on specific industries and regions of the country. The link to energy sub-models provides specific detailed information

about the interaction of the energy sector with the rest of the economy.[1] The DRI model also includes the interaction of the financial markets with markets for goods and services and enables the analysis of the interaction of fiscal and monetary policy with the rest of the economy.

The SGM model is a computable general equilibrium good at identifying an economy's long-term trends in response to climate policies. As such, it is particularly good at describing the economy's long-term path while not as good at describing short-term transition issues. In this sense, its strengths and weaknesses are counterpoised to those of DRI. International in scope, SGM also provides detail for 12 global regions that allows the IAT to examine the effects of permit trading and joint implementation. SGM assesses the impacts of greenhouse gas emissions policies on economic growth, consumption, and energy.

The DRI model and SGM can be thought of as lying at opposite ends of an axis that measures time horizons. A second dimension of the climate change problem concerns the role of technology. Both DRI and SGM allow technological progress to move forward in response to the parameters of their models. But given the unpredictable character of innovation, the IAT concluded that a second approach would be helpful. The Markal-Macro model consists of an integrated energy supply and demand modeling system (Markal) and a macroeconomic model (Macro) useful for translating technological assumptions into economic outcomes.

The Markal-Macro model is particularly useful in answering the question, "How do we get there from here?" Markal-Macro identifies optimal, under perfect foresight, for achieving and quantified goal. Markal-Macro allows the user to control technology innovation and diffusion and its cost to the user in order to determine the levels of energy efficiencies that might be expected from a long-term policy announcement. This model also allows us to understand the implications of technology and its interaction with the economy, and helps us determine whether expected energy efficient technologies hold the key to continued economic growth.

The DRI model and the SGM model in some sense provide notional brackets for estimates of the economic effects of carbon-limiting policies. The DRI model is focused on short-term transitions and measures the economy in quarters. In some sectors, the DRI model has forward-looking behavior, but it is structured to examine the effects of short-term changes in the economy, and is often held to overstate the transitions created by broad, secular changes in the economy (and, as will be discussed below, might overstates subsequent economic improvements as well). The SGM model focuses on long-term transitions and measures the economy in five-year intervals. Thus, it risks racing past short-term transition issues, while identifying the economy's ultimate destination.

[1] The majority of the DRI results reported by the IAT use DRI's own Energy sub-model. In a limited number of cases, DOE's National Energy Modeling System (NEMS) has been also used been used in conjunction with the DRI model to analyze various sensitivities.

The Base Case

The domestic energy and emissions baseline forecasts were taken from the Energy Information Administration's 1997 Annual Energy Outlook (AEO97). The DRI baseline is DRI's own October 1996 long-term forecast, adjusted in part for the Climate Change Action Plan (CCAP). It is very similar to the AEO97 forecast, but not specifically calibrated to it. The international baseline forecast was taken from the International Energy Agency's World Energy Outlook, except for the baseline forecast of the Former Soviet Union (FSU), which came from World Bank projections. The IAT then imposed, as best possible, consistency across the models with regard to projections of baseline GDP, total energy consumption, and carbon emissions. Once these were calibrated into the 3 models, the models solved for energy prices by fuel type. Thus, the baselines of the three models are consistent, but not identical.

Tables 1 and 2 summarize the IAT baseline. In the baseline, U.S. economic growth is projected to slow over the next several decades, as the retirement of "baby boom" workers slows labor force growth and reduces the economy's potential growth rate. Energy demand therefore grows somewhat more slowly than it now does. Energy intensity, measured as energy use per dollar of GDP (the E/GDP ratio), is a key ingredient in the AEO97 forecast, because it measures the growing efficiency with which the economy uses energy. In the 1970s and 1980s, the E/GDP rate of decline averaged almost 2 percent annually--1.5 percent due to price effects and 0.5 percent due to non-price effects. Moderate price increases and the growth of more energy-intensive industries in the late 1980s led to a stabilization of energy intensity. The baseline projection used for this study incorporates a 1.0 percent annual reduction in energy consumption per unit of real output, which is taken from the EIA's Annual Energy Outlook. With these improvements included, energy demand grows at an annual rate of about 0.8 percent over the period from 1995 to 2020, tailing off at the end of the period as does economic growth.

Carbon emissions in the baseline are projected to increase by about 1.2 percent a year through 2010, and by 0.6 percent annually from 2010 to 2020, reaching 1805 million metric tons in 2020. In 1990, the year most frequently used in the international negotiating process as the reference level of carbon, carbon emissions were 1,340 million metric tons, 22 percent below EIA's projection for 2010 and 36 percent below DRI's projection for 2020.

Table 1: IAT Domestic Baseline

	Year							Average Annual Growth Rate (percent) [1]					
	1990	1995	2000	2005	2010	2015	2020	90-95	95-00	00-05	05-10	10-15	15-20
Population													
DRI-DRI Energy	250	263	276	287	299	311	323	1.0	0.9	0.8	0.8	0.8	0.7
AEO97 (NEMS) [2]	250	264	276	287	299	311	n/a	1.0	0.9	0.8	0.8	0.8	n/a
SGM	250	263	276	287	299	311	323	1.0	0.9	0.8	0.8	0.8	0.7
Markal-Macro	250	263	276	287	299	311	323	1.0	1.0	0.8	0.8	0.8	0.8
GDP (Billion 1992$)													
DRI-DRI Energy	$6,139	$6,743	$7,515	$8,320	$9,163	$9,996	$10,670	1.9	2.2	2.1	1.9	1.8	1.3
AEO97 (NEMS)	$6,139	$6,739	$7,544	$8,390	$9,185	$9,880	n/a	1.9	2.3	2.1	1.8	1.5	n/a
SGM	$6,139	$6,739	$7,544	$8,390	$9,185	$9,880	$10,591	1.9	2.3	2.1	1.8	1.5	1.4
Markal-Macro	$6,139	$6,739	$7,549	$8,384	$9,198	$9,880	$10,498	1.9	2.3	2.1	1.9	1.4	1.2
OMB [3]	$6,142	$6,721	$7,470	$8,343	$9,225	$9,929	$10,581	1.8	2.1	2.2	2.0	1.5	1.3
Total Energy Consumption (Quads) [4]													
DRI-DRI Energy	82.6	88.9	95.9	101.0	105.3	107.4	108.9	1.5	1.5	1.0	0.8	0.4	0.3
AEO97 (NEMS)	83.7	90.0	97.9	103.4	107.9	110.9	n/a	1.5	1.7	1.1	0.9	0.5	n/a
SGM	81.2	90.6	96.0	102.0	107.0	110.3	113.0	2.2	1.2	1.2	1.0	0.6	0.5
Markal-Macro	83.7	90.9	98.0	103.7	107.8	110.7	115.3	1.7	1.5	1.1	0.8	0.5	0.8
Energy Intensity (TBtu/$92GDP)													
DRI-DRI Energy	13.5	13.2	12.8	12.1	11.5	10.7	10.2	-0.4	-0.7	-1.0	-1.1	-1.3	-1.0
AEO97 (NEMS)	13.6	13.4	13.0	12.3	11.7	11.2	n/a	-0.4	-0.6	-1.0	-1.0	-0.9	n/a
SGM	13.2	13.5	12.8	12.2	11.6	11.2	10.7	0.4	-1.0	-1.0	-1.0	-0.9	-0.9
Markal-Macro	13.6	13.5	13.0	12.4	11.7	11.2	11.0	-0.2	-0.8	-1.0	-1.1	-0.9	-0.4
Minemouth Coal Price ($95/ton)													
DRI-DRI Energy	$23.92	$18.45	$15.28	$14.41	$13.76	$13.16	$12.70	-5.1	-3.7	-1.2	-0.9	-0.9	-0.7
AEO97 (NEMS)	$19.88	$18.83	$18.38	$17.47	$16.92	$15.46	n/a	-1.1	-0.5	-1.0	-0.6	-1.8	n/a
SGM	$19.88	$19.45	$18.48	$17.30	$16.47	$15.73	$14.96	-0.4	-1.0	-1.3	-1.0	-0.9	-1.0
Markal-Macro	$19.88	$18.83	$17.37	$16.39	$15.90	$16.39	$16.14	-1.1	-1.6	-1.2	-0.6	0.6	-0.3
World Oil Price ($95/Barrel)													
DRI-DRI Energy	$25.23	$17.14	$16.18	$18.93	$21.24	$22.86	$23.95	-7.4	-1.1	3.2	2.3	1.5	0.9
AEO97 (NEMS)	$24.87	$17.26	$18.20	$19.72	$20.41	$20.98	n/a	-7.0	1.1	1.6	0.7	0.6	n/a
SGM	$24.87	$17.26	$18.20	$19.72	$20.41	$20.98	$21.57	-7.0	1.1	1.6	0.7	0.6	0.6
Markal-Macro	$24.87	$17.26	$18.59	$19.75	$20.29	$21.05	$22.20	-7.0	1.5	1.2	0.5	0.7	1.1
Natural Gas Price (wellhead $95/Mcf)													
DRI-DRI Energy	$1.81	$1.46	$1.87	$2.15	$2.42	$2.54	$2.65	-4.2	5.1	2.8	2.4	1.0	0.9
AEO97 (NEMS)	$1.97	$1.61	$1.82	$1.94	$2.01	$2.13	n/a	-4.0	2.5	1.3	0.7	1.2	n/a
SGM	$1.97	$1.99	$2.07	$2.10	$2.16	$2.11	$1.97	0.2	0.9	0.2	0.6	-0.5	-1.4
Markal-Macro	$1.71	$1.55	$2.22	$2.28	$2.46	$2.77	$2.97	-1.9	7.4	0.5	1.6	2.4	1.4
Gasoline Prices ($95/Gal) [5]													
DRI-DRI Energy	$1.40	$1.21	$1.20	$1.26	$1.31	$1.37	$1.40	-2.9	-0.1	1.0	0.8	0.8	0.4
AEO97 (NEMS)	$1.34	$1.15	$1.19	$1.21	$1.22	$1.17	n/a	-3.1	0.8	0.3	0.1	-0.7	n/a
SGM	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Markal-Macro	$1.34	$1.15	$1.34	$1.39	$1.40	$1.41	$1.44	-3.0	3.1	0.7	0.1	0.1	0.4
Carbon Emissions (MMTC) -- Total													
DRI-DRI Energy	1338	1413	1516	1612	1693	1767	1805	1.1	1.4	1.2	1.0	0.9	0.4
AEO97 (NEMS)	1339	1424	1543	1639	1722	1799	n/a	1.2	1.6	1.2	1.0	0.9	n/a
SGM	1350	1480	1550	1637	1729	1808	1871	1.9	0.9	1.1	1.1	0.9	0.7
Markal-Macro	1338	1459	1574	1674	1741	1806	1914	1.7	1.5	1.2	0.8	0.7	1.2

1 Growth rates are calculated from non-rounded levels. 2 AEO97 projections extend only to 2015. 3 Office of Management and Budget fiscal year 1998 assumptions. 4 SGM projections do not include geothermal, wind, biomass waste, and other municipal waste. 5 The SGM model does not include gasoline.

Table 2: IAT International Baseline
Average Annual Growth Rates (percent)

	Real Economic Growth (GDP)			Energy Growth (Quads)			Emissions Growth (MMTC)		
	1990-00	2000-10	2010-20	1990-00	2000-10	2010-20	1990-00	2000-10	2010-20
Australia	2.8	2.8	2.6	2.1	1.5	0.9	2.0	1.5	0.9
Canada	2.6	2.5	1.2	1.7	1.0	0.4	2.2	1.4	0.7
China	8.4	7.5	5.8	3.9	2.8	2.1	3.8	2.8	2.2
Former Soviet Union	-3.5	4.6	4.2	-3.5	1.8	1.2	-4.0	1.8	1.2
Eastern Europe	-4.5	4.2	4.3	-3.0	1.3	1.2	-3.5	1.3	1.2
India	4.1	4.5	3.9	3.9	1.3	3.1	4.1	2.1	3.3
Japan	2.1	1.7	0.9	2.2	0.9	0.1	2.1	0.9	0.1
Korea	5.0	5.9	4.4	4.0	3.1	2.4	2.6	3.3	2.9
Mexico	4.0	4.0	3.2	4.2	2.9	2.3	4.2	2.9	2.4
Western Europe	2.3	2.5	2.4	1.5	1.4	0.6	1.2	1.4	0.6
United States	2.1	2.2	1.4	1.7	1.1	0.6	1.4	1.1	0.8
Rest-Of-World	3.6	3.4	3.0	3.0	2.0	2.0	3.0	2.2	2.2

The Analytical "Starting Point"

The IAT began its analysis of emissions reductions policies by examining one core emissions reduction scenario. Then we explored the economic effect of changes to this scenario. The central policy modeled -- the "starting point" scenario -- is aimed at reducing carbon and other greenhouse gas emissions by stabilizing them at 1990 levels. The "starting point" scenario pursues those reductions by issuing tradable emission permits at the earliest point of energy production or when imported into the United States. The policy is announced in 2000 and its restrictions are phased-in over a ten year period, so that the policy takes full effect in 2010. The permits are initially auctioned so that all revenues generated through permits would be recycled through the economy through deficit reduction. The initial discussion of the "starting point" scenario assumes no international cooperation. An option incorporating international trading is discussed once the dynamics of the no trading "starting point" scenario have been established.

Estimates of reductions of non-carbon emissions, such as methane and forest carbon sinks, are obtained from engineering estimates outside the models. Early in the process, the IAT estimated a strike-price for these sources of $70 per ton (which turned out to be low). Appendix Table A shows baselines for, and the quantities of emissions obtained from, these non-carbon sources at this price. These carbon tons were subtracted from the emissions targets being modeled. But the cost of obtaining them was not factored back into the models and, is therefore missing. While the engineering estimates are uncertain, the cost of abating non-carbon sources could increase the estimates of economic effects by as much as 14 percent.

The "starting point"scenario was employed as an analytical starting point for this analysis primarily because it has already been the subject of much attention within the analytical literature. Most analysts of climate change policies have used an emissions freeze in the year

2010 at 1990 levels as their framework. The IAT, therefore, used this scenario in order to facilitate comparisons of its work to that of other researchers.

Industry and regional effects, as presented here, show only the effects of the climate change policy on the industry's output (shipments plus inventory change). We considered this our first step in understanding the likely sectoral consequences of emissions reductions.

The "starting point" scenario incorporates a slight improvement in energy intensity (E/GDP) over the EIA/AEO baseline, which declines by 1.0 percent per year. This improvement could come about because the climate change policy undertaken generates foreseeable increases in the future price of energy, or because of the implementation of the Climate Change Action Plan (CCAP), or other policies. The prospective "announcement effect," therefore, is what allows the model to distinguish between a change in future policy regarding carbon emissions and an exogenous shock, such as the two oil price increases in the 1970s. This leads to somewhat faster rate of diffusion of energy efficient technologies and a higher rate of innovation through R&D in anticipation of future higher energy prices. The IAT assumes an improvement in energy-intensity of 0.25 percent so that the total annual change in the ratio of energy to GDP is 1.25 percent per year. A faster technology alternative is also investigated. (More detail on energy-efficient technology improvement is provided later in this paper.)

Unless otherwise stated, the tables and figures that follow were derived using the DRI model and using the "starting point" scenario, which does not incorporate international emissions trading. These estimates, therefore, will be at the high end of the likely range, due to both model structure and the absence of trading.

"Starting Point" Results

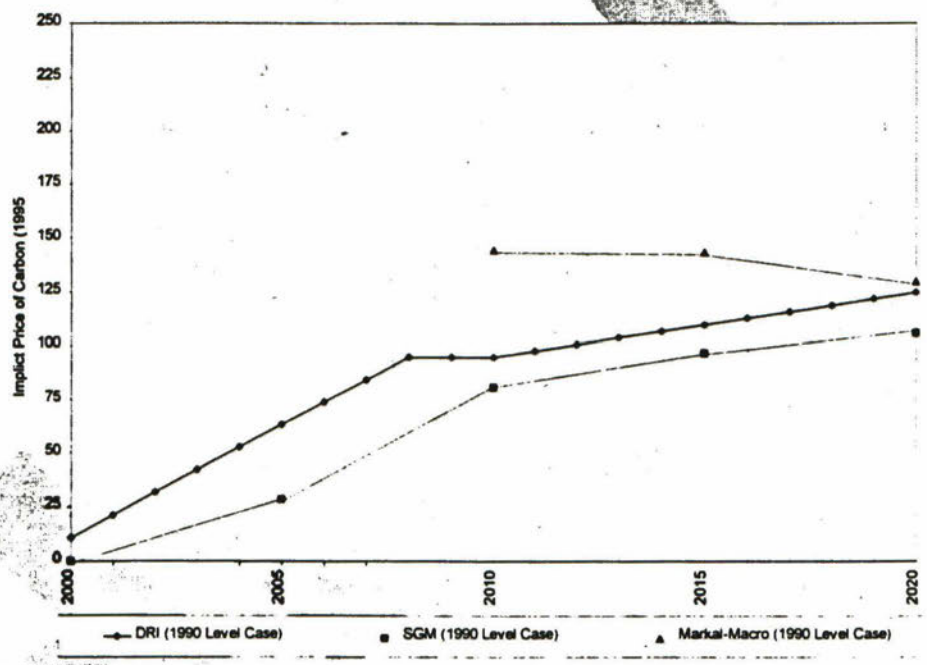
Estimates of permit prices are around $100 per ton of carbon in 2010 and rising slightly thereafter, and are consistent across models. While the three models used for this analysis vary in structure and often in terms of macroeconomic outcomes, they generate fairly consistent results as to the implicit price of carbon in the economy. Table 3 presents the results obtained by the three models for the value of a permit to emit a ton of carbon. Figure 1 shows the path for the value of carbon in these models. All of these estimates pertain to the "starting point" option in which emissions are frozen at their 1990 level in 2010 and thereafter.

Table 3: The Implicit Price of Carbon (1995$) in 2010 and 2020
1990 Level Case, No International Trading

	2010	2020
DRI-DRI Energy	95	125
SGM	81	106
Markal-Macro	145	130
NEMS	n/a	n/a

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM permit prices are calculated using the rate of change in carbon to GDP (C/GDP), which incorporate emission rates by the different fuel types. NEMS estimates are forthcoming.

Figure 1: Price Path of the Implicit Price of Carbon (1995$)
1990 Level Case, No International Trading



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM permit prices are calculated using the rate of change in C/GDP. SGM and Markal-Macro models use data and generate results in five year intervals.

The DRI model concludes that an implicit price of $95 (1995$) per ton of carbon in 2010 would result in stabilization. The Markal-Macro model estimated $145 (1995$) while the SGM model predicted about $81 (1995$), in 2010.[2] A permit price of $100 per ton is the equivalent of a price increase of 26 cents per gallon of refined petroleum product, $1.49 per thousand cubic feet of natural gas, $52.52 per ton of coal, and 2 cents per kilowatt hour of electricity produced.

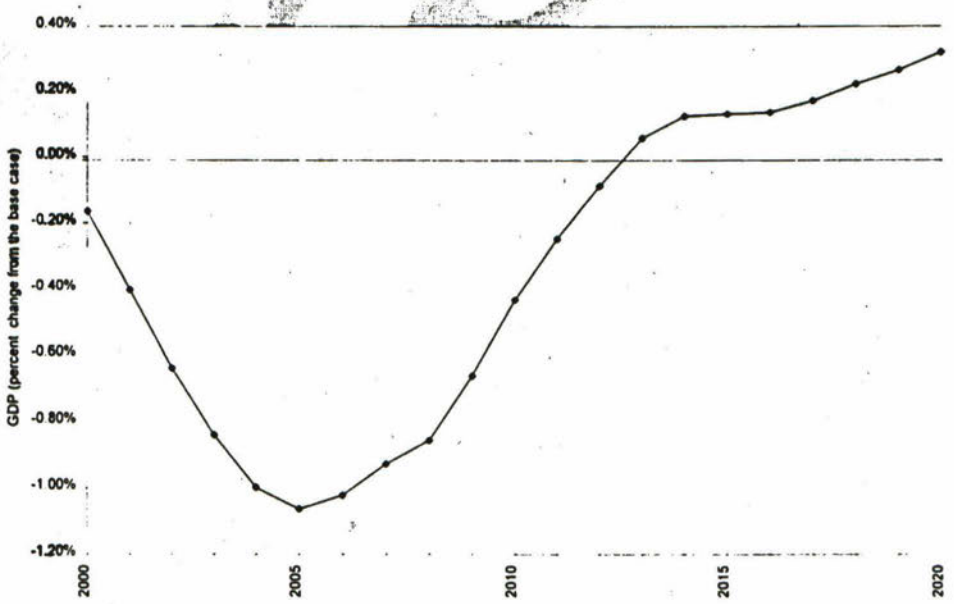
[2] The higher permit price from the Markal-Macro model reflects, in part, differences in model structure, but results mostly from differences in the calibrations of baseline emissions.

The models also agree that this implicit price of carbon grows somewhat over time. This reflects the fact that the 1990 emission ceiling becomes a progressively more binding constraint over time, given projected growth in base case emissions. By the year 2020, the implicit price of carbon rises to $125, $106 and $130 per ton (1995$) in the DRI, SGM, and Markal-Macro models, respectively.

Emissions reductions lead to small reductions in short-term economic growth (GDP), but growth later appears to recover. The burden of reducing carbon and other greenhouse gas emissions leads to short-term reductions in economic growth as measured by GDP. These reductions, however, are not large and, in many instances, are recovered in later years.

Results from the DRI model are presented in Figure 2. The results indicate that there is an initial GDP loss as the emission-limiting policy begins to be phased in. These losses cumulate to a peak loss of about one percent of total economic output in the year 2005 -- that is, the economy's growth slows until the size of the economy is, at worst, about one percent smaller in that year when compared to the base case. After 2005, the economy actually grows faster than it would have absent climate change policy and starts to make up the lost ground. By the year 2013, the economy is back to the point at which it would have been had no policy been enacted. In subsequent years, the economy improves slightly compared to the "no policy" base case--this differential reaches 0.3 percent by 2020, the last year of the model run.

Figure 2: DRI-DRI Energy 1990 Level Case,
No International Trading--Gross Domestic Product

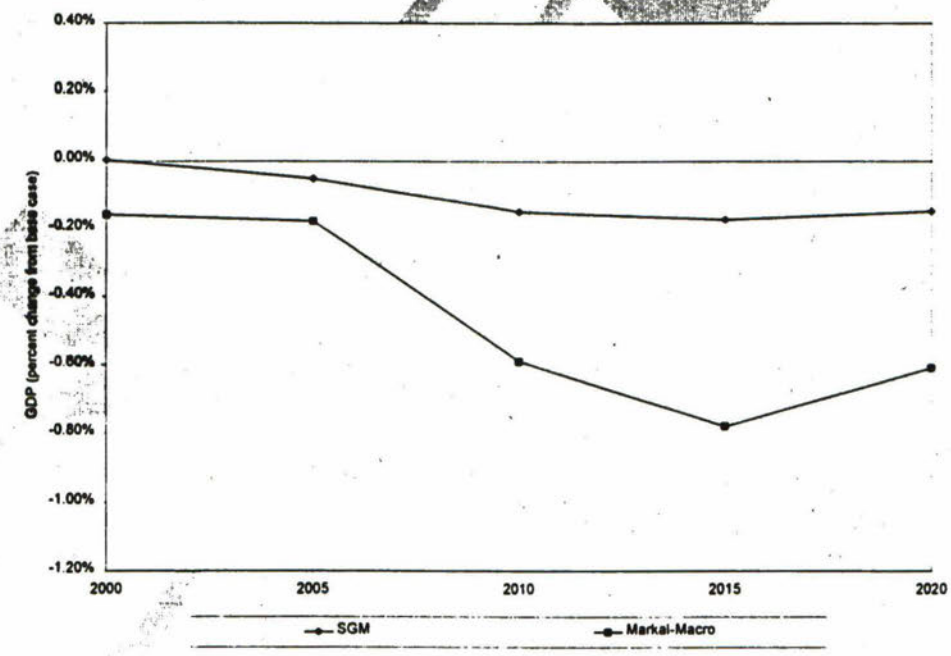


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

This improvement occurs in the DRI model because the emissions reduction policies modeled have some effects that favor savings and investment at the expense of consumption. If the Federal government auctions off emissions permits, it acquires the wherewithal to reduce the deficit (or retire debt) and, in effect, increase the nation's savings. This allows the cost of capital to fall and favors investment. The marginal profitability of investment also rises under these policies because new investment allows firms to neutralize higher energy costs. In effect, capital is a long-term substitute for energy and is favored after a transition period. Thus, the cost of investment falls and the incentive to invest is strengthened. This faster rate of investment (discussed in greater detail below) gives the economy a newer and larger capital stock: as a result the economy's ability to grow improves until it actually reaches a modestly higher growth path in the years following the transition.

Figure 3 shows comparable results for the SGM and Markal Macro models. In contrast to the DRI model, which focuses on short-term transition issues and may, therefore, tend to produce larger estimates of GDP losses, the SGM and Markal-Macro models move quickly through these issues and focus on longer-term prospects. The SGM model estimates peak losses for the economy of 0.17 percent of GDP in 2015, but the economy then stabilizes through 2020.

Figure 3: SGM and Markal-Macro 1990 Level Case
No International Trading, Gross Domestic Product



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

The Markal-Macro simulation results show a reduction in GDP of 0.60 percent from baseline in 2010 in the stabilization case. GDP remains below baseline levels throughout the forecast horizon. The GDP impact profile reflects the model structure, which represents the base case solution as a set of optimal energy use and technology choices given fuel prices, technology

characteristics, and discount rates. Since a carbon constraint limits the use of fuels and technologies that would otherwise be chosen, projected GDP must fall. Moreover, since the balance between investment and consumption is optimized within each case considered, economic welfare cannot be increased by an investment-oriented revenue recycling scheme. Consequently, although investment will adjust, the maximization of economic welfare under a carbon constraint does not lead to higher GDP in the future years in the Markal-Macro model.

The models used by the IAT offer a similar picture in some regards--all show initial losses in aggregate economic output that are not very large (even the DRI peak loss is spread over five years). But they also differ in predictable ways, given their structure. A recent analysis by Dr. Robert Repetto and Dr. Dunkin Austin of the World Resources Institute examined 162 analyses of climate change policy and found that model structure can account for two-thirds of the difference in results, if environmental benefits are ignored.[3]

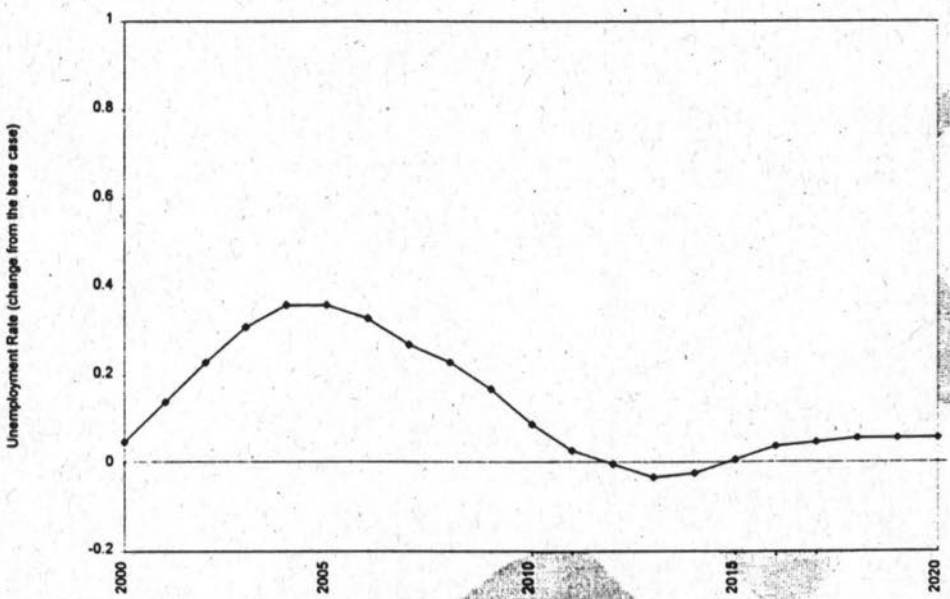
Disequilibrium macro models, such as DRI, tend to identify deeper transitional losses and steeper transitional rebounds. Computable general equilibrium models, such as SGM, see more sanguine short-term effects and see the economy stabilizing after a more frictionless adjustment. The SGM model, however, is less flexible than some computable general equilibrium model because it does not allow instantaneous shifts in capital. The SGM model maintains vintaged capital stock in the electricity sector and retires old electricity related capital only when it cannot cover operating expenses or reaches its fixed lifetime. This feature allows the analysis to incorporate the costs of reallocating capital stock.

Which, then, is right? DRI's transitional losses may be overstated, but so would be the rebound and the shift to a higher growth path it estimates for later years. SGM and Markal-Macro probably understate the transitional problem, but also avoid the later-year growth surge that DRI sees as driven by higher levels of investment. The models probably serve as brackets for the range of reasonable estimates of the economic effects of an emissions freeze at 1990 levels in 2010 and thereafter.

Unemployment and Inflation. The effect of the emissions stabilization policy results in approximately a 0.2 percentage point increase in the unemployment rate from 2001 through 2011, with a peak increase of about 0.4 percentage points in 2015, as estimated using the DRI model. The unemployment rate first rises as GDP falls, but then returns to its pre-policy level by 2012, as shown in Figure 4. The inflation rate increases by about 0.3 percentage points until 2009, measured by the annual rate of change in the Consumer Price Index (CPI). The annual rate of change in the CPI declines by about 0.1 to 0.2 percentage points per year for 2010 through 2020, as shown in Figure 5.

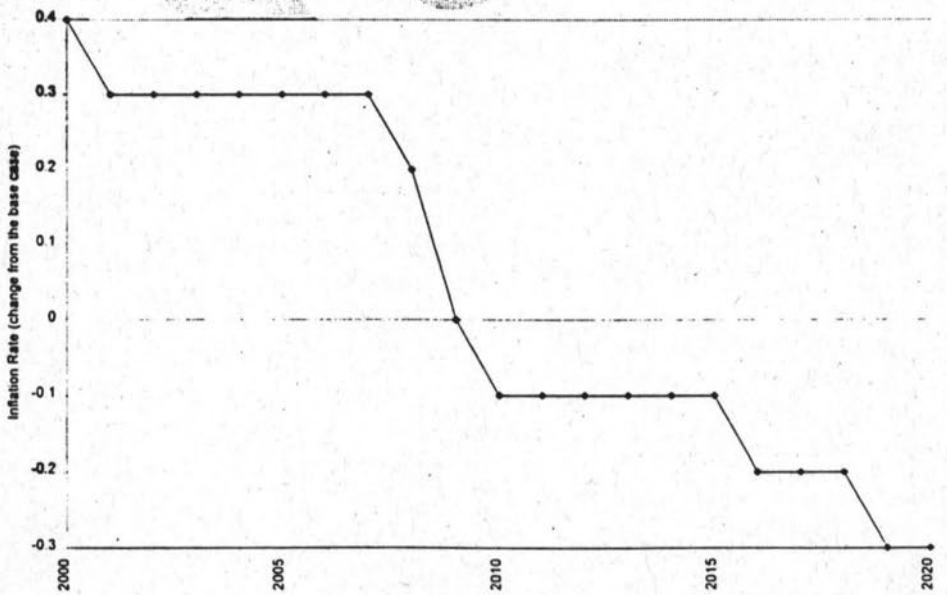
[3] Repetto, Robert and Dunkin Austin. "The Cost of Controlling CO2 Emissions: A Guide for the Perplexed." *World Resources Institute* (Forthcoming).

Figure 4: DRI-DRI Energy 1990 Level Case, No International Trading--Unemployment Rate



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 5: DRI-DRI Energy 1990 Level Case, No International Trading--Inflation Rate

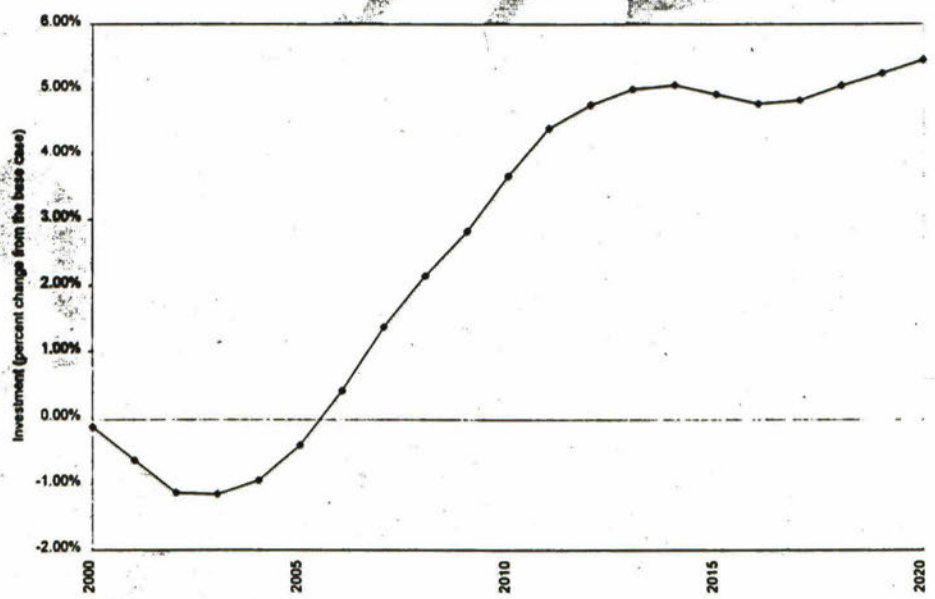


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Investment policies are key to getting the economy back on track. In the baseline forecast, slow labor force growth of 0.8% per year leads to slow potential GDP growth, which results in slow capital stock turnover. The slower rate at which the capital stock is renewed is of direct consequence to mitigating carbon and other related emissions, since improvements in energy-efficiency or carbon-abating technologies generally must be embodied in the capital stock in order to be effective. Thus, any global climate change policy, to be effective, must focus on investment at the expense of consumption. The deficit reduction policy option, one of the several revenue recycling options examined, promotes savings, which boosts this investment.

The DRI model suggests that investment under a climate change policy scenario begins to exceed investment in the baseline by 2006, as seen in Figure 6. By the time the policy is fully implemented in 2010, investment exceeds the baseline by about $50 billion (1992$), with this difference rising to about $100 billion in 2020. Personal Consumption Expenditures (PCE), on the other hand, remain below the baseline level throughout the forecast period, so that PCE drops by about $80 billion in 2008, as seen in Figure 7. After the trough in 2008, PCE gradually moves toward baseline by 2020.

Figure 6: DRI-DRI Energy 1990 Level Case, No International Trading--Investment

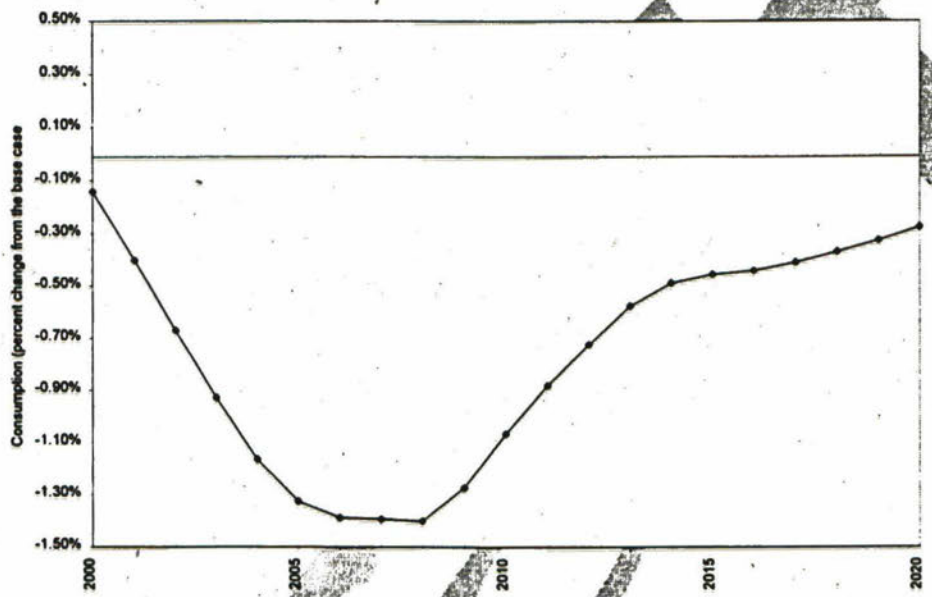


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

The faster rate of investment drives the rebounding of real economic growth in the later years of the model simulation. But it should be noted that consumption does not rebound in the same manner, although it does recover from its peak losses, as seen in Figure 7. But consumption can be taken as the measure of economic activity that is closer to consumer "welfare" than total GDP,

which includes investment, because consumption includes all activities that are of direct consequence to households. Thus, while increases in investment drive the economy's growth path back to and perhaps even above its original trend, it does so by diverting resources away from uses that allow consumers to enjoy them directly in the short term.

Figure 7: DRI-DRI Energy 1990 Level Case, No International Trading--Consumption



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

The paths of consumption and investment following the imposition of a climate change policy depend critically on assumptions regarding the manner in which revenue flows related to the allocation of emissions permits are managed and the conduct of monetary policy by the Federal Reserve. These sensitivities are discussed in a later section.

Among fuels, demand for coal bears the brunt of greenhouse gas stabilization The reduction in energy-related greenhouse emissions in the 2010 time frame will require a combination of three types of energy system changes: increased end-use efficiency, reduced end-use activity, or fuel-switching towards an increased market share of low- and no-carbon fuels in the energy mix. Increased end-use efficiency or reduced end-use activity tends to lower the demand for all fuels, while fuel-switching favors low- and no-carbon fuels, such as natural gas and renewable energy, relative to coal. The three models used by the IAT place different emphasis on these three strategies, with corresponding differences in projected fossil fuel impacts.

Table 4 presents the effects of carbon-limiting policies on the economy's energy consumption and fuel mix. Using the DRI model, total energy consumption falls from 105 quadrillion Btus (quads) in the base case in 2010 to a level of 88 quads under the policy, a reduction of 16 percent

in that year. By 2020, energy consumption in the economy has declined by 20 percent, from 109 quads to 87 quads, when compared to the base case for that year. The table shows comparable results using the Markal-Macro model, when the 1990-level emissions freeze produces a decline in projected energy consumption of 14 percent in 2010 and 16 percent in 2020. SGM model results are similar to both the DRI and Markal-Macro results; energy consumption drops by 15 percent in 2010, and 20 percent in 2020.

Table 4: Effects of Carbon Stabilization on Energy Consumption and Fuel Mix (quadrillion Btus)

	1990	2010		2020	
	Actual	Base case	1990 Level Case, No International Trading	Base case	1990 Level Case, No International Trading
DRI-DRI Energy					
Total U.S. Energy Consumption	84.3	105.3	88.2	108.9	86.7
Natural Gas	19.3	27.4	22.9	29.8	24.9
Oil	33.6	41.1	35.6	44.1	37.4
Coal	19.0	24.3	17.2	25.8	15.2
SGM					
Total U.S. Energy Consumption	84.3	107.0	91.4	113.0	90.0
Natural Gas	19.3	33.2	33.1	37.7	36.7
Oil	33.6	36.5	33.1	39.0	34.0
Coal	19.0	23.9	11.3	25.8	8.5
Markal-Macro[1]					
Total U.S. Energy Consumption	84.3	107.8	92.6	115.6	96.7
Natural Gas	19.3	29.0	30.7	35.1	36.7
Oil	33.6	43.4	37.9	45.0	40.1
Coal	19.0	22.5	9.4	24.6	4.7
NEMS					
Total U.S. Energy Consumption	n/a	n/a	n/a	n/a	n/a
Natural Gas	n/a	n/a	n/a	n/a	n/a
Oil	n/a	n/a	n/a	n/a	n/a
Coal	n/a	n/a	n/a	n/a	n/a

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM uses a similar rate of change in C/GDP. 1. Under the Markal-Macro results, the increase in the use of renewable energy sources, such as wind, account for the difference the total U.S. energy consumption and the sum of the component fuels. NEMS estimates are forthcoming.

DRI, Markal-Macro, and SGM demonstrate that dampened energy consumption and reduced carbon emissions are concentrated in coal use. As seen in Table 5, DRI results show that about 57 percent of the total emissions reductions in 2010 result from reduced demand for coal, 30 percent from oil, and 13 percent from natural gas. By 2020, 65 percent of emission reductions are generated from reductions in demand for coal. This translates to a 25 percent total emission reduction for coal in 2010 and a 36 percent reduction in 2020. Markal-Macro produces somewhat similar results: it shows that about 57 percent of total emissions reductions in 2010 occur due to reduced coal use; and 16 percent due to reduced oil use; while natural gas consumption is 5 percent above the base case. By 2020, coal accounts for about 80 percent of

emissions reductions. The SGM model results are also similar; i.e., coal is responsible for 80 percent of emissions reductions in 2010 and 2020.

The different spread of percent of total emissions reductions by fuel occurs because renewable energy sources and increases in the consumption of natural gas play important roles in the Markal-Macro and SGM models. It is also true because DRI's model sees strong transportation demands and more limited technological prospects for serving it, while transportation choices do not take into account price expectations. This is in contrast to DRI's treatment of the utility sector, which is relatively forward looking when examining fuel choices.

Table 5: 1990 Level Case, No International Trading--
Percent of Total Emissions Reduction by Fuel

	2010	2020
DRI-DRI Energy		
Natural Gas	13	8
Oil	30	28
Coal	57	65
SGM		
Natural Gas	0	3
Oil	18	18
Coal	82	79
Markal-Macro		
Natural Gas	-5	-4
Oil	16	15
Coal	57	80
NEMS		
Natural Gas	n/a	n/a
Oil	n/a	n/a
Coal	n/a	n/a

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. NEMS estimates are forthcoming.

On the demand side, according to DRI, about 46 percent of total emission reductions in 2010 come from the electric sector due to fuel switching and decreases in demand for electricity, 26 percent come from reduced demand for transportation and 19 percent come from reduced demand by the industrial sector, as shown in Table 6. The commercial and residential sectors contribute a combined 8 percent to the total of emissions reductions. The corresponding estimates obtained from the Markal-Macro model show that electricity uses account for 40 percent of total reduction in emissions, and transportation, industrial, and residential and commercial uses for 16 percent, 17 percent, and 15 percent, respectively.

Table 6: 1990 Level Case, No International Trading
Percent of Total Emissions Reduction by Demand Sector

	2010	2020
DRI-DRI Energy		
Residential	5	4
Commercial	3	2
Industrial	19	21
Transportation	27	25
Electricity	46	47
SGM		
Residential	n/a	n/a
Commercial	n/a	n/a
Industrial	n/a	n/a
Transportation	n/a	n/a
Electricity	n/a	n/a
Markal-Macro		
Residential and Commercial	15	15
Industrial	17	22
Transportation	16	17
Electricity	40	53
NEMS		
Residential	n/a	n/a
Commercial	n/a	n/a
Industrial	n/a	n/a
Transportation	n/a	n/a
Electricity	n/a	n/a

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM uses a similar rate of change in C/GDP. SGM does not generate data by demand sector. NEMS estimates are forthcoming.

Thus, across models and when viewed from different perspectives, the majority of reductions in emissions obtained under the broadest strategies comes from reducing utility consumption of coal. Reducing coal use under utility boilers is generally the largest, cheapest option to reduce carbon emissions in the economy. This is accomplished through better operating rates and through the substitution of gas-fired combined-cycle units for coal-fired units. The implicit price of carbon obtained in most model runs is usually the one that accomplishes this transition in electricity baseload. The range of carbon values -- generally about $100 per ton in the no trading cases -- is as high as it is because most coal-fired units are fairly old and already fully amortized. Thus, their product costs mainly consist of fuel and operating and maintenance expenses but not capital costs. The price of coal, therefore, must rise considerably to make coal-fired electricity more expensive on the margin than electricity generated by a new gas-fired plant that entails new capital costs.

International trading of carbon permits among the Annex I countries leads to sizable reductions in costs needed to stabilize emissions. The discussion so far has centered on the how the U.S. economy reacts when the United States independently reduces emissions. However, establishing an international market to trade emissions permits is a preferred to unilateral action that has been

proposed by the United States for inclusion in a multinational agreement. The purpose of such a market would be to increase the efficiency and lower the cost of reducing global emissions by giving all emitters the incentive to search for least-cost solutions across national boundaries.

In brief, under a system of tradable permits, a country could either reduce emissions domestically or purchase additional emissions "rights" (i.e., permits) from other countries. Countries with opportunities to reduce emissions that cost less than the going permit price would have an incentive to reduce emissions and sell their "right to emit" for cash. Countries that had only high cost options to reduce emissions (that is, reduction options that cost more than the permit prices) could purchase emission permits. The forces of supply and demand would set the permit price and the market incentives would push the trading group, as a whole, to institute the least cost emissions reductions first. As a result, it costs less for the trading group, as a whole, to reach the target emissions levels, than it would for each country unilaterally to reduce its emissions to the target levels. Such a policy, of course, raises a variety of legal and institutional questions regarding how it would be implemented with certainty. These issues are not addressed here: instead, the simple assumption is made that the policy works as intended and least-cost approaches to abating carbon are identified and traded.

Using the SGM model, the IAT modeled two international trading scenarios. In the first, it examined the affects of establishing a permit market among the United States, Canada, Western Europe, Eastern Europe, Japan, the Former Soviet Union (FSU), and Australia (collectively known as Annex I countries under the Climate Convention). In the second scenario, it examined the effects of Joint Implementation, that is, establishing a wider permit market that includes the rest of the world. These scenarios are compared to a scenario in which each of the Annex I countries independently implemented our "starting point" scenario for stabilizing carbon emissions; that is, stabilizing emissions at 1990 levels in 2010 with a ten year phase in, where revenues are used to reduce the deficit, and under the assumption of moderate technological change (i.e., a 0.25 percent increase over the baseline in the annual increase in energy or carbon efficiency).

International emissions trading calls into question one of the basic assumptions regarding international compliance when performing the estimates. This concerns the case of the FSU. The "starting point" case assumes that all countries are restricted to their 1990 emissions level before they trade. The FSU nations, however, will have emissions below their 1990 levels for years to come. Thus, under this rule, they would be able to sell to other nations their "right to emit" up to their 1990 levels, but would not have to perform any actual emissions reductions. Thus, emissions trades would not result in "corresponding reductions" in annual emissions.

The IAT performed its analysis both with and without "corresponding reductions." The case without "corresponding reductions" allows the FSU to sell emissions rights up to its 1990 base. The case with "corresponding reductions" does not allow these trades. Instead the IAT specified that if a nation's emissions were below their 1990 level in the base case, its baseline for the purposes of trading was shifted down from the 1990 level to whatever the nation's actual emissions would be. For example, the FSU had carbon emissions of 1050 million metric tons (MMT) in 1990, and is projected to have emissions of 836 MMT in 2010. Their baseline in

2010, therefore, is 836 MMT, even though it is lower than the 1990 level. Thus, any tons "sold" from the FSU in these simulations represent actual emissions reductions. The results obtained using the SGM model appear in Tables 7a and 7b.

Under the Annex I trading scenario, the United States, Canada, Western Europe, Japan, and Australia each bear real costs for emissions reduction. The losses experienced by the different nations reflect the economic assumptions made for them (which are presented earlier in this report, in Table 2) and their energy policies to date. Japan, for example, is projected to have relatively slow economic growth and already has relatively high energy prices and an extensive nuclear program. Thus, it is not projected to have strong growth in emissions over the next few decades. Japan has a high implicit price of carbon ($268 per ton) as shown in Table 8. Western Europe fares somewhat worse than the United States, since its economic growth is projected to be stronger, and its energy policies have already been raised.

Table 7a: SGM 1990 Level Case--GDP Impacts to Annex I Countries
No Trading vs. Annex I Trading,

	No Trading					Annex I Trading (With Corresponding Reductions)				
	2000	2005	2010	2015	2020	2000	2005	2010	2015	2020
Australia	0.0%	-0.2%	-0.5%	-0.4%	-0.2%	0.0%	-0.1%	-0.3%	-0.2%	-0.1%
Canada	0.0%	-0.4%	-1.1%	-1.1%	-1.1%	0.0%	-0.1%	-0.4%	-0.3%	-0.2%
Eastern Europe	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%
Former Soviet Union	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.5%	0.6%	0.5%
Japan	0.0%	-0.2%	-0.6%	-0.4%	-0.3%	0.0%	-0.1%	-0.2%	-0.1%	-0.1%
Western Europe	0.0%	-0.2%	-0.7%	-0.4%	-0.2%	0.0%	-0.1%	-0.3%	-0.2%	-0.1%
United States	0.0%	-0.1%	-0.2%	-0.2%	-0.2%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

Table 7b: SGM 1990 Level Case--GDP Impacts to Annex I Countries
No Trading vs. Annex I Trading

	No Trading					Annex I Trading (With out Corresponding Reductions)				
	2000	2005	2010	2015	2020	2000	2005	2010	2015	2020
Australia	0.0%	-0.2%	-0.5%	-0.4%	-0.2%	0.0%	0.0%	-0.1%	-0.2%	-0.1%
Canada	0.0%	-0.4%	-1.1%	-1.1%	-1.1%	0.0%	0.0%	-0.2%	-0.2%	-0.2%
Eastern Europe	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.7%	0.5%
Former Soviet Union	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.5%	0.5%
Japan	0.0%	-0.2%	-0.6%	-0.4%	-0.3%	0.0%	0.0%	-0.1%	-0.1%	-0.1%
Western Europe	0.0%	-0.2%	-0.7%	-0.4%	-0.2%	0.0%	0.0%	-0.2%	-0.2%	-0.1%
United States	0.0%	-0.1%	-0.2%	-0.2%	-0.2%	0.0%	0.0%	-0.1%	-0.1%	-0.1%

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

GDP losses in Canada are the most severe among the Annex I countries. Canada is already less carbon intensive, but not as energy efficient as other Annex I countries. For example, Canada's carbon to population ratio is about 17 percent below that of the United States, while its energy to GDP ratio is about 46 percent higher. Canada also relies more heavily on non-carbon sources of

energy, such as hydroelectrical generation, making emissions reductions more difficult to come by.

Table 8 shows the implicit price of carbon by country without trading, trading with Annex I countries, and with Joint Implementation with the developing countries. The United States shows smaller output losses than Japan or Western Europe predominantly because it has more "cheap" carbon-abating opportunities. Thus, it is somewhat easier for the United States to reach emission targets than other regions, which have already "picked the low fruit."

Table 8: Implicit Price of Carbon (1995$) Under Annex I Trading and Joint Implementation--SGM 1990 Level Case

	2010					2020				
	No Trading	Annex I Trading		Joint Implementation		No Trading	Annex I Trading		Joint Implementation	
		with CR	without CR	with CR	without CR		with CR	without CR	with CR	without CR
Australia	132	56	23	20	9	126	50	35	16	12
Canada	222	56	23	20	9	252	50	35	16	12
China	*	n/a	n/a	20	9	*	n/a	n/a	16	12
Former Soviet Union	0	56	23	20	9	0	50	35	16	12
Eastern Europe	0	56	23	20	9	0	50	35	16	12
India	*	n/a	n/a	20	9	*	n/a	n/a	16	12
Japan	268	56	23	20	9	257	50	35	16	12
Korea	*	n/a	n/a	20	9	*	n/a	n/a	16	12
Mexico	*	n/a	n/a	20	9	*	n/a	n/a	16	12
Western Europe	130	56	23	20	9	139	50	35	16	12
United States	82	56	23	20	9	107	50	35	16	12
Rest of World	*	n/a	n/a	20	9	*	n/a	n/a	16	12

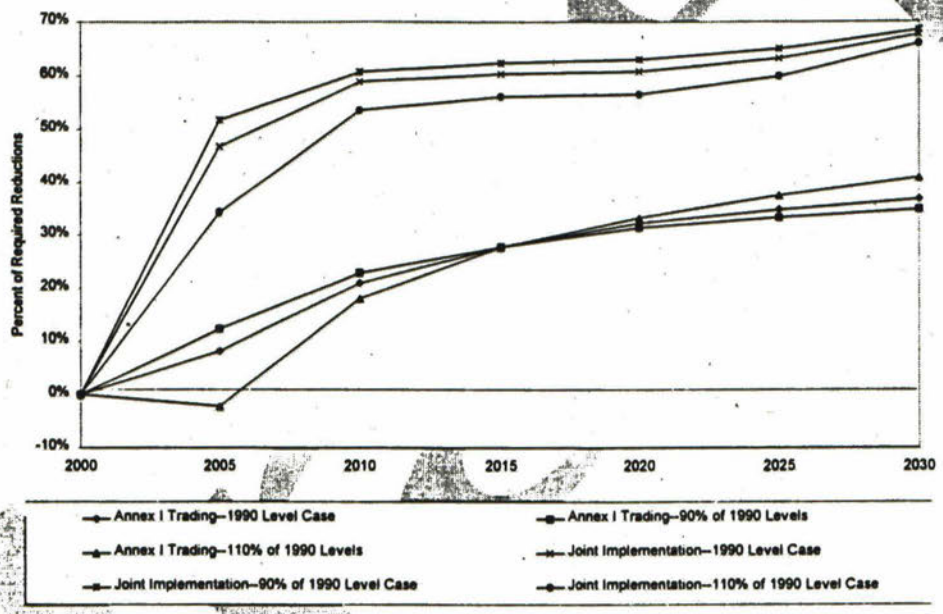
Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in C/GDP. * indicates the cell is blank because the country is a non-Annex I country. CR=corresponding reductions.

Under Annex I trading with "corresponding reductions," the implicit price of carbon falls dramatically--to $56 in 2010 and $50 in 2020. All countries gain through these lower permit prices, because as a whole they achieve stabilization at 1990 levels more cheaply. The source of these cheap emissions is the FSU and the Eastern European nations. The implicit price of carbon falls because it is cheaper for all of the industrialized nations to pay for carbon abatements in those nations (due to lax environmental standards and slow economic growth) than to pursue domestic options only. These nations gain as they become emissions permit sellers under Annex I trading. If "corresponding reductions" are not required, the FSU would be allowed to sell permits up to its 1990 level further depressing the price to $23 per ton in 2010 and $35 in 2020.

Under Annex I trading with "corresponding reductions," the United States purchases 72 million metric tons of permits from the FSU and Eastern Europe in 2010 at a cost of $4 billion ($95), which offsets $5 billion of abatement expenditures within the United States. U.S. purchases of permits abroad increases to 157 million metric tons of permits in 2020 at a cost of $7.8 billion, which offsets $12.2 billion of cost increases that would have occurred domestically if the U.S. did not participate in international trading.

Joint Implementation with developing countries reduce the costs of permit prices even further. Joint implementation -- emissions trading on a global scale -- reduces the permit price further, to $20 in 2010 and $16 in 2020 (with corresponding reductions). If corresponding reductions are not required the implicit price of carbon falls to $9 in 2010 and $12 in 2020. Under this broader market for tradeable emissions permits the FSU and Eastern Europe lose their monopoly on permit sales. Specifically, Joint Implementation encourages China and India to reduce their use of coal and enter the market as emissions permit sellers. As shown in Figure 8, imports of carbon permits are greater under Joint Implementation than under Annex I trading.

Figure 8: U.S. Imports of Carbon Permits Under Alternate Mitigation Targets--Annex I Trading and Joint Implementation

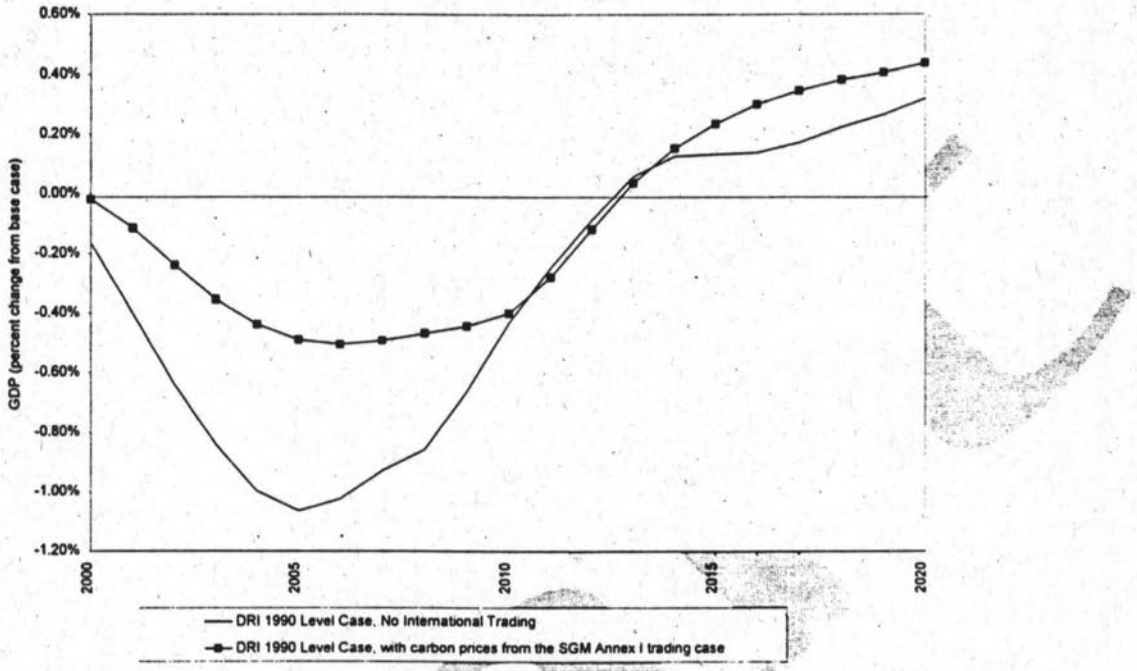


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

Using the SGM implicit carbon prices from Annex I trading to simulate macroeconomic conditions for the DRI Model moderates the short-term economic effects of emissions reductions. The IAT incorporate Annex I implied permit prices estimated by the SGM model under permit trading, with corresponding reductions into the DRI model. For in 2010 SGM's Annex I trading implicit price of carbon estimate ($56) was incorporated into the DRI model.

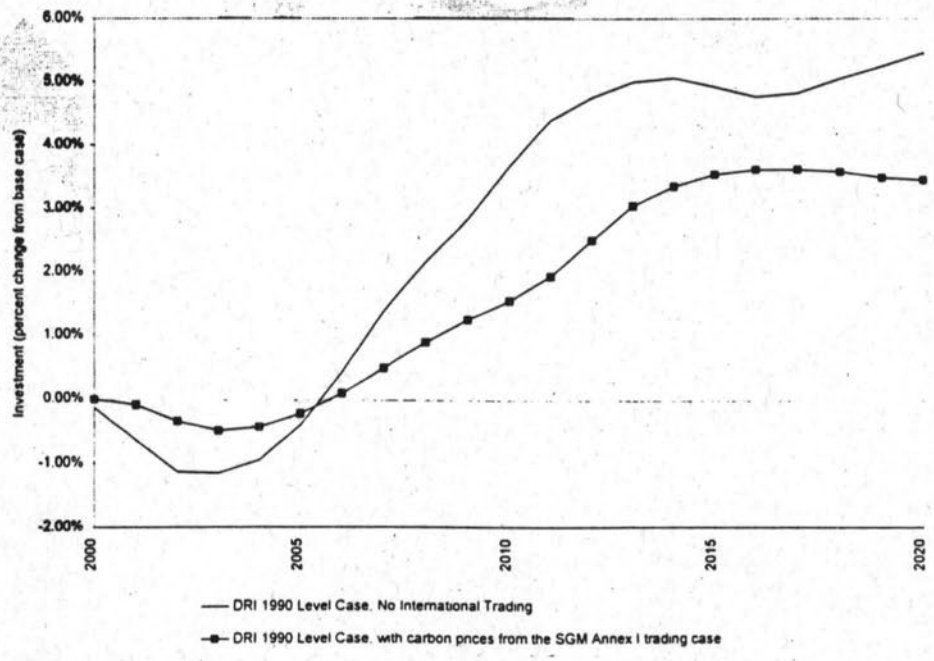
The results from the DRI model using the SGM permit trading implied permit prices are represented in Figures 9, 10, and 11. As shown in Figure 9, the maximum effect on GDP is less than half, 0.5 percent less than the baseline in 2006 compared with about one percent in 2005. The lower permit prices also has a somewhat dampening effect on the increase in investment under the no trading case, but shows a much improved effect on the impact on consumption, a -0.7 percent change in 2010 compared with a -1.4 percent change in 2008, and reaches the baseline consumption estimates in 2018.

Figure 9: DRI-DRI Energy 1990 Level Case with and without Annex I Trading--GDP



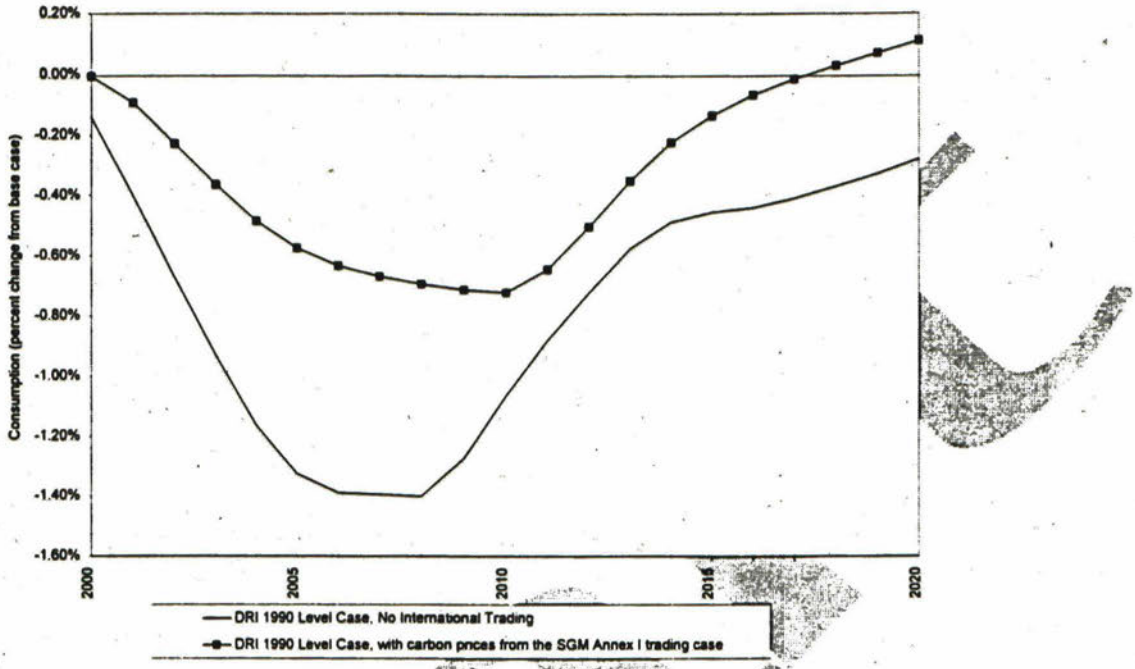
Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 10: DRI-DRI Energy 1990 Level Case with and without Annex I Trading--Investment



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 11: DRI-DRI Energy 1990 Level Case with and without Annex I Trading--Consumption



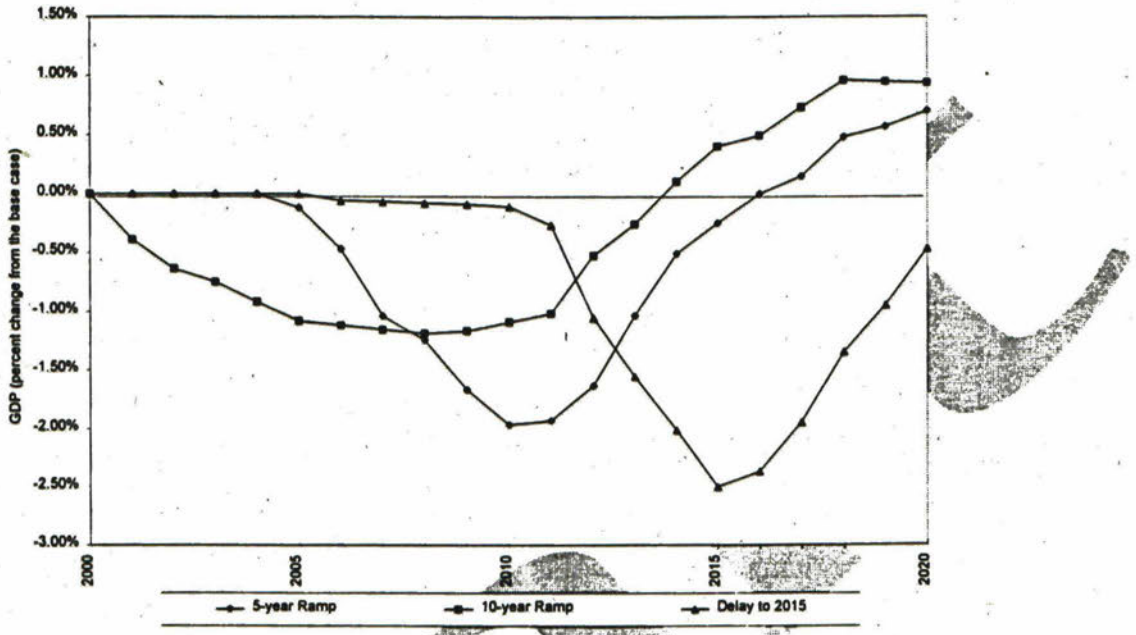
Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Important Sensitivities

The following represents a number of variations from the "starting point" scenario that the IAT analysts examined to address a number of factors that will influence the climate change policy process. These include the effects of: (1) timing, including different transition periods to full implementation and delaying implementation; (2) lower or higher emission level targets; (3) different revenue recycling options, including comparing the deficit reduction case with scenarios where revenues are distributed to consumers, distributed to business, and a combination of both consumers and business; (4) policy announcement on the rate if technological innovation and diffusion as well as the steps needed to achieve a higher level of innovation and diffusion; (5) other collateral environmental benefits; and (6) international trade; and (7) Federal Reserve reaction assumptions in the DRI model.

Increasing the implementation period from 5 to 10 years dampens the negative effects on GDP. Delaying implementation until 2015 does little to improve GDP effects. The IAT examined differing effects on GDP of a 5-year and a 10-year implementation period for the "starting point" scenario with the NEMS model. These results are shown in Figure 12. A 5-year ramp-up between 2005 and 2010 results in a maximum output loss in 2010 that is 65 percent greater than that associated with a ten year ramp-up and a return to the baseline two years later. Thus, shorter transition periods result in a more pronounced economic cycle in response to policy--a sharper downturn and deferred recovery.

Figure 12: NEMS 1990 Level Case, No International Trading--Sensitivity to the Length of the Implementation Period and to Implementation Timing



Note: These simulations were conducted using DRI and the NEMS Energy Model and they do not conform in detail to those conducted using DRI and the DRI Energy Model. 5-Year and 10-Year Ramp to 1990 Levels in 2010; 1990 Levels in 2015 using a 5-Year ramp-up. Revenues are used for Federal deficit reduction, assuming 1.25 percent annual decrease in E/GDP.

Figure 12 also shows the result of delaying the implementation by 5 years, to 2015 combined with the shorter 5-year ramp-up period. GDP effects for the delayed case are less severe in the initial period, but become greater than either the 5-year or 10-year ramp-up to stabilization in 2010.

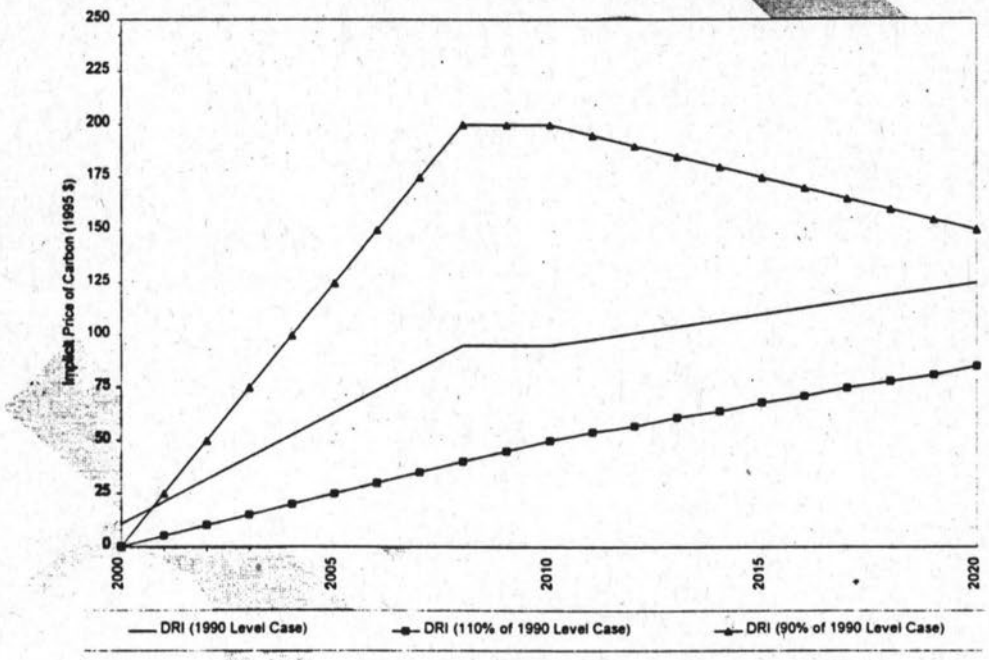
Raising or lowering emission targets lead to obvious results--more stringent emission targets lead to greater economic losses while less stringent ones have less severe impacts The three models were used to analyze how changes in the level of emissions affect the implicit price of carbon. If the emission target for the year 2010 and beyond is raised (made less severe) to a level equal to 110 percent of the 1990 emissions level (that is, to a target of 1,472 million tons as opposed to 1,338 million tons), then the DRI model estimated that the implicit price of carbon drop almost by half -- to about $50 per ton of carbon, while the SGM model dropped from $81 to $37. The very large decline in the implicit price of carbon reflects the fact that additional emissions reductions are progressively harder to find. On the other hand, a more stringent target, one that freezes emissions at 90 percent of their 1990 level in the year 2010 and beyond, leads to an implicit price of carbon of $200 per ton in 2010 and $150 per ton in 2020, according to the DRI model. The SGM model estimated that the implicit price of carbon would be $145 and $183 in 2010 and 2020, respectively. The implicit price of carbon generated by Markal-Macro for the 90 percent of the 1990 level case with no international trading would be $187 and $207 in 2010 and 2020, respectively. Table 9 and Figures 13 and 14 describe the sensitivity of these results using DRI, SGM, and Markal-Macro.

Table 9: Sensitivity of the Implicit Price of Carbon to the Stringency of the Emissions Target No International Trading

	2010	2020
DRI-DRI Energy		
Carbon Emissions 90% of 1990 Level Case	200	150
Carbon Emissions 110% of 1990 Level Case	50	85
SGM		
Carbon Emissions 90% of 1990 Level Case	145	183
Carbon Emissions 110% of 1990 Level Case	37	56
Markal-Macro		
Carbon Emissions 90% of 1990 Level Case	187	207
Carbon Emissions 110% of 1990 Level Case	101	93

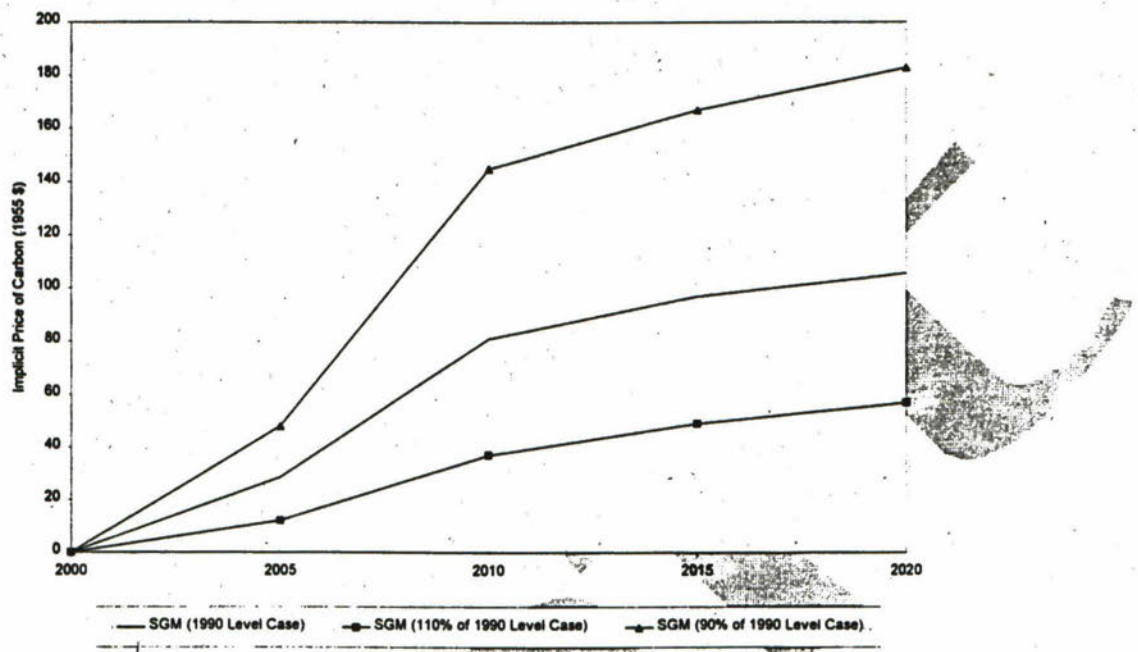
Note: 10 year phase-in with revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM uses a similar rate of change in C/GDP.

Figure 13: DRI-DRI Energy No International Trading--Sensitivity of the Implicit Price of Carbon to the Stringency of the Emissions Target



Note: 10 year phase-in with revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 14: SGM No International Trading--Sensitivity of the Implicit Price of Carbon to the Stringency of the Emissions Target



Note: 10 year phase-in with revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

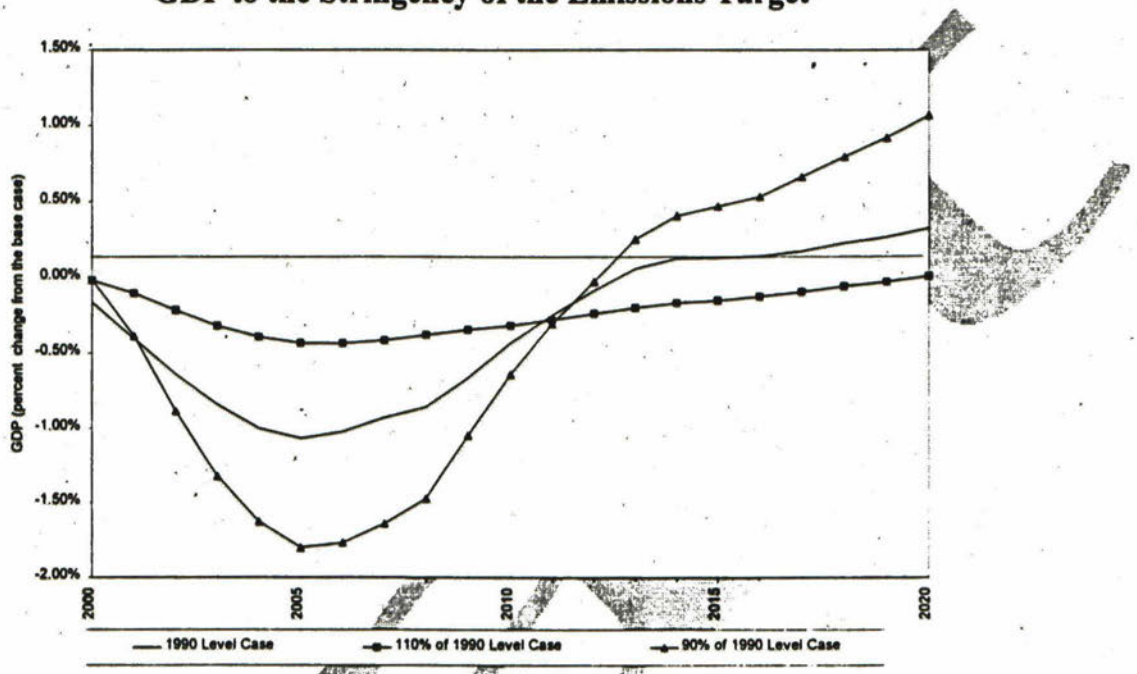
In 2020, permit prices rise to about $85 compared with the $125 permit price under stabilization. Using the DRI model, an emissions target of 90 percent of 1990 level results in an implicit price of carbon of $200 per ton in 2010 and $150 in 2020. Unlike in the other cases, the implicit price of carbon falls after 2010. This is because the initial price increase is large enough to set in motion a series of capital stock improvements, particularly in utilities, that reduce the ongoing level of emissions by enough to allow the implicit price to fall in the future. Thus, this result is predicated on the idea that future price expectations could be wrong. In fact, if decision makers had perfect price expectations, the implicit price of carbon would lie somewhere between these two values over the period.

It is no surprise that the 90 percent of 1990 emissions case results in a more severe decline of GDP in the transition period. But what is surprising, and questionable, is that this scenario also has a greater long-term potential for economic recovery. As shown in Figure 15, GDP declines to a peak loss of 1.9 percent below the base case in 2005. It recovers to the base case level in 2013 and increases to 1.0 percent above the base case in 2020. The long-term rebound effect results from a greater amount of revenue used for deficit reduction (or debt retirement), which pushes interest rates down substantially and drives up investment. The magnitude of this result is questionable.

The DRI model, as discussed, is prone to depicting large effects of interest rates on investment. Thus, when confronted with a very large implicit price of carbon and, in turn, large amounts of forced saving, either through deficit reduction or by grandfathering these new property rights to

firms, it produces much higher levels of investment and a higher long-term growth path. The reality is probably more moderate at both ends. In essence, this case appears to tax the ability of the model to manage these revenue flows.

Figure 15: DRI-DRI Energy No International Trading--Sensitivity of GDP to the Stringency of the Emissions Target



Note: 10 year phase-in with revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

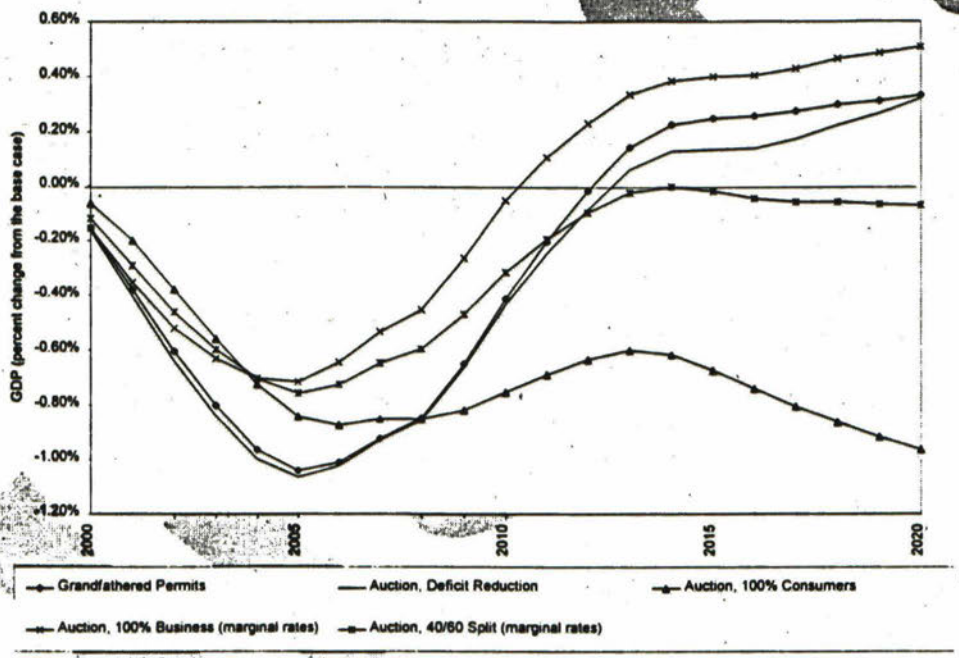
The portion of total emission reductions from coal and oil in both the 90 percent and 110 percent of 1990 Level Case, No International Trading, increases only slightly--about 5 percentage points--while total emission reductions from natural gas change significantly. In 2010, under stabilization, about 13 percent of total emission reductions are from natural gas. Under a 10 percent increase in the target (that is, a target of 90 percent of 1990 emissions), about 9 percent of total emission reductions are from natural gas. This occurs because the substitution of gas for coal in electric utilities is not enough to achieve the bulk of the 90 percent (more stringent) target. Additional emissions reductions must be found, which forces the burden to be spread more evenly among fuel types and sectors.

Adopting a revenue recycling option that favors capital formation leads to less impact on the economy during the transition and greater returns to the economy in the long term. The IAT looked at a number of revenue recycling policies in addition to the deficit reduction case. These options are depicted in Figure 16. These include:

- "grandfathering" permits to producers, meaning that every carbon-emitter would be given sufficient permits to allow them to emit at their 1990 level. The permits allowing them to do so would then be traded freely, allowing a least-cost response to the problem to emerge;

- a 100 percent recycling of any revenues from permit auctions to consumers through a reduction in the personal income tax;
- a 100 percent return to business through a reduction in the marginal rates of the corporate income tax; or
- a 40/60 split to consumers and businesses, in proportion to their shares of energy use, through tax rate reductions.

Figure 16: DRI-DRI Energy 1990 Level Case, No International Trading--Sensitivity of GDP to Revenue Recycling Options



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Assuming a 1.25 percent annual decrease in E/GDP.

According to the IAT analysis, the revenues generated from the implementation of this policy have the most positive effect when returned through either the deficit reduction plan, grandfathered permits, or to business through lower taxes. Revenue recycled to consumers, in either case, result in a greater and longer-term reductions in GDP, when measured against the baseline, but would have correspondingly lower impacts on consumption.

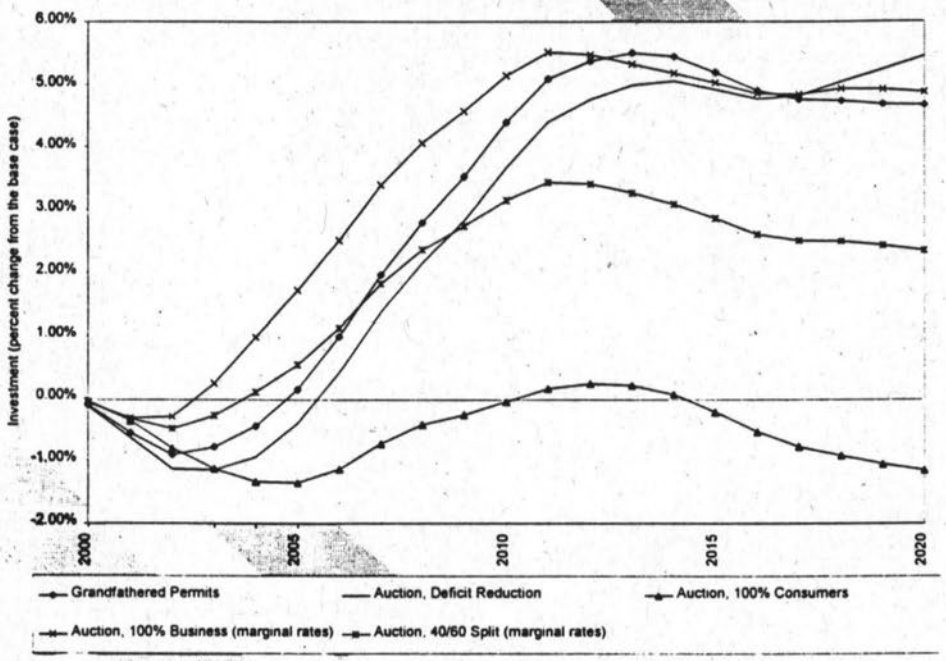
The revenue recycling options that lead to better economic outcomes are all those associated with greater investment and capital formation. Deficit reduction leads to lower interest rates, which lowers the cost of capital and facilitates investment. Recycling revenues to companies has the effect of increasing savings through apparent profits and provides the wherewithal for greater investment spending. Similarly, grandfathering permits to producers allows them to "assetize"

their right to produce emissions. This allows firms to realize gains on this "right" and again provides the wherewithal to invest.

Peak GDP losses during the transition period are less severe for the 100 percent to business and 40/60 split when accomplished through reductions in the marginal tax rates, (about 0.7 percent in 2005), compared with the other recycling options, (between 0.8 and 1.0 percent in that year).

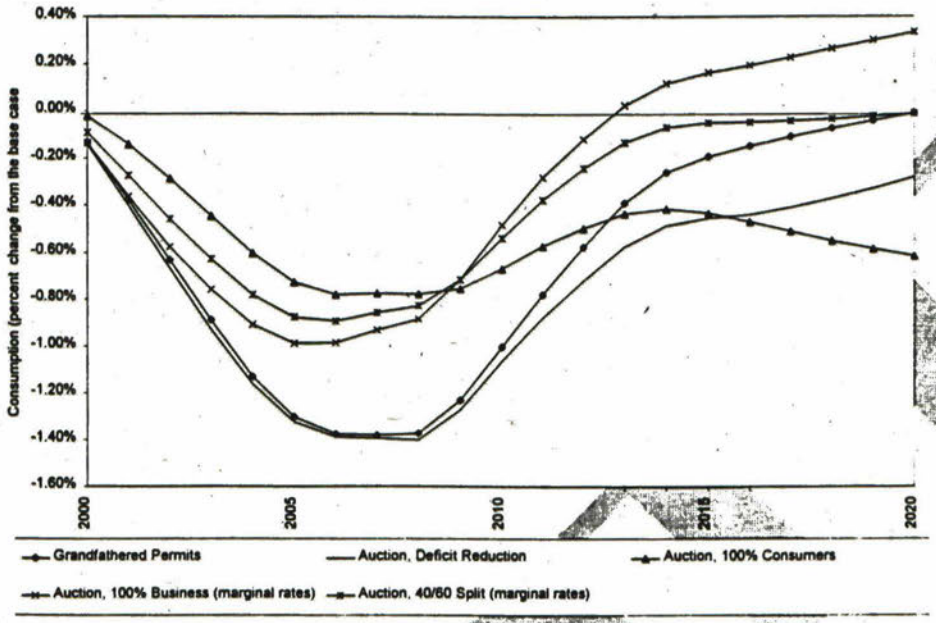
Figures 17 and 18 demonstrate the effects of revenue recycling on investment and consumption, in relation to the effect on GDP, as shown in the previous figure. As these figures show, the key to economic recovery among the revenue recycling options is to improve investment in the economy.

Figure 17: DRI 1990 Level Case, No International Trading--
Sensitivity of Investment to Revenue Recycling Options



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Assuming a 1.25 percent annual decrease in E/GDP.

Figure 18: DRI-DRI Energy 1990 Level Case, No International Trading-- Sensitivity of Consumption to Revenue Recycling Options

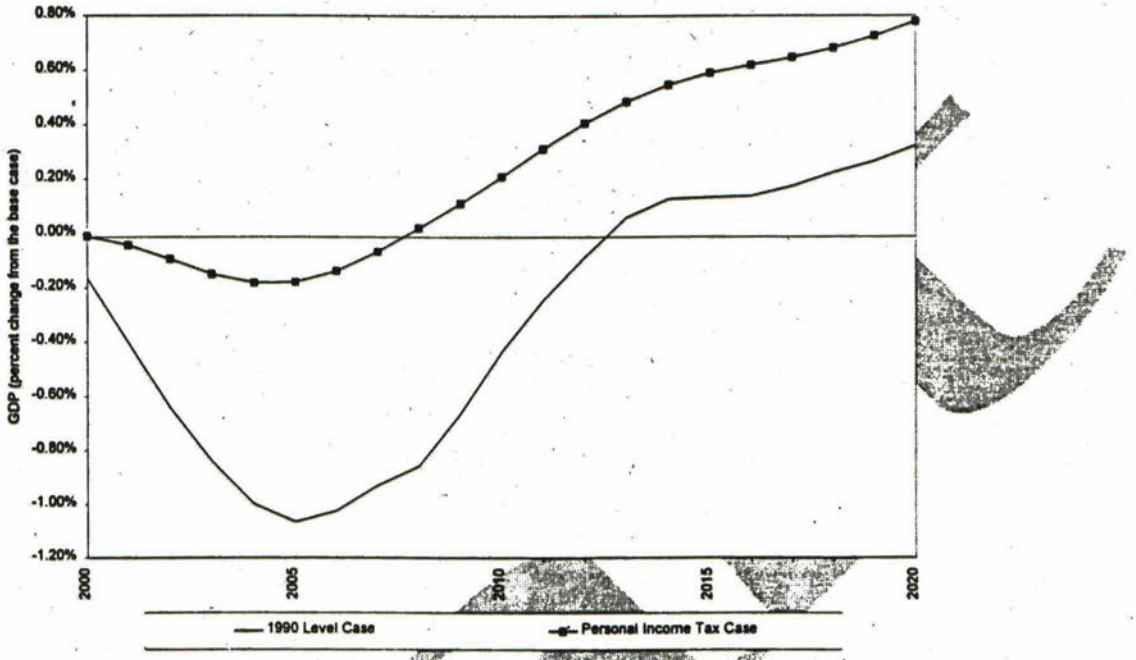


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Assuming a 1.25 percent annual decrease in E/GDP.

But the economic effects of these recycling options must be separated from the economic effects of carbon limitations *per se*. That is, economic analysis can make the case -- and models are often structured to demonstrate -- that reducing taxes on capital could improve long-term economic performance. In order to separate these effects, the 1990 emissions freeze accompanied by the use of any permit auction revenues to reduce the deficit was compared to a conventional increase in the personal income tax to achieve a comparable level of deficit reduction.

An increase in the personal income tax results in smaller economic losses and a more prompt economic rebound than a "deficit-equivalent" carbon reduction policy, as shown in Figure 19. Thus, while revenue recycling options can affect significantly the outcome of a carbon-reduction policy, the gains they create are unrelated to carbon reduction itself.

Figure 19: DRI-DRI Energy, No International Trading--Comparison of GDP, Recycling Revenue Recycling through Deficit Reduction and a Personal Income Tax Increase



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Assuming a 1.25 percent annual decrease in E/GDP.

Technological progress can be very helpful, especially in the long term. In its analysis of technology, the Markal-Macro model was used to determine whether higher levels of energy to GDP (E/GDP) savings are realistic. This analysis assumed two benchmarks for technological progress. In the first, the annual steady-state improvement in the economy's efficient use of energy was increased from the level of 1.0 percent in the AEO97 projections (found in the "no policy" base case) to a level of 1.25 percent. In the second case, this improvement in energy efficiency was increased to 1.75 percent. These two benchmark levels were obtained by examining the historical record and engineering estimates of potential technical progress. The point of the analysis was then to determine not only what effect technical progress might have on the economic effects of climate change policy, but also whether these rates were themselves technically feasible.

According to results from the Markal-Macro model, an improvement in the energy intensity of 0.25 percent annually, or a total annual decline of 1.25 in energy per unit of real output, can be achieved without great difficulty using both off the shelf technologies as well as new technologies that are near commercial viability. For example, such an improvement can be produced if the "hurdle rates" -- that is, the premium that households and firms appear to place in their discount rate when considering energy-efficiency investments -- declines by 81 percent. (For example, the discount rate households use when considering installing better insulation would have to fall from 46 percent to 23 percent). Thus, this improvement can be achieved through diffusion practices even without assuming a higher rate of innovation and technological

progress. In fact, some analysts believe that the enactment of the CCAP gets us to the 1.25 annual reduction.

The Markal model demonstrates that the higher technological case -- an increase in the annual rate of improvement in energy-efficiency of 1.75 percent -- is more difficult to achieve. Specifically, this higher level of energy savings cannot be achieved through better diffusion of best technical practices alone. Thus, new innovation must occur if we are to move beyond the 1.25 case. To achieve the 1.75 case, a new set of advanced energy efficiency technologies was added to the pool of technologies. These are part of the DOE research portfolio. Some of these technologies are aggressive in their scope: For example, the average fuel efficiency of new cars entering the vehicle fleet in the year 2020 is 33 miles per gallon in the 1.25 case, but rises to 55 miles per gallon for new cars entering the vehicle fleet in the 1.75 case. They were all deemed viable in an outside peer-review of the DOE program. The IAT will be circulating the technological assumptions necessary to achieve this 1.75 benchmark in a separate paper.

Rather than use the specific technological assumptions developed in Markal, the IAT represented technological progress in the DRI model by targeting a 1.75 percent annual rate of energy improvement in the economy for supply and end-use technologies in all sectors. For residential and commercial sector space heating/cooling and water heating, DRI assumed improved performance and cost characteristics for various heating and cooling equipment types and allowed the model to choose the optimal technologies. The model selects equipment based on life-cycle cost estimates, which include a "first-cost bias" that weights up-front capital costs more heavily than future fuel costs. This is comparable to the higher discount rates used in Markal.

For all other residential and commercial sector energy end-uses, the DRI model uses estimates of the average efficiency of all new and retrofit equipment purchases to determine fuel use requirements. These average efficiencies were increased to reflect improvements to technology performance and higher rates of diffusion for more efficient technologies. No changes were made to the rates of capital stock turnover and replacement.

Table 10 summarizes the effects of higher technological progress (that is, the 1.75 percent annual rate versus the 1.25 annual rate) on the economic effects of carbon-limiting policies. As seen, higher rates of technological progress can dramatically cut the implicit price of carbon and the associated transitional GDP losses. In the IAT "starting point" case (assuming 1.25 percent annual efficiency improvements), the implicit price of carbon in the three models is $95, $81 and $145 per ton in 2010 and $125, $106 and $130 per ton in 2020, for DRI, SGM, and Markal-Macro respectively. In the more advanced technology case, the implicit price of carbon is $88, $53, and $77 per ton in 2010 and $30, $51, and $35 per ton in 2020, for DRI, SGM and Markal-Macro respectively.[4]

[4] SGM applied the rate of carbon-efficiency for purposes of modeling technological improvement in energy-efficiency because it is easier for SGM to manage C/GDP than E/GDP. Carbon to GDP is an equally appropriate target and the differences in the results of the two specifications is not large.

Table 10: Sensitivity of Implicit Price of Carbon (1995$) to Rate of Technological Change --1990 Level Case, No International Trading

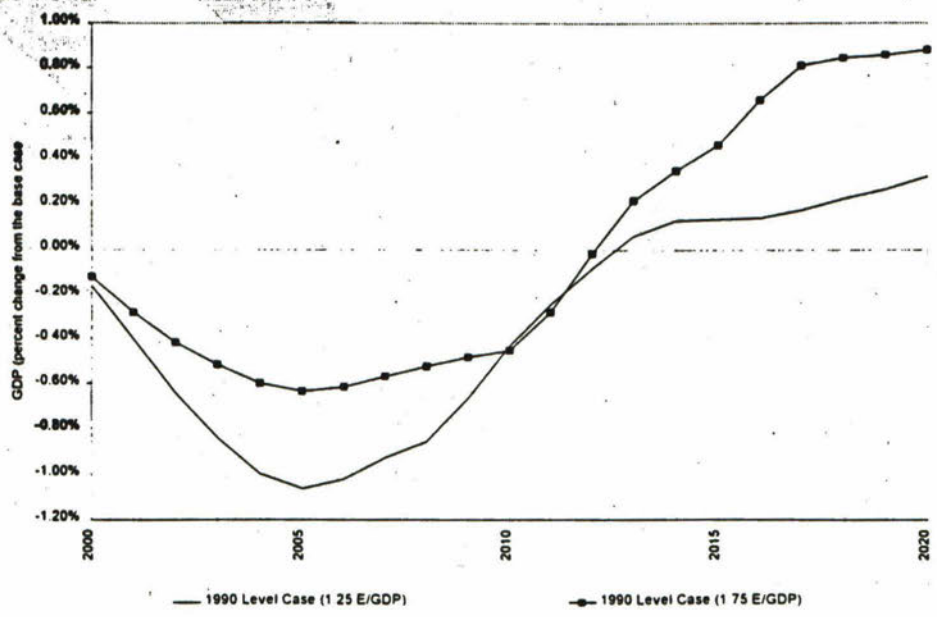
	2010		2020	
	1.25 Case	1.75 Case	1.25 Case	1.75 Case
DRI-DRI Energy	95	88	125	30
SGM	81	53	106	51
Markal-Macro	145	77	130	35

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for deficit reduction. DRI permit prices are generated using the annual rate of change in E/GDP. SGM uses a similar rate of change in C/GDP.

The peak GDP losses change accordingly, as shown in Figure 20. Using the DRI model, the peak output loss of -0.6 percent occurs in 2005, and the economy reaches its pre-policy growth path by 2012. The economy's shift to a higher growth path is also more pronounced, but here the result is more believable, because it is achieved through technological progress rather than revenue recycling that raises savings and fosters investment (in fact, the level of revenue recycling falls dramatically along with the implicit price of carbon).

The risk, however, is that these output gains may be somewhat overstated, because they do not account for the cost of the investments needed to reach the higher rate of technological progress. For example, firms will have to perform R&D that might distract them from other R&D tasks. If other R&D in the economy fell as energy- and carbon-related R&D was performed, overall productivity could drop and offset the economy's potential growth elsewhere. Alternatively, firms might increase total R&D effort, but leave the economy with fewer resources to do other things. While it is likely that these effects are second-order when compared to the effects of the improvement in carbon-related efficiency, they are still absent from the analysis.

Figure 20: DRI-DRI Energy 1990 Level Case, No International Trading--Sensitivity of GDP to the Rate of Technological Progress



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues used for deficit reduction.

These results indicate how important technological progress especially in the long term. A substantially higher rate of technological progress will improve short-term results. But it is capable of moving the analysis significantly once its effects are allowed to accumulate.

Reducing carbon emissions would also reduce other pollutants leading to direct economic benefit. The release of CO_2 is inherent in the activity of burning fossil fuel under current technologies. When CO_2 emissions in the utility, industrial boiler, and transportation sectors are reduced--either by using less fuel or by altering the mix of fuels--emissions of nitrogen oxides (NO_X) and sulfur dioxide (SO_2) are also reduced. In the atmosphere, NO_x and SO_2 react with ammonia to form ammonium nitrate and ammonium sulfate--significant components of fine particulate matter ($PM_{2.5}$), which may cause significant respiratory health problems and mortality.[5]

To investigate this effect, the NEMS model was used to estimate SO_2 and No_x emissions from electricity generation. When emissions are frozen at 1990 levels without trading, NEMS estimates decreases in utility NO_x and SO_2 emissions of 60 percent 47 percent, respectively in 2010.

The NEMS model provided emissions for each of the thirteen NERC regions. These results were then translated into disaggregated county level emissions by calibrating the NEMS results to the county specific data from EPA's National Particulate Inventory. The results were then fed through EPA's climatological regional dispersion model, which calculates the resulting air quality changes for each county. Finally, these results were used to estimate health and welfare effects of air pollution using EPA methodology developed under Section 812 of the Clean Air Act Amendments and reviewed and endorsed by EPA's Science Advisory Board.

Health benefits from reducing utility NO_x and SO_2 emissions in the "starting point" stabilization case include avoided mortality, avoided cases of chronic bronchitis, reduced acute bronchitis, fewer upper and lower respiratory symptoms, and a decline in lost work days. The results are very sensitive to the value attributed to avoided mortality, here estimated at $5 million per episode. When monetized these benefits could have a mean value of over $4 billion per quad of coal based energy generation. Assuming the estimated 7 quad reduction found by DRI (in Table 4), this would yield benefits of about $30 billion.

NOTE TO READERS: The IAT has not yet quantified the NO_x and SO_2 emission reductions from the industrial and transportation sectors or estimated the reduction in emissions of other criteria air pollutants--e.g., carbon monoxide and volatile organic compounds.

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[5] This analysis assumes that no new regulations to control criteria air pollutants would be implemented at the Federal or state level. It is important to note that actions are being considered at the Federal and state levels, including proposed new National Ambient Air Quality Standards, the Clean Air Policy Initiative, and new State Implementation Plans, that could reduce NO_x and SO_2 emissions from utilities over the next decade independently of controlling CO_2 emissions.

The losses experienced by the United States by handicapping energy-intensive industries in international trade need not be large. There is widespread and legitimate concern that forcing an implicit energy price increase on U.S. producers will disadvantage them substantially through trade, particularly with those countries outside of Annex I that might not be subject to the same emissions limits. The IAT used the DRI model to examine the overall trade implications of such a possible energy price differential. Industry trade results are discussed in the Industry Results section of this report.

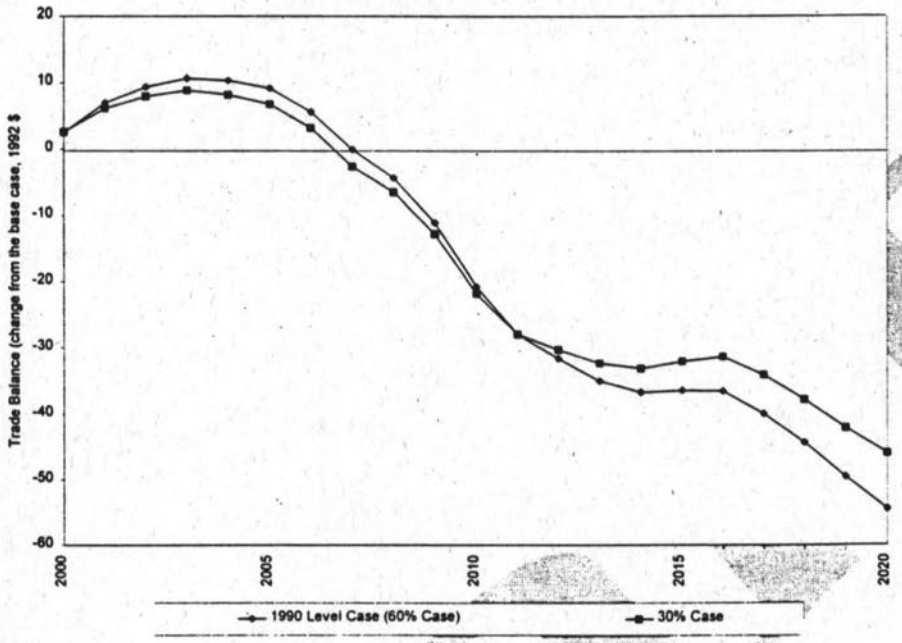
The DRI model examines overall trade effects by assuming a rate at which producers who export to the U.S. experience cost increases. In the aggregate, about 60 percent of imports of manufactured goods come from Annex I countries that will also experience higher implicit carbon prices (and, therefore, energy prices). The DRI model, therefore, assumes that manufactured imports, in general rise by an average of 60 percent of the full cost increase experienced by U.S. manufacturers.

This assumption, however, can be criticized as being too favorable to U.S. producers. If exporters from non-Annex I countries do not experience the cost increase that Annex I producers do, then they will no doubt substitute their production for Annex I production. Given this likely switching of export sources, the DRI model was also run with the assumption that foreign producers experience a cost increase equal to, on average, 30 percent as opposed to 60 percent of the U.S. cost increase.

Figure 21 presents the results under these two cases. The effect of the carbon-limiting policy on trade is depicted in these runs as surprisingly small. Some of the change in trade flows is reconciled in the DRI model by allowing the exchange rate to move, but as seen in Figure 22, the anticipated changes in the exchange rate themselves are not large and do not vary between the two assumptions. The small differences are not necessarily counterintuitive. There are already substantial energy price differences and differing environmental restrictions among trading nations that are larger than the price increase that results from the policies considered here.

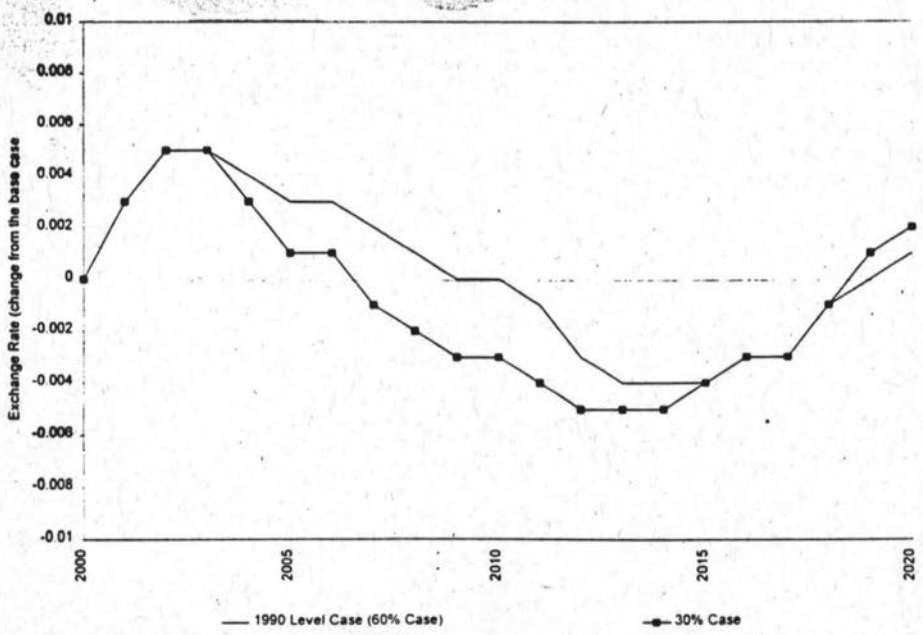
This aggregate treatment does not capture the effects that might be borne by specific industries due to their varying energy intensities. This more detailed examination is presented in Table 13, in the section on industry effects

Figure 21: DRI-DRI Energy 1990 Level Case, No International Trading--Sensitivity of the Trade Balance to International Price Ratio Assumptions



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 22: DRI-DRI Energy 1990 Level Case, No International Trading--Sensitivity of the Exchange Rate to International Price Ratio Assumptions



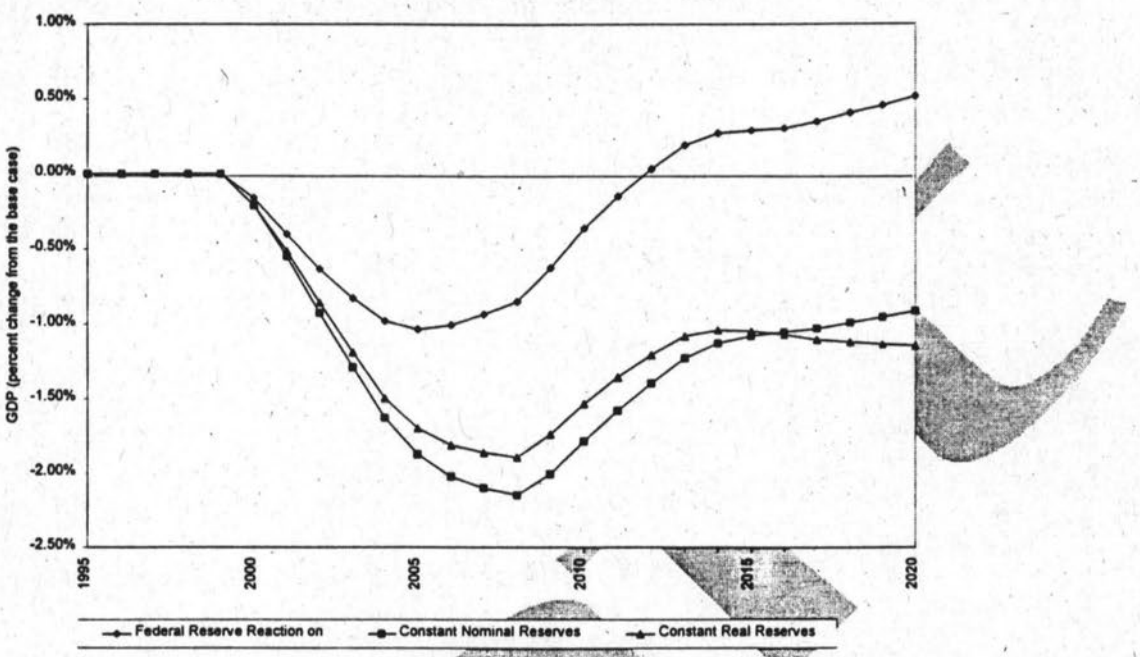
Note: Emissions stabilized at 1990 levels in 2010. Revenues used deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Alternative views about Federal Reserve policy can yield significantly different results. The Federal Reserve reaction function in the DRI model is an empirically derived estimation of likely Federal Reserve policy responses to changes in price inflation and the unemployment rate, among other variables. It is seen by DRI as the best proxy for Fed decisions in the model simulations. In essence, the reaction function will abate unemployment unless doing so would lead to high rates of inflation. This reaction function was used in the analysis as the default setting for the assessment of the alternative target profiles and implementation strategies. This section reports on a set of sensitivity analyses which consider different Federal Reserve actions: maintaining *nominal* non-borrowed reserves at baseline levels, and a case where *real* non-borrowed reserves are held at baseline. As can be seen from Figure 23, the effects of the alternative monetary policy assumptions are substantial.

If the Federal Reserve maintains nominal reserves at baseline, the size of the GDP loss is approximately doubled, from a 1 percent peak loss when the reaction function is on to just over 2 percent peak loss when more restrictive policies are pursued. There is essentially no difference between holding nominal non-borrowed reserves constant and holding real non-borrowed reserves constant. (The level of non-borrowed reserves in the banking system is an important Federal Reserve policy. If the Fed chooses to hold nominal reserves constant, then the funds that banks have to lend goes down when inflation rises. If real reserves are held constant, banks can lend more if prices go up.)

The sensitivity cases presented here, however, focus only on using the collected funds to reduce the federal deficit. The lower deficit (or greater surplus) makes it easier for the Fed to ease credit conditions without making inflation worse (indeed, as shown in Figure 5 inflation subsides by 2009 and inflation thereafter is lower than in the base case).The Federal Reserve can therefore do much to ease the economic transition in such an environment. But, the impact of the Federal Reserve reaction function fundamentally depends on how revenue recycling policy affects price inflation and the unemployment rate. In cases where price inflation remains high and unemployment losses are lower, the reaction function would ease credit conditions at a slower rate, and the divergence between the reaction function results and the nominal reserves at base case may be much smaller.

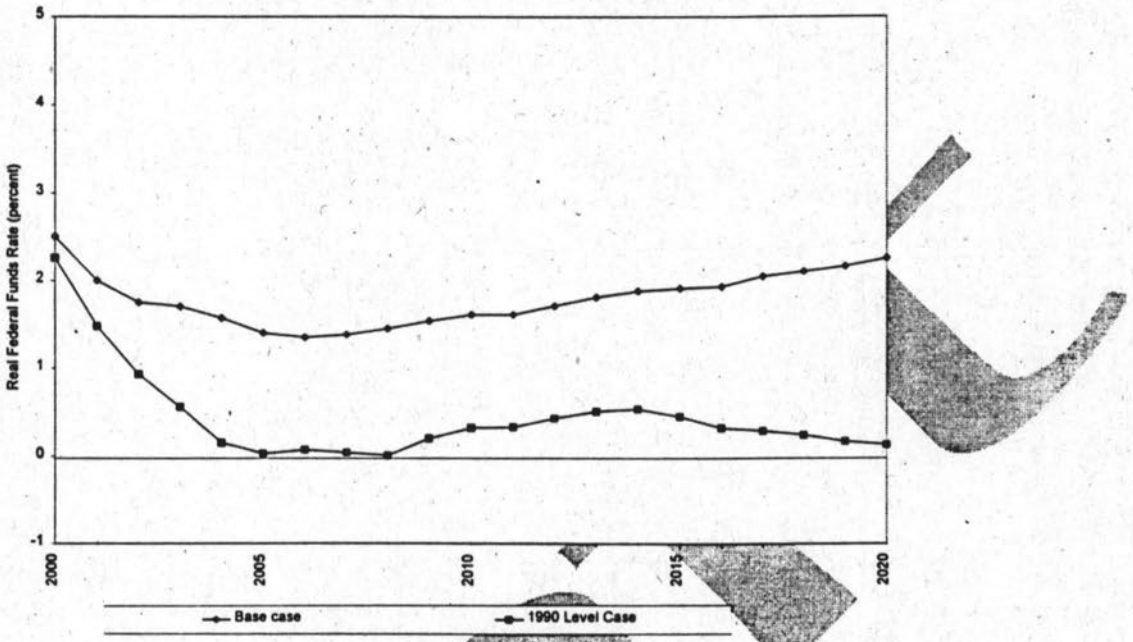
Figure 23: DRI-DRI Energy, No International Trading-- Sensitivity of GDP to Federal Reserve Policy Assumptions



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

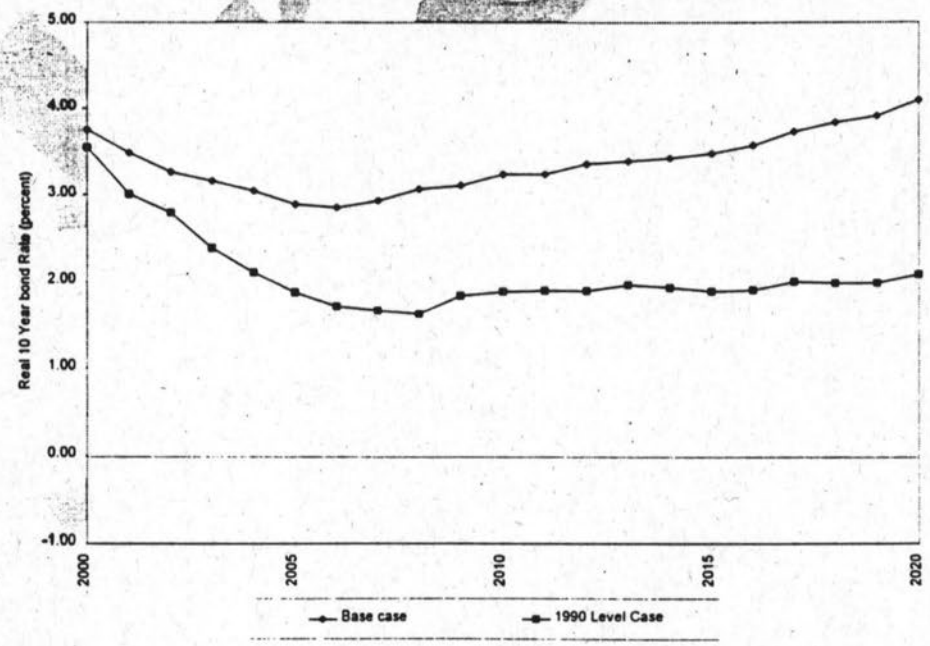
Figures 24, 25, and 26 show projections of the Federal Funds Rate, the 10-year Long Term Bond Rate, and the Federal Deficit/Surplus, respectively, from the DRI model with the Federal Reaction Function used in the analysis of the 1990 Level Case, No International Trading ("starting point"). These results show how important the treatment of revenue flows is in the DRI model. Substantial declines in the deficit (these runs were produced before the agreement to balance the budget in 2002 was achieved in May) allow interest rates to fall, which is the key to the economy's investment response.

Figure 24: DRI-DRI Energy 1990 Level Case, No International Trading-- Real Federal Funds Rate



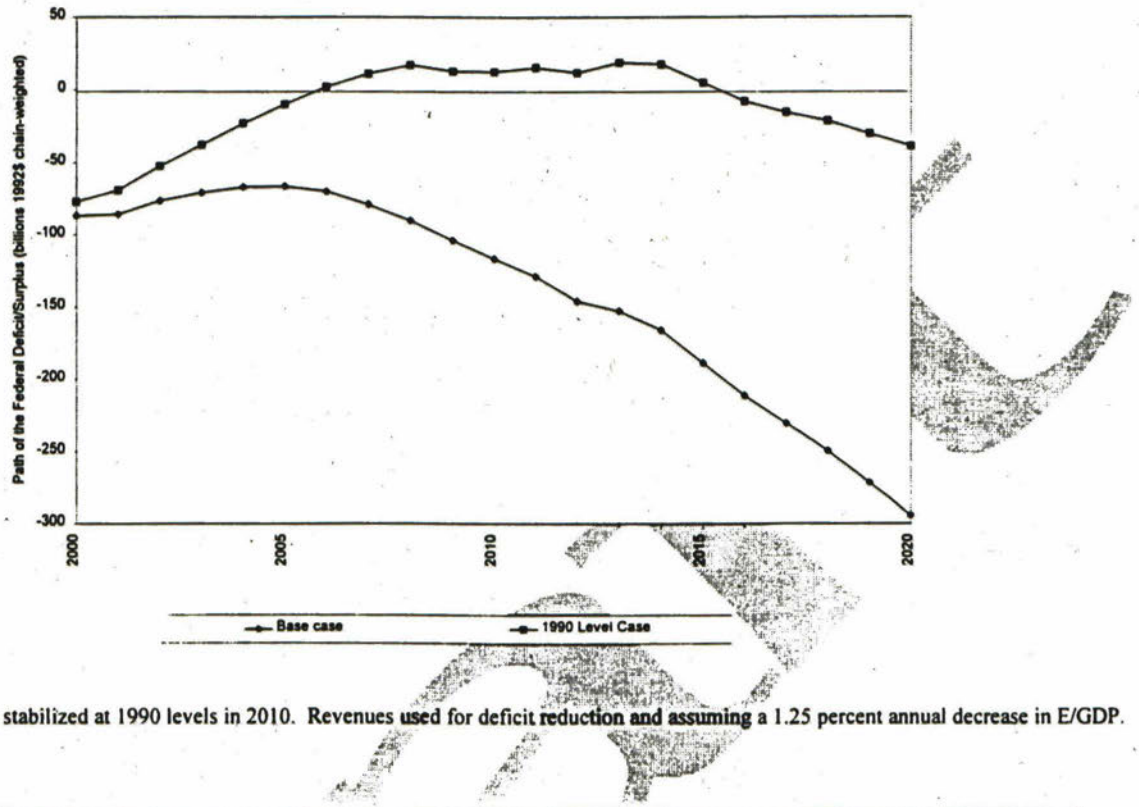
Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 25: DRI-DRI Energy 1990 Level Case, No International Trading-- Real 10 Year Long-Term Bond Rate



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 26: DRI-DRI Energy 1990 Level Case, No International Trading--Path of the U.S. Federal Deficit/Surplus



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

The results presented in the sections below on "Industry Results" and "Regional and Employment Effects" do not include cross-border emissions trading. The IAT is in the process of generating industry and regional results based on using implicit carbon prices from SGM Annex I trading results to simulate macro economic conditions for the DRI model, which will extend the final section of the core results to the industry and regional levels.

Industry Results

Using the DRI model, the IAT examined both the industry impacts and the impacts to regional employment associated with carbon-limiting policies. Regional impacts are discussed in the next section of the report. Table 11 provides impacts to the energy producing industries and to industries that are considered to be energy intensive. Table 12 lists the industries with the greatest increase from base case output and the largest decline from base case output in 2010.

Different energy models place different emphasis on three strategies for coping with energy price increases, with corresponding differences in projected fossil fuel impacts. These strategies include increased end-use efficiency, reduced end-use activity, or fuel-switching towards an increased market share of low- and no- carbon fuels. Increased end-use efficiency or reduced end-use activity tends to lower overall fuel demand, while fuel-switching favors low- and

no-carbon fuels, such as natural gas and renewable energy, relative to high carbon fuels such as coal.

The DRI energy model results (reported here) emphasize improved efficiency and reduced end-use activity. In this model, stabilization reduces the use of all fossil fuels (coal, oil, and natural gas) relative to baseline levels. In contrast, for example, the NEMS results rely more heavily on fuel switching opportunities in the utility and transportation sectors, as well as efficiency improvements in cars. The NEMS stabilization runs show greater reductions in coal use than the DRI runs, but natural gas use actually increases relative to baseline due to fuel switching and a higher level of end-use energy demand.

Table 11: DRI-DRI Energy 1990 Level Case, No International Trading
Impact on the Output of Energy Producing Industries and Energy Intensive Industries
(percent change from the base case)

	2010		2020	
	No trading	With International Trading	No trading	With International Trading
Energy Producers				
Electric Utilities	-11.6%	n/a	-17.7%	n/a
Petroleum Refining	-8.8%	n/a	-9.3%	n/a
Coal Mining	-25.9%	n/a	-39.3%	n/a
Natural Gas	-19.9%	n/a	-18.2%	n/a
Gas Utilities	-11.4%	n/a	-10.9%	n/a
Crude Petroleum	-11.8%	n/a	-12.4%	n/a
Fuel Oil	-13.6%	n/a	-16.7%	n/a
"Pipelines, ex. Natural Gas"	-7.8%	n/a	-8.0%	n/a
Energy Intensive Industries				
Food and Kindred Products	-0.9%	n/a	0.2%	n/a
Chemical and Allied Products	-1.9%	n/a	-1.6%	n/a
Petroleum and Coal Products	-9.2%	n/a	-10.0%	n/a
Stone, Glass, and Clay Products	0.8%	n/a	2.3%	n/a
Paper and Allied Products	-0.6%	n/a	0.4%	n/a
Primary Metals	-1.0%	n/a	-1.0%	n/a

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues are used for Federal deficit reduction, assuming a 1.25 percent annual decrease in E/GDP. Estimates for the international trading scenario are forthcoming.

Energy intensive industries are put at a disadvantage by higher implicit prices for fossil fuels following the imposition of policy. This occurs because they are displaced through trade -- an effect that DRI depicts as relatively minor -- or because the composition of the economy's output changes in favor of less energy-intensive goods and services. These composition shifts drive the industry results. For some industries, however, composition may shift in favor of energy intensive industries because the economy's composition shifts from consumption to investment, which calls up a different mix of goods itself.

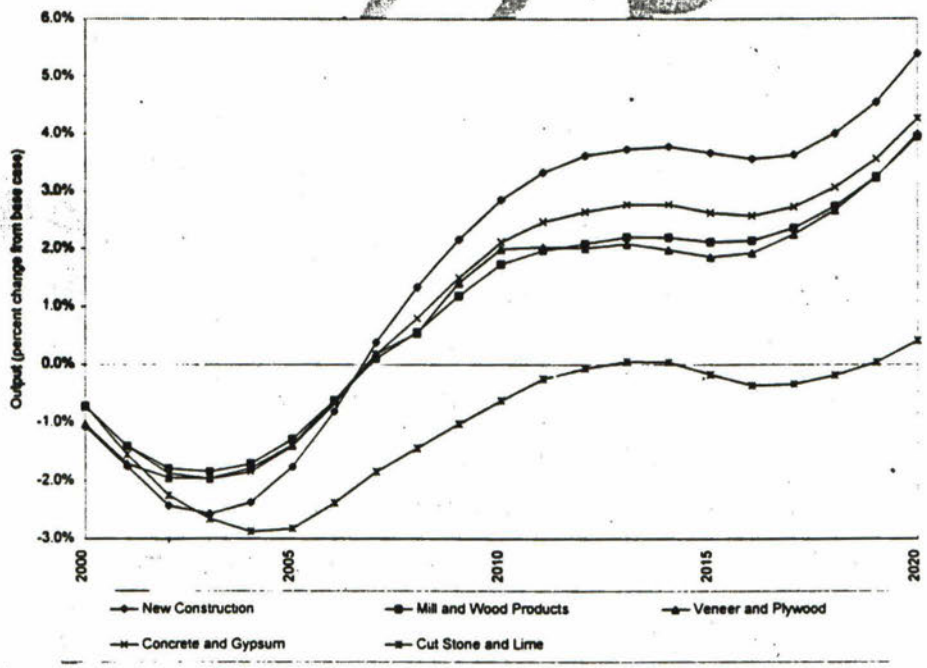
For example, a number of energy intensive manufacturing and construction sectors benefit in the long-term by the stimulus to investment created by the reduction of the deficit. Table 12 shows that 6 of the top 10 industries, in terms of output increasing above the base case, are directly or indirectly related to construction, which reflect the increase to the investment component of the

economy. Figures 27 and 28 show the short-term output losses and the long-term output gains of a number of these industries.

On the other hand, industries whose production is used primarily for consumption, particularly energy products such as petroleum and coal, but also including paper, chemicals, and food and kindred products, continue to show losses in annual output. The energy producing industries show losses in output from between 8 percent for pipelines and 26 percent for coal mining. Consumer non-durable goods producing industries show losses of output that ranges from 1 percent for food processing to 10 percent for rubber and plastic footwear. In the longer-term, other than the energy producers, the consumption-oriented industries are expected to just about reach their output levels in the baseline.

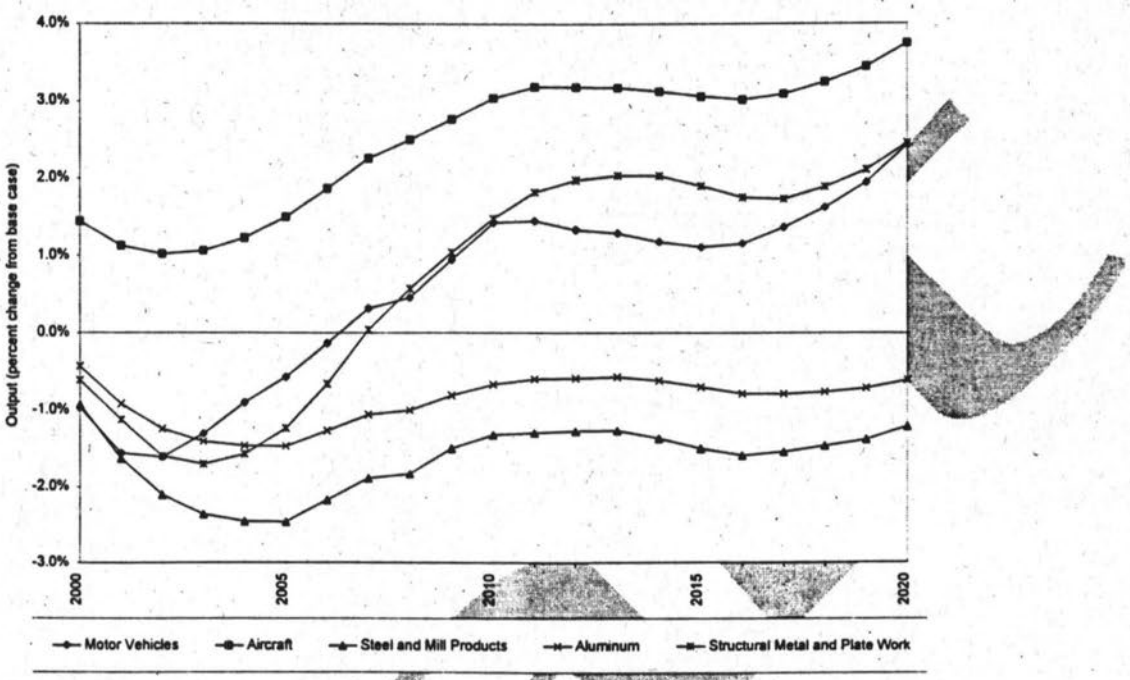
This mix effect is particularly and obviously important for energy producers. The DRI model suggests output of petroleum products will decline by 9 percent in 2010 and in 2020, when compared to the base case. As seen in Table 12, coal production in the United States will be 26 percent lower in 2010 and 39 percent lower in 2020 when compared to its projected levels in the base case.

Figure 27: DRI-DRI Energy 1990 Level Case, No International Trading--Output in Key Industries--New Construction, Mill and Wood Products, Veneer and Plywood, and Concrete and Gypsum



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 28: DRI-DRI Energy 1990 Level Case, No International Trading--Output in Key Industries--Motor Vehicles, Steel and Mill Products, Structural Metal and Plate Work, Aircraft, Aluminum



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Mining (including coal, oil, and natural gas extraction) employment would be 6 percent and 7 percent lower, respectively, in 2010 and 2020: these declines are lower than output losses because productivity in the industry is generally anticipated to improve and the nation's coal mix is projected to shift to more productive coal reserves. These employment losses are particularly severe in the east and west south central regions.

Electric utilities experience smaller percentage reductions in output, but their losses are larger in dollar terms. Utility output declines by about $30 billion in 2010 and $52 billion in 2020 when compared to the base case. Petroleum refining and coal mining also experience larger losses than other energy-related industries on a dollar basis.

Table 12: DRI-DRI Energy 1990 Level Case, No International Trading
Impacts on the Output of Selected Industries
(percent change from the base case)

	2010	2020
Industries with the Largest Percent Increase in Output		
Aircraft	3.0	3.7
Truck Trailers	3.0	3.7
New Construction	2.8	5.4
Truck and Bus Bodies	2.7	3.5
Partitions and Fixtures	2.5	3.9
Lawn and Garden Equipment	2.3	3.3
Elevators and Materials Handling Equipment	2.3	2.8
Structural Metal Products	2.2	2.9
Concrete and Gypsum	2.1	4.3
Plumbing and Heating Equipment	2.1	4.0
Packaging Machinery	2.1	2.7
Industries with the Largest Percent Decline in Output*		
Rubber and Plastic Footwear	-10.3	-3.9
Nonferrous Metals	-3.2	-5.4
Household Audio and Video Equipment	-3.2	-6.1
Chemical and Fertilizer Mining	-3.1	-3.3
Watches and Clocks	-2.8	-4.9
Iron and Ferroalloy Ores	-2.6	-2.8
Other Leather Goods	-2.5	0.4
Nonferrous Wire and Cable	-2.5	-2.8
Misc. Nonferrous Ores	-2.3	-3.7
Industrial Organic and Inorg. Chemicals	-2.2	-2.1
Computers	-2.1	-6.1

Note: Emissions stabilized at 1990 levels in 2010. Revenues used for deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.
* Excluding energy producing sectors.

As discussed earlier, the DRI model found that the effect of a carbon-limiting policy on international trade is relatively small across all industries. However, as Table 13 shows, the trade impact on some specific industries are relatively large. For example, imports by the cement industry increase by 13 percent and exports are off by 3 percent, a net trade loss of 16 percent. Steel imports increase by almost 7 percent while its exports are cut by about 1 percent, a net trade loss of about 7 percent. On the other hand, fuel oil imports decline by about 39 percent, while exports increase by about 1 percent, a net trade gain of 40 percent. Imports for the industries listed in this table generally increase, while exports decline slightly.

Table 13: DRI-DRI Energy, 1990 Level Case, No International Trading
Effects on Exports and Imports in 2010
(percent change from base case)

	Imports	Exports
Paper and Allied Products		
Pulp Mills	0.9%	0.1%
Paper and Paperboard Mills	2.3%	-0.5%
Paperboard Boxes and Containers	1.6%	-0.2%
Paper Coating and Laminating	1.2%	0.1%
Sanitary Paper Products	0.8%	0.3%
Chemical and Allied Products		
Industrial Inorg. and Organic Chemicals	3.6%	-1.0%
Fertilizers	5.3%	-2.0%
Pesticides and Agr. Chemicals	0.2%	0.4%
Petroleum and Coal Products		
Petroleum Refining	-7.7%	0.5%
Fuel Oil	-38.6%	0.6%
Stone, Glass, and Clay Products		
Cement	13.3%	-2.8%
Concrete and Gypsum	5.3%	-0.2%
Cut Stone and Lime	7.4%	-1.1%
Primary Metals		
Steel and Mill Products	6.6%	-1.4%
Iron and Steel Foundries	2.7%	0.0%
Iron and Steel Forgings	3.6%	-0.1%
Aluminum	3.8%	-0.5%
Transportation Equipment		
Truck and Bus Bodies	3.4%	0.1%
Truck Trailers	4.7%	0.0%
Motor Vehicles	3.1%	-0.1%
Motor Vehicle Parts and Accessories	1.4%	-0.1%
Aircraft	3.0%	3.7%
Aircraft and Missile Engines and Parts	1.5%	2.5%
Computer and Electronic Equipment		
Computers	2.7%	-0.8%
Computer Peripheral Equipment	2.3%	-0.2%
Semiconductors	0.3%	-0.6%

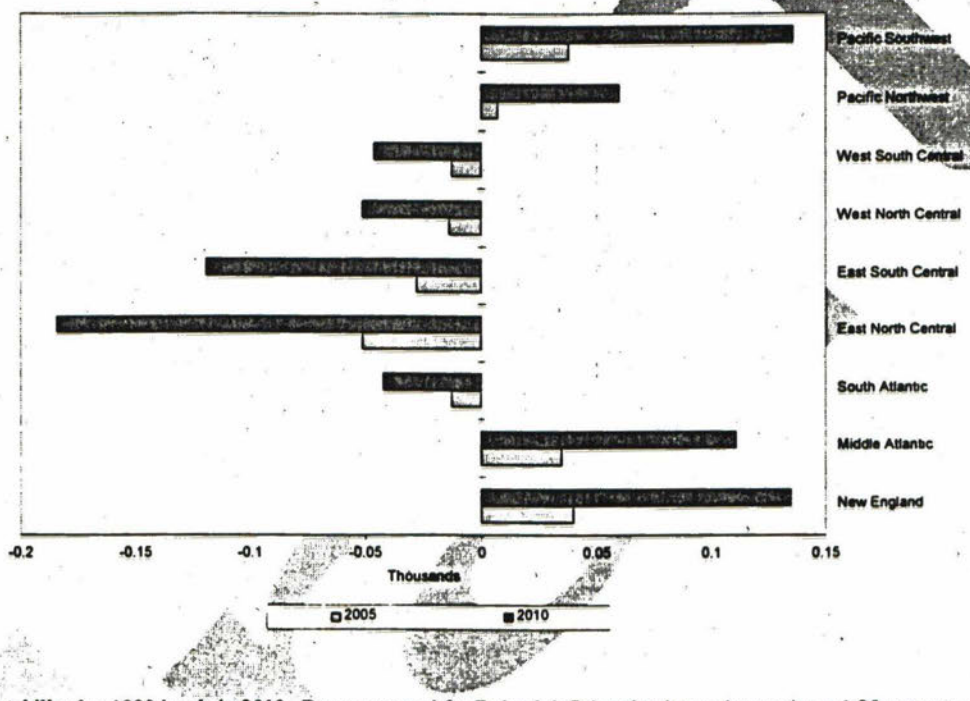
Note: Emissions stabilized at 1990 levels in 2010. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Regional and Employment Effects

The effects of climate change policy on the various regions of the country are shown in Table 14. In general, states in the East North Central, East South Central, and West North Central regions will have proportionally greater losses in population, 150-, 125-, and 75-thousand, respectively, and employment, 210-, 165-, and 125-thousand, respectively, than the other regions of the country. See Figures 29 and 30. Total non-farm employment loss due to the climate change policy is about 900 thousand in 2005 compared with the baseline total non-farm employment of

135.3 million in that year. In 2010, total non-farm employment loss due to the climate change policy is only 400 thousand, compared with the baseline total non-farm employment of 140.9 million, as the economy starts to recover. The New England, Middle Atlantic, and the Pacific Southwest are expected to show long-term gains in population of 125-, 110-, and 130 thousand, respectively, and in employment of 125-, 45-, and 65-thousand, respectively, because of climate change policy implementation.

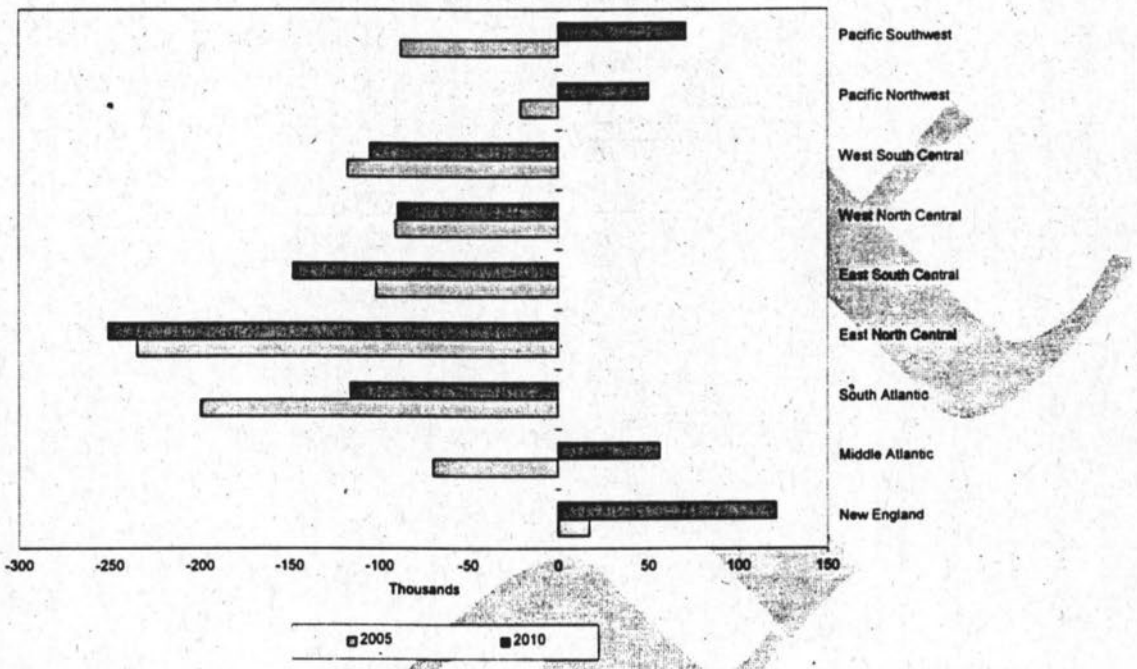
Figure 29: DRI-DRI Energy 1990 Level Case, No International Trading-- Population by Region (change from the base case)



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

The key to the regional effects relies on how revenue raised through permit sales is recycled to the economy. In the policy reviewed for regional effects, revenues are used to reduce the Federal budget deficit, which supports savings and, thus, increases investment. The climate change policy favors those states where production in industries support investment in structures and capital goods equipment, and of course, those areas of the country that are not as dependent on fossil fuel production. The climate change policy's effects are mitigated in those regions whose mix of industries favor investment goods industries and where the levels of industry production are large and can absorb the losses in production in industries that produce consumer goods.

Figure 30: DRI-DRI Energy 1990 Level Case, No International Trading--Total Non-Farm Employment by Region (change from the base case)



Note: Emissions stabilized at 1990 levels in 2010. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

As shown in Table 14, although the West South Central region is expected to have the greatest losses in fossil fuel employment, about 15 thousand in 2010, this represents only about 6 percent of its total mining employment in that year. On the other hand, the East South Central Region is expected to lose about 8 thousand in 2010, but this represents about 22 percent of its total fossil fuel employment in the same year.

Table 14: DRI-DRI Energy 1990 Level Case, No International Trading Regional Impacts

Year	New England	Middle Atlantic	South Atlantic	East North Central	East South Central	West North Central	West South Central	Pacific North-west	Pacific Southwest
Disposable Income, % change from the base case									
2005	0.9	0.4	-0.1	-0.4	-0.5	-0.7	-0.2	0.3	0.3
2010	1.9	0.7	-0.1	-1.1	-1.3	-1.2	-0.4	1.1	0.6
2020	2.9	0.9	0.1	-1.4	-1.5	-1.9	-0.7	1.4	0.7
Total Non-farm employment, % change from the base case									
2005	0.3	-0.4	-0.8	-1.0	-1.3	-0.9	-0.8	-0.4	-0.4
2010	1.7	0.3	-0.4	-1.1	-1.8	-0.8	-0.7	0.8	0.3
2020	2.7	0.5	-0.2	-1.1	-1.7	-0.9	-0.8	1.1	0.5%
Mining, Oil, and Gas Employment, % change from the base case									
2005	0.4	-8.5	-8.3	-5.9	-10.9	-0.8	-1.4	-2.1	-0.9
2010	4.4	-10.9	-11.6	-7.8	-20.5	1.0	-6.4	-1.1	0.8
2020	9.0	-14.0	-15.6	-6.2	-27.8	4.3	-4.8	-8.3	0.6
Population, change from the base case (millions)									
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	0.1	0.1	0.0	-0.2	-0.1	-0.1	-0.1	0.1	0.1
2020	0.3	0.2	0.0	-0.3	-0.2	-0.1	-0.1	0.1	0.2
Manufacturing Employment, change from the base case (thousands)									
2005	9.6	1.7	-32.5	-77.1	-24.7	-19.5	-21.5	-1.0	-0.6
2010	26.5	21.7	-28.4	-116.1	-32.5	-28.3	-28.5	6.7	17.3
2020	36.9	13.9	-33.8	-142.5	-32.7	-35.3	-41.8	7.3	23.9
Transportation, Communication & Utilities, change from the base case (thousands)									
2005	1.7	-4.1	-12.1	-15.5	-4.9	-8.1	-8.7	-1.6	-6.5
2010	5.7	-2.9	-16.5	-25.9	-9.4	-13.5	-14.9	0.3	-5.5
2020	8.4	-4.8	-18.1	-31.8	-10.0	-16.1	-17.9	0.4	-5.4

Note: Emissions stabilized at 1990 levels in 2010. Revenues used for Federal deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Appendix Table A: Assumptions Regarding Non-Carbon Greenhouse Gases (million metric tons of carbon equivalent)

	1900	1995	2000	2005	2010	2015	2020
Baseline Emissions							
CH4	169	178	150	152	152	154	155
HFC PFC	24	n/a	42	69	91	115	133
N2O	37	34	31	32	34	36	37
Sinks	-136	-128	-121	-120	-119	-111	-103
Total	95	n/a	102	133	158	194	223
Cost Effective Reductions in Emissions (assuming an implicit price of carbon of $70 per ton)							
CH4					[illegible]	29	[illegible]
HFC PFC					51	75	110
N2O					4	4	4
Sinks				7	15	15	15
Total Reduction					97	123	159
Emissions with Cost Effective Reductions							
CH4	169	178	150	152	125	126	126
HFC PFC	24	n/a	42	69	40	41	23
N2O	37	34	31	32	30	31	33
Sinks	-136	-128	-121	-120	-134	-126	-118
Total Other Gas Emissions	95	n/a	102	133	61	71	64
Reductions Below 1990 Levels					34	23	31

Note: Million metric ton of carbon equivalent calculated using 100 year Global Warming Potentials (GWP) (IPCC, 1995). The $70 per ton implicit price of carbon was an estimate used by the IAT prior to generating implicit price of carbon using the IAT models.

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Divider Title: **V. Sectors**

SECTOR EMISSIONS AND OPPORTUNITIES FOR MITIGATION UNDER A CLIMATE CHANGE MITIGATION STRATEGY

A Pre-Decisional Draft
Do Not Cite or Quote

June 19, 1997

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Sector Emissions and Opportunities for Mitigation under a Climate Change Mitigation Strategy

U.S. climate change policies will be anchored by a productivity-led investment strategy. Such a strategy will focus on the diffusion of cost-effective technologies, some of which are now available, others of which require continued research and development.

Because sectors of the economy vary widely in how they produce goods and services, so too will both the impacts of any climate policies, and the opportunities available both to sectors as a whole, and individual firms within those sectors. For policy makers and business leaders, it is important to understand these different impacts and opportunities.

Sources of U.S. Greenhouse Gas Emissions

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Chlorofluorocarbons (CFCs) and partially halogenated fluorocarbons (HCFCs), a family of human-made compounds, their substitutes hydrofluorocarbons (HFCs), and other compounds such as perfluorinated carbons (PFCs), are also greenhouse gases. Of these gases, CO_2 accounts for the largest share by far of all anthropogenic emissions and is primarily the result of fossil fuel combustion for energy use. The emissions are typically measured in "carbon equivalents," according to their respective "global warming potential."

Total U.S. greenhouse gas emissions in 1995 were 1,557 MMTCe (million metric tons of carbon equivalent), with gross emissions of 1,674 MMTCe offset by 117 MMTCe of carbon sequestered by the nation's forests. Emissions have increased by about 7% since 1990. Annual U.S. fossil-related carbon emissions have grown by about 1.2% per year since 1950 and are projected to rise at almost the same rate over the next twenty years.

U.S. Carbon Emissions by Fuel

Petroleum products are the leading source of carbon emissions from energy use and nearly 80 percent of the petroleum emissions result from transportation. Coal is the second leading source of carbon emissions, with most of the projected future increases in emissions from coal result from electricity generation.

	1995	Percentage of Total 1995 Emissions	2010	Percentage of Total 2010 Emissions
Petroleum	599	42%	730	42%
Natural Gas	317	22%	412	24%
Coal	507	36%	579	34%
Other (includes methanol and liquid hydrogen)	0.0	0%	1	0%

	1995	Percentage of Total 1995 Emissions	2010	Percentage of Total 2010 Emissions
TOTAL	1423	100%	1722	100%

Source: DOE Annual Energy Outlook 1997

U.S. Carbon Emissions by End-Use Sector

End-use sectors include the following: residential and commercial (collectively called "buildings"), industrial, and transportation. Emissions from each of these sectors are roughly equally distributed among the three: buildings (35%), transportation (33%), and industry (32%). These shares are projected to remain fairly constant over the next twenty to twenty-five years. The most diverse of the end-use sectors is that of industry, which consists of farming, agricultural services, fisheries, forestry, mining, construction, and manufacturing.[1]

	1995	Percentage of Total 1995 Emissions	2010	Percentage of Total 2010 Emissions
Buildings	494	35%	576	33%
Industry	464	33%	548	32%
Transportation	465	32%	598	35%
TOTAL	1423	100%	1722	100%

Source: DOE Annual Energy Outlook 1997

Energy End-Use Sectors

The Buildings Sector

As noted above, residential and commercial end uses combined consume 35 percent of the nation's energy. The major components of energy use within the buildings sector are summarized by the following table:

END USE	PERCENTAGE OF TOTAL
Space Heating	26%
Space Cooling	9.4%
Water Heating	10.8%
Refrigeration	4.9%
Lighting	14.9%

1. U.S. Census Bureau

END USE	PERCENTAGE OF TOTAL
Cooking	2.6%
Other Appliances	31.5%
TOTAL	100%

Source: DOE Annual Energy Outlook 1997

Residential primary energy use per household has declined only two percent in the period 1979 to 1995. According to the Energy Information Administration's *Annual Energy Outlook 1997* (AEO97), total energy consumption in the residential sector is projected to increase by 13 percent between 1995 and 2010. Most of the growth in this sector is expected occur in the "other uses" category, which includes items such as electronic equipment and small appliances. Not surprisingly, therefore, most of the increase in energy demand during this period is attributed to greater use of electricity.

Measured in terms of energy use per square foot of building space, the commercial sector has witnessed improvements in energy efficiency on the order of 30 percent between 1979 and 1992. However, total energy consumption has been rising over the past two decades as a result of overall growth of the commercial sector. Future energy demand is predicted to increase by 12 percent in the period 1995-2010. As is the case with the residential sector, end-use products such as office equipment and consumer electronics account for the majority of net growth in energy demand through 2010.

The following table summarizes the category of end-use energy in the combined buildings sector for the years 1997 and 2015:

Total 1997 and 2015 Building Energy Consumption By End-Use (in Quads)			
	1997	2015	Percent Change
Space Heating	8.77	8.89	1.4%
Space Cooling	3.17	3.08	-2.8%
Water Heating	3.63	3.73	2.8%
Refrigeration	1.67	1.40	-16.2%
Lighting	5.04	4.99	-1.0%
Cooking	0.87	0.91	4.6%
Other Uses/Appliances	10.62	15.04	41.6%
TOTAL	33.77	38.04	12.6%

Source: DOE Annual Energy Outlook 1997

From this table, it is clear that in the buildings sector, most of the growth in energy demand will occur in the "other uses" category, which is expected to account for 31 percent of end-use energy consumption in 2015. This category currently accounts for 29 percent of total residential energy use

and is expected to increase to 39 percent in 2015 as small appliances continue to penetrate the market. In the residential sector, this category includes smaller appliances such as personal computers, dishwashers, clothes washers, and dryers. The highest growth rates in the commercial sector are expected to be for end uses that have not yet saturated the commercial market. This includes office equipment such as personal computers, monitors, fax machines, copiers, printers, scanners and multifunction devices. Additional products included in the "other" category include new telecommunications technologies, medical imaging equipment and vending machines.

Factors Shaping Industry Response

Currently, numerous opportunities exist to improve the level of energy efficiency within the buildings sector. By tightening the building shell and installing properly sized, energy efficient heating and cooling equipment, consumers can experience substantial monetary gains through greater savings as a result of lower monthly utility bills. In addition to saving money, consumers can benefit from improved overall comfort resulting from better indoor air quality, superior lighting, and reduced noise levels. However, the savings are often hard to verify, sometimes varying from building to building. As a result, consumers and builders are not as bullish on many of the more complicated or advanced savings opportunities despite clear acceptance of improved insulation levels and some other energy savings features.

Technology Options

Cost effective technologies which are currently available in the buildings sectors include, but are not limited to, the following:

- Better insulation of building shells
- Better control systems for regulating the use of energy consuming equipment (time and temperature controls by zone, energy-use optimizers, energy management systems)
- High efficiency heat pumps
- Heat pump water heaters
- Decreased hot water requirements through better designed clothes washers and dishwashers
- Increased motor/compressor efficiencies for refrigerators
- High efficiency lighting – fluorescent fixtures, electronic ballasts, control systems
- Substitution of lower-carbon fuels (on a full fuel-cycle basis)
- Reduced air infiltration practices, including improved duct work
- Energy efficient windows
- Whole house design that allows for substantial equipment downsizing

Barriers to Adoption

Despite the proven cost effectiveness of these and other energy efficiency technologies, it is clear that they are not widely adopted by consumers. This is due to a number of institutional, organizational, and other barriers. The existence or availability of a financially attractive technology does not by itself mean the technology will be purchased and used in sizable quantities. For high rates of market penetration, a number of other key factors must be in place:

- Potential buyers of products need to know about the technology
- Potential buyers need clear, reliable information on the performance and economic benefits of the technology

- Potential buyers must be the ones to see the benefits of lower energy bills
- Service providers and users of the technologies must have expertise to appropriately design for, install, and operate the technology
- Sources of capital must understand the low-risk nature of these investments

The Department of Energy (DOE), the Environmental Protection Agency (EPA), and members of the financial community are developing innovative financing methods for energy efficiency investments. In addition, DOE operates a program of test procedures, energy conservation standards, and labeling for certain major energy using equipment in the residential and commercial sectors. These include refrigerators, freezers, air conditioners, water heaters, furnaces, dishwashers, clothes washers, clothes dryers and kitchen ranges, ovens, commercial heating and air-conditioning equipment, certain incandescent and fluorescent lamps, distribution transformers, and electric motors. The Energy Policy Act of 1992 (EPACT) also established maximum water flow-rate requirements for certain plumbing products and provided for voluntary testing and consumer information programs for office equipment, luminaires, and windows.

The Industrial Sector

Trends in the Industrial Sector

The industrial sector directly emitted approximately 463 MMTC in 1995 from the combustion of fossil fuels, and about 20 million MMTC from industrial processes. This includes carbon emissions from electricity generation, which are distributed across all the industrial sectors. Emissions data for individual industrial sectors is not currently reported in any published sources.

Combustion-Related Carbon Emissions by Industrial Sector (MMTCE)

Industry	1985		1988		1991		1994	
	Direct	Primary	Direct	Primary	Direct	Primary	Direct	Primary
Aluminum	3.86	10.64	4.01	11.28	5.57	12.48	4.88	11.31
Chemical	55.73	68.97	68.11	81.62	78.91	93.19	83.24	100.11
Forest[a] Products	55.57	65.77	60.76	71.91	64.79	76.72	69.15	82.4
Glass	*	*	*	*	2.01	2.60	2.96	3.93
Metal-casting	*	*	*	*	*	*	1.63	2.71
Petroleum Refining	66.63	69.64	83.77	86.56	76.5	79.23	83.15	86.29
Steel	39.22	45.02	43.38	49.39	35.11	40.78	36.66	44.6
Food	15.96	21.26	16.71	22.68	16.07	21.98	20.06	26.97
Cement	6.87	8.4	6.74	8.22	6.76	8.2	7.08	8.75
Other Mfg	46.3	75.2	56.85	91.06	59.7	93.2	60.57	96.39
Total Manufacturing	298.78	375.75	350.14	435.08	345.42	429.37	369.39	463.47

Notes
a - includes lumber, wood products, and pulp and paper industries
* indicates essential 4-digit SICs were not reported or were not broken out by segment for that year
Direct represents end-use only; primary includes electricity generation and transmission losses.

The industrial sector is an extremely diverse set of business enterprises — both in terms of products and processes. Even within the manufacturing subsector, a range of industries exist from beer, paper, and clothing to aluminum ingots, plastic resins, cars, and computers. Energy requirements for each of these industries are as different as the products they produce. As a result, it necessary to gain a thorough understanding of the issues facing individual industries so that they will have the ability to respond to policies in a manner that is most appropriate to their particular circumstances.

The table above provides estimates of carbon emissions from fuel combustion based on energy consumption as reported in the Manufacturing Energy Consumption Survey (MECS), using a weighted average for fuel type and published carbon emission coefficients. It includes only

manufacturing sources, and does not include other significant contributions from agriculture, mining, construction and oil and gas exploration. In general, carbon emissions have increased across all industrial sectors over the last decade, along with an increase in the combustion of fossil fuels.

Process Emissions

In addition to emissions resulting from the combustion of fossil fuels, the primary industrial processes that generate carbon emissions include:

- the manufacture and consumption of limestone (e.g., in iron smelting, steelmaking, glass manufacture, flue gas desulfurization)
- dolomite consumption
- soda ash manufacture and consumption (e.g., in glass manufacture, flue gas desulfurization, and chemicals production)
- carbon dioxide manufacture
- aluminum production

One example of non-energy related process emission occurs in the production of portland cement. The calcination reaction which converts the limestone raw material into clinker results in direct emissions of approximately 30 MMTC.

Economic Modeling Results for the Industrial Sector

The Interagency Analytical Team (IAT) used a number of models to analyze the range of impacts of climate policies on the nation's economy. In general, the model results suggest that policies which promote the diffusion of cost-effective technologies to reduce both energy consumption and carbon emissions show the most positive impact on the economy. Similarly, model results which show the greatest flexibility in adopting productive technology investments and incorporate the ability to trade emission permits also show the most positive impact on the economy. Analysis completed using the Markal-Macro model, for example, suggests a positive impact on both the overall cost of energy services and on GDP when more aggressive assumptions are used with respect to the availability of energy-efficient technology investments. On the other hand, the DRI/McGraw-Hill Inter-Industry Model shows a small loss to GDP using less optimistic assumptions about technology investments.

The DRI model also provide detailed estimates about the impact of climate policies on the production and inter-industry transactions and trade for 246 industries over time. Under the "central stabilization case," which estimates the effects of stabilizing greenhouse gas emissions at 1990 levels from the year 2010 through 2020, direct emissions reductions in the industrial sector account for about 19 percent of total emission reductions (48 MMTC) in 2010 and 21 percent (70 MMTC) in 2020. Reductions in overall energy demand as well as improvements in industrial energy efficiency account for these reductions. Also under the central stabilization case, energy intensity across all industries initially declines at a rate of 3.25 percent per year vs. 1.5 percent in the base case and later slows to about 1.5 percent per year vs. 1 percent in the base case.

One major area of concern is the effect of carbon constraints on the most highly energy-intensive industries such as cement, aluminum, steel, pulp and paper mills, and the energy-intensive sectors of the chemicals industry who account for a relatively small portion of total output (2% to 3% of GDP) but a relatively large portion (38%) of total industrial energy use. These concerns reflect both domestic demand, and international competitiveness.

As suggested earlier, however, the impact of climate stabilization policies on the demand for energy-intensive industrial products may be very sensitive to how the policy is implemented.

- *If emission permits are auctioned off and the revenues are used to reduce the budget deficit, the reduction in government borrowing will reduce real interest rates and, in turn, stimulate demand for consumer durables, new construction and business investment.* Higher construction, investment, and durables demand raises the demand for such energy-intensive goods as cement, aluminum, and steel. Pulp and paper products, energy-intensive chemicals and other energy intensive products more closely tied to non-durable consumer good consumption -- pulp and paper products, and some chemicals -- fair less well under this scenario.

- *In contrast, if emission permits are given to households (or the revenues from auctioned permits are returned to them through income tax reductions), the main effect is to stimulate household consumption expenditures rather than business investment.* In this case, higher non-durables consumption stimulates the demand for paper and paperboard from the pulp and paper industry.

A second and central concern is the following: as higher energy prices raise production costs, U.S. energy-intensive producers might lose market share to competitors from non-Annex I countries under a climate treaty that affects Annex I but not Annex II countries.

The results from the DRI analysis stand in contrast to those of a number of other studies, which tend to predict that carbon stabilization policies would severely impact U.S. energy-intensive industries and perhaps drive large portions of these industries overseas, with little net effect on global emissions. The results from this analysis show that while a carbon stabilization policy would affect energy-intensive industries, the most dire predictions overstate the impacts of climate policies. For the policy cases, other than for oil and coal, the impacts on output for energy intensive industries relative to the base case are less than 1.9 percent assuming no international emissions trading, and less than 1.2 percent with international trading.

Geographic and regional shifts in global energy-intensive production are inevitable even without a climate policy. For instance, according to the DRI Baseline Forecast, the carbon and energy intensive industries in the U.S. will experience declines in their share of both U.S. employment and output. These industries are projected to employ only 2.9 percent of the U.S. workforce by 2010. This figure decreases to 2.3 percent by 2020. Similarly, the energy intensive industries share of output drops from 9.1 percent of GDP or 27.9 percent manufacturing output in 2010 to 7.2 percent of GDP or 23.3 percent of manufacturing output in 2020. Even in the baseline, emerging Asian countries share of basic metals exports is expected to increase from 11 percent to 17 percent by the year 2010, and chemicals and plastics exports are forecast to increase from 13 percent to 19 percent.

The IAT analysis did account for changes in terms of trade for U.S. industries. Under this analysis, non-Annex I producers (including China Mexico, Korea and Brazil), which currently account for about 40 percent of U.S. imports, would not be faced with energy price increases from a stabilization. Under such conditions, there would be an increase in imports from non-Annex-I countries and decreases of U.S. exports to the world market. The IAT undertook a detailed analysis of possible effects.[2]

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2. To reflect such changes in U.S. import and export shares the analysis took the following steps: (a) based on the share of energy as an input to each sector, the percentage increase in cost of production was calculated; (b) the production cost increases where then adjusted on the basis of the changes in wages, interest rates, and exchange rates occurring under the policy; (c) the share of imports coming from and exports going to Annex I

Such an analysis could be a more conservative (i.e. — severe from the perspective of US industry) estimate of the actual changes that would occur under the policy. Additionally, the relatively rigid representation of substitution possibilities in production that characterizes the model may overstate the effect of energy price increases on production costs. In contrast to the DRI model, models that have a more detailed and flexible representation of production technologies (such as general equilibrium models) or that represent technological shifts (i.e. from integrated steel mills to electrometallurgical mini-mills or from primary aluminum to secondary aluminum) would yield lower estimates of production cost increases. Argonne National Laboratory's AMIGA model, for example, shows that while the energy intensive sectors are negatively affected by climate policies, the impacts are not as deep as suggested by other forecasts. Perhaps more important, the set of AMIGA scenarios which incorporate the more positive technology assumptions from a recent study of five leading national energy laboratories show a small but positive impact on GDP and the majority of the nation's business sectors.

Factors Shaping Industry Response

Within the manufacturing subsector, several industries are substantially more energy intensive than others. And among these energy-intensive industries, numerous differences exist in terms of the products each industry produces and the processes they employ.

Aluminum

The aluminum industry has three major segments - primary materials, semifabricated materials, and finished products. The U.S. aluminum industry is globally competitive in all parts of the industry and is a net exporter of semifabricated aluminum products. The last greenfield smelter in the U.S. was built in 1980 and there are currently no plans to build any new facilities.

Unlike other basic industries, the U.S. aluminum industry is highly dependent upon the cost of electricity, such that any future changes due to restructuring would have major impacts on the competitiveness of this industry. The primary aluminum industry in the U.S. purchases electricity at approximately half the price of other industries, in part because of hydropower (Pacific Northwest) and in part because of long-term negotiated rates. The future of U.S. primary aluminum will depend on differences (if any) in the price and availability of hydro- and coal-generated electricity. These differences will have substantial regional impacts. Almost all the smelters in the eastern part of the United States rely upon coal- based electricity, whereas the smelters in the Northwest use hydro-based electricity. Should a policy be implemented based on carbon emissions, the eastern smelters in the United States would be impacted more than western smelters.

Technological change in the aluminum industry has been incremental. Continuous process improvements have reduced energy consumption per ton by approximately 25 percent between 1960 and 1994 and retrofit technologies with significant improvements in existing energy efficiency levels are expected to be in place by 2010. Increased use of recycled metal could also yield substantial energy savings. This depends on developing advanced scrap separation and smelting processes and on overall advances in process design.

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countries in each sector was adjusted to account for significant changes that would immediately occur under the policy (i.e. the share of cement imports to the U.S. from annex I countries, currently at 74.50% is reduced to 37.25%); and (d) the non-annex I import and export shares for each sector from step "c" were then used with product specific elasticities to determine the relative shifts in imports and exports that would result from the price increases.

Petroleum Refining

Petroleum refineries distill crude oil, crack the resultant intermediate products into smaller molecules, and then purify and blend the various fuels to produce a number of useful products. Gasoline is the principle refinery product, accounting for over half of industry sales. U.S. refining industry is the largest in the world with capacity at about 15 million barrels per day (bpd). However, no new refineries have been built in the U.S. for more than a decade and the number of refineries has decreased from about 285 in the late 1960s to about 175 currently.

In the petroleum refining sector, industry impacts will depend on sensitivities such as the extent to which prices of fuel used as an input are increased as opposed to policies that affect the overall demand for the refinery products produced. Other factors that will affect the petroleum refining industry include the price of marine bunker fuel which can account for 25 to 55 percent of transportation costs. The characteristics of individual refineries will also affect the response of the industry. The refineries most vulnerable are located in highly competitive regions, they are typically old, and they produce a standardized product subject to a high degree of competition. Many of the old refineries are only marginally profitable under existing conditions. Less affected refineries will be those that have been renovated and modernized in the last five years, or produce specialized products.

In the near to mid-term, process energy utilization can be reduced by 5-10 percent through utility system modifications, monitoring and maintaining equipment/process energy efficiency through development and adoption of advanced sensor/control technologies, and by minimizing and controlling heat exchanger fouling. In the mid to long-term, opportunities to improve energy efficiency include areas such as fired heaters, distillation catalytic hydrocracking, reforming and hydrotreating, alkylation, and hydrogen production.

Glass

The manufacture of glass and glass products in the U.S. is a large, widely diversified, energy-intensive industry. The glass industry includes the following four segments: glass packaging, fiberglass, flat glass, and specialty glass. The diversified nature of the glass industry highlights the fact that competitive challenges faced by one sector will not always be applicable to the other sectors, and solutions must be tailor-made as well.

The two most pressing challenges for the glass industry are competition from other materials such as plastic and aluminum, and competition from foreign glass manufacturers with lower labor and environmental compliance costs. To meet these challenges the industry will need to improve manufacturing processes, create additional markets and uses for glass products, and reduce energy and waste disposal costs. Reduction in energy consumption, as well as the increased use of recycled glass, both support reduction in greenhouse gases through reductions in fuel combustion.

Options to improve energy efficiency in the glass industry include technological advances that accomplish the following:

- enable the use of oxygen rather than air to fire glass furnaces,
- increase the use of waste glass, or cullet, in glass manufacturing,
- lead to the new coatings and new structural components needed to enhance the performance of manufacturing equipment, and
- create new temperature sensors for furnaces to increase energy efficiency.

Steel

The U.S. steel industry is comprised of integrated producers, electric arc furnace (EAF) based mills, and specialty steel producers. Manufacturing processes for iron and steel production have changed considerably since the 1980s. The open hearth furnace, which was the workhorse of integrated mills in the 1950s, is now obsolete. The basic oxygen furnace (BOF), however, held on to a relatively constant share of total production during the same period, although this share has begun to fall gradually since 1992 with the rise of steel mini-mills. These mini-mills use electric arc furnaces which use 100 percent scrap metal and therefore require less energy per ton of steel produced. Mini-mills are highly dependent on the price and availability of electricity and scrap.

Over the next five years, steelmaking capacity in the U.S. is expected to increase significantly as many new EAF-based mills are scheduled to come on line. As the percentage of EAF-based steel production increases, the average energy intensity of steelmaking will decrease, with associated decreases in coal use and increases in electricity use (and corresponding changes in the amount and type of emissions). In addition, this increase in EAF capacity will likely affect steel imports and domestic scrap prices. Measures that increase coal prices would have a far more dramatic impact on integrated mills than on EAF facilities, while all of the industry will be affected by increases or decreases in electricity price. Deregulation of the electric utility industry is expected to benefit the industry by lowering electricity prices.

After a historical record of lagging technologically, the U.S. steel industry has begun to exhibit a high rate of technological change, including direct smelting processes that replace the blast furnace and coke oven, and direct strip casting processes that replace the continuous caster and hot strip mill.

Chemicals

The chemical industry is more diverse than virtually any other U.S. industry. Chemicals are the keystone of U.S. manufacturing, essential to a wide range of industries, such as pharmaceuticals, automobiles, textiles, paper, electronics, agriculture, construction, furniture, paint, and appliances. The U.S. is the world's largest producer of chemicals. More than 9000 corporations develop, manufacture, and market over 70,000 chemical products. Investments in plant and equipment have tripled since 1985 and R&D spending has more than doubled from $8.3 to $17.7 billion.

The chemical industry has reduced energy intensity over the last decade and has made strides in reducing the environmental impacts of chemicals production. However, to remain at the forefront of the global market and to maintain its competitive position, the industry will need to continue to take steps to strengthen market share, such as increased development of markets where the U.S. has a technological advantage. Improvements to energy, resource and process efficiency will also play an important role in the future competitiveness of the industry. The U. S. chemical industry has an excellent opportunity to greatly reduce U.S. industrial greenhouse gas emissions through advances in current and emerging separation technologies. Advances in separations technology and chemical processes are anticipated to strengthen the U.S. chemical industry and ensure its competitive edge in the increasing globalization of markets. They will allow the chemicals industry to balance and sustain society's demands for higher environmental performance with industry's demands for increased profitability and capital productivity.

Pulp and Paper

The U.S. has the world's largest installed pulp, paper, and paperboard production capacity, some 86

million air-dry metric tons (ADMT) per year in 1993, or about 30 percent of global capacity. Manufactured products from the paper and allied products industry include newsprint, printing and writing paper, tissue, paper plates, card stock, corrugated cardboard, cartons, and construction-grade paperboard. The U.S. is home to close to 550 pulp and paper mills located in 42 states. Over the last twenty years or so, many of the smaller, older mills have been closed down and replaced with larger integrated mills. The integrated mills produce both pulp and paper and/or paperboard. The trend is toward larger size (over 2000 tons/day) plants with the capability to consistently process high-quality products at higher speeds.

The U.S. pulp and paper is both capital and energy intensive. New capital expenditures in the last decade have averaged 10.4 percent of revenues, making paper and allied products the most capital intensive of the manufacturing industries. This factor could conceivably restrain the ability of the industry to install new technologies – especially technologies that will not significantly contribute to lowering production costs. However, because of the energy-intensive nature of the industry, rising fossil fuel costs would create additional incentives to increase reliance on self-generated energy and further increase the energy efficiency of pulp and paper production processes.

There are major opportunities for improving the efficiency of process energy use in the pulp and paper industry. An number of new energy-saving process technologies such as digesters and paper or pulp dryers, are under development or recently commercialized and process heat integration analysis has been applied in several mills. Most process specific changes that bring energy efficiency improvements also bring productivity and other improvements. Advanced biomass-based cogeneration systems, which would provide major improvements in efficiency over existing systems, are currently undergoing rapid development.

Cement

The U.S. hydraulic cement industry consists of firms producing portland, masonry, prepared hydraulic, natural, lime, and oil well cements. Portland cement represents more than 95 percent of total hydraulic cement production; the remainder is mostly masonry cement. There are currently 47 cement companies operating close to 118 plants and 207 kilns in the U.S. Total industry shipments in 1995 were 75 million metric tons with total U.S. consumption of 86 million metric tons. There were approximately 11 million metric tons of finished cement imports and half a million metric tons of exports the same year.

Compared to world standards, the U.S. cement industry is characterized as aging and relatively inefficient. Plants continue to be shut down and others may be slated for closure due to technological or competitive obsolescence. Currently, there remains a need to replace and upgrade plants in order to increase productivity in domestic plants. Most major producers, however, are not in a good financial position to invest in extensive and expensive additional capacity. No new greenfield plants have been built in the U.S. in ten years.

Currently, 65-70 percent of U.S. cement capacity is foreign-owned — including three of the top five firms. Approximately 90 percent of cement imports are handled by domestic producers, who use imports to supplement domestic capacity, such that corporate profitability is not necessarily linked to the health of the domestic industry.

A number of opportunities exist to reduce emissions such as increasing the share of production using dry process technology, increasing the use of efficiency enhancing machinery such as particle classifiers which reduce grinding loads, increasing the use of mix-ins when making concrete, and fuel

switching.

High-Growth Industries

Industries other than the energy intensive sectors discussed above also depend on energy and will likely be affected by climate change mitigation policy. Among the reasons for focusing attention on these sectors are that:

- Some of these industries are growing more rapidly than the energy-intensive industries. Most of the growth (75 percent) in industrial energy use from 1997-2015 will be by non energy-intensive industries (3.79 of 5.03 quads).

- Service Industries employ 77% of the U.S. workforce and account for 74% of GDP. The distinction between service and manufacturing industries is becoming increasingly blurred.

- Opportunities exist for new technologies in high-growth sectors that have capital turnover rates that are higher than those of energy-intensive industries. With high rates of capital turnover, the opportunities to accelerate the diffusion and acceptance of energy efficient technologies are substantial, and can collectively lead to significant reductions in carbon emissions.

- Under a climate change mitigation policy, industries involved in producing energy-saving products and providing energy services will benefit as demand increases for their products and services.

Non-Energy Minerals Industry

The non-energy mining includes the extraction of industrial minerals such as crushed stone, sand and gravel as well as metallic ores including iron, and copper. In 1992 the non-energy minerals industry had a production of $32 billion dollars. As in coal mining, employment has been steadily declining since the early 1980s. Projections indicate that by the year 2000 this sector will employ 25 percent fewer people than in 1980, dropping from 236,000 to 176,000 jobs. As with other sectors, the minerals industry will be affected by rising prices resulting from efforts to stabilize carbon emissions. However, there are indications that the industry will be able to reduce overall energy consumption to at least partially offset increased energy prices. Among others, using high efficiency electric motors, incorporating new process improvements, increasing maintenance of motor vehicles, system conveyor belts, drives, and compressed air systems can each provide savings of 10 to 15 percent, conservatively.

Construction

The construction industry is as varied as it is large. It includes firms with thousands of employees and firms with just one. In 1992 there were just under 2 million construction establishments employing over 4.6 million persons. Combined, the construction industry performed business totaling almost $582 billion in 1992. Although much of the construction industry rises and falls with fluctuations in the economy, the industry as a whole is likely to remain stable through the next 10 years, both in terms of employment and value of business.

Much of the construction industry is labor intensive. Most construction work involves using small trucks to transport workers and materials, and hand and power tools, and physical labor to complete work. It is one of the least energy intensive industries in the nation. Energy costs (including selected power, fuels, and lubricants) account for approximately 1.6 percent of each dollar of business

done in the construction industry as a whole. Nevertheless, there are important opportunities to reduce energy costs within the industry. These opportunities range from using more efficient motor vehicles to incorporating the use new building materials (e.g., laminated beams, recycled products, engineered lumber products such as roof and floor trusses, insulated wall panels, and modular components) that reduce both construction waste and costs.

Motor Vehicle and Related Industries

The motor vehicle industry is much more diverse than the mere manufacture of new cars and trucks. It also includes road construction and maintenance, freight and passenger services, petroleum refining and wholesale distribution, and automotive sales and services. Total employment in these related industries approaches 7 million persons, providing about 7 percent of the nation's jobs.

Continuing productivity gains in the motor vehicle industry has strengthened its overall economic position. The number of employees per hundred vehicles sold, for example, has fallen 2.9 percent per year in the decade ending 1994. At the same time, the industry should be fairly unaffected by geenhouse gas emisssions policies. This is due to the fact that the assembly of motor vehicles requires only about 15 million Btu of energy per car. If carbon prices rose as high as $100 per ton, for example, this would add between 0.1 and 0.2 percent to the cost of manufacturing a new car. On the other hand, new car and truck sales might slip as the cost of driving increases as a result of climate policies. But new technologies can be incorporated into the design and contruction of both light and heavy duty vehicles to reduce the overall cost of driving despite the prospect of initially higher gasoline prices. Technology improvements include engine designs that reduce friction and increase combustion efficiency and body designs that decrease the acrodynamic drag on the vehicle. Meeting the PNGV goals of an 80 MPG car that costs no more than today's vehicles will go a long way to minimize the impacts on both the auto industry and the many related industries.

Barriers to Adoption

From the above discussion, it is clear that numerous energy-saving technologies are available in the industrial sector — many of which offer additional benefits such as improved product quality. Despite this, however, many of these industries have historically avoided investing in energy efficiency technologies. Several factors help to explain why this may be the case.

For most industries, energy expenditures represent a minor portion of their operating costs, averaging less than two percent of value of shipments for the manufacturing sector. Industries such as primary aluminum, hydraulic cement and industrial gases are notable exceptions, with energy accounting for more than 20 percent of value of shipments. However, for some of the fastest growing industries, such as electronics and computers, energy expenditures represent only 1.2 and 0.6 percent of shipments respectively. In most industries, larger costs, such as labor and raw materials, receive attention before energy. For example, employee compensation averaged 24 percent of shipments in 1994.[3]

Opportunities for energy efficiency improvements must compete with other issues for finite resources within a company. While capital is the most often cited resource, staff time may be of equal or greater importance. Downsizing is common when industrial companies undergo restructuring, resulting in fewer total personnel available to address all issues. When a choice must be made

3. "Considerations in the Estimation of Costs and Benefits of Industrial Energy Efficiency Projects," ACEEE/EPA

between addressing a potential emissions-compliance, production-reliability or product-quality problem, and identifying and implementing energy efficiency projects, the former receives the attention since failure to do so may result in the plant being shut down. One manifestation of this staffing constraint is the reduction in the number of corporate energy managers[4]

Many businesses operate with a tight constraint on their capital budgeting. Hence, the allocation of capital remains a significant barrier to achieving greater levels of energy efficiency. Given a choice between expanding existing production capability and introducing new products, and reducing energy bills, the production-related projects will invariably win out. Hence, presenting projects based on total benefits will likely be more effective than building a case on the energy savings alone.

The Transportation Sector

Trends in the Transportation Sector

Over the last decade, new light vehicle fuel economy has remained relatively flat in the U.S. This is due to both an absence of increased fuel-efficiency standards and a lack of consumer demand for greater fuel efficiency. As fuel prices declined following the oil shocks on the 1970s, consumers began turning away from fuel economy and looked more toward amenities such as speed, acceleration, size, and greater utility when making their purchasing decisions. Corporate average fuel economy of the new light vehicle fleets (i.e., cars and light trucks such as minivans, sport utility vehicles, and pickup trucks) grew along with increasing CAFE standards throughout the late 1970s until the mid 1980s. Since 1982, however, the average horsepower rating of the combined new light vehicle fleet (cars plus light trucks) has increased by 60 percent while the average fuel economy of the same fleet has remained unchanged. Had new cars sold in 1996 retained the same average acceleration performance and weight as new cars sold in 1984, the technologies actually incorporated into the fleet during this period could have increased new car fuel economy by about five miles per gallon, or close to 20 percent.

In addition, the share of light trucks is increasing, having gone from under 25 percent of the market in 1982 to almost 45 percent today. Light trucks face lower CAFE standards than cars (almost 7 mpg lower). Moreover, since light trucks tend to last longer than cars, they are likely to be driven more miles over their lifetime than cars.

Contribution to Greenhouse Gas Emissions

Passenger cars and light-duty trucks contribute the majority of transportation emissions. Emissions from light-duty vehicles alone accounted for 20 percent of total U.S. greenhouse gas emissions in 1990, and in the absence of new policy measures are expected to rise from about 250 MMTC in 1990 to 350-400 MMTC in 2010. Energy use in trucks used for commercial transport is only about 40 percent of energy used in passenger vehicles, but is growing significantly faster.

The major factors underlying the rapid increase in emissions from light-duty vehicles are growth in VMT, stagnant new fleet fuel economy levels (miles per gallon, or mpg), and growth in the relative proportion of light trucks sold, which have lower (i.e., less stringent) CAFE standards than cars.

Actual growth in VMT since 1990 has averaged 2.4 percent per year. Growth in VMT is a function of a number of factors, including demographic changes (e.g., more women in the workforce;

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4. Ibid.

immigration), land use patterns, the cost of driving each mile (now at an all-time low on an inflation-adjusted basis), among others.

Factors Shaping Industry Response

With consumers continuing to exhibit preferences for performance, size, and utility rather than fuel economy, no significant increase in new fleet fuel economy is expected to occur absent a driving force such as policy changes or fuel price increases.

Technology Trends and Options

Three principal ways exist to reduce carbon emissions from light vehicles: (1) reduce vehicle miles traveled (VMT); (2) improve fuel economy; and (3) use fuels with lower life-cycle carbon emissions. Work developed for the "Car Talk" committee[5] suggested estimated reductions of 445 to 585 MMT would be possible in the period 2005 to 2025 from a combined package of land-use and transit policies as well as efforts to improve overall fuel economy and reduce the carbon content of transportation fuels.

Reducing VMT would involve a wide mix of policies. The goals would be to encourage land use away from auto dependency, and shift the relative (full) cost of driving versus other transportation/ communication alternatives such as workplace parking subsidy reform, and shifting of state and local subsidies to cost-of-driving fees.

Improving fuel economy represents an important opportunity to reduce GHG emissions since only about 15 percent of the energy in gasoline is actually used to propel a typical vehicle. The Partnership for a New Generation of Vehicles (PNGV) builds on the prospect for an improved fuel economy. PNGV is a Federal-industry research partnership created in 1993 to encourage innovation in the US auto industry. The PNGV focuses on a research goal of tripling fuel economy of a typical 1994 family sedan by 2003-2004, while meeting or exceeding federal safety and emissions requirements, and without sacrificing performance, size, utility, or affordability. Most current PNGV work on this goal is focused on improving drive train efficiency, developing practical on-board energy storage systems, and reducing vehicle mass through the use of light weight materials. A pre-production prototype vehicle with a 100 percent improved fuel efficiency is expected in 2001; vehicles with 150-200 percent improved efficiency will be available in the 2005-2010 period.

Future technological innovations would come from technologies such as multi-valve engines, lighter materials, and next-generation tires, which have already been partially but not completely integrated into the new vehicle fleet. An additional component of the overall fuel economy improvement would be technologies such as direct injection engines and fully variable valve timing, still in the development stage.

Alternative fuels — such as biofuels — are another large opportunity for reducing transportation carbon emissions. While ethanol produced from corn actually results in higher greenhouse gas

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5. The "Car-Talk" committee is the *Policy Dialogue Advisory Committee to Assist the President in the Development of Measures to Significantly Reduce Greenhouse Gas Emissions from Personal Motor Vehicles* formed in 1993 to see whether a consensus set of policies could be developed to return personal transport GHG emissions to 1990 levels by 2005, 2015 and 2025. The committee failed to agree on such policies, but substantial analytic results were developed by a team of government analysts working with several expert committee members.

emissions than gasoline (on a full fuel cycle basis), ethanol from woody-biomass-derived ethanol can results in a 90 percent reduction in greenhouse gases. Federal R&D has brought down the cost of biomass ethanol (from $3.60 per gallon in 1980 to $1.20 per gallon today). Further research has the goal further cost reductions to under $0.70 per gallon by 2005, competitive with oil at its current price. Estimated carbon savings from use of ethanol largely as a gasoline blend is 20 MMTC in 2010.

Agriculture

Basic farm commodity production was about 0.9 percent of GDP in 1995 and accounted for about 1.2 percent of US employment. These numbers, however, belie the true importance of agriculture — the farm sector and agriculturally related industries in total account for about 13.5 percent of GDP and 17.3 percent of employment. Processing and distribution is the largest component and is relatively more labor intensive.

Contribution to Greenhouse Gas Emissions

Agricultural greenhouse emissions include methane, nitrous oxide, and carbon dioxide. Estimates of non-energy greenhouse gas emissions are relatively imprecise. While agriculture represents less than 5 percent of total national greenhouse gas emissions, it is an large source of methane and nitrous oxide.

The principle sources of agricultural methane are enteric fermentation (animal digestion) and manure management associated with livestock production. Applications of synthetic and organic fertilizers account for almost all of agriculture's N_2O emissions.

Globally, agriculture is a much more important source of GHG emissions than in the United States, accounting for about 20 percent of all greenhouse gas emissions. Agriculture's share of world emissions of CO_2, CH_4, and N_2O are estimated at 21-25 percent, 57 percent, and 65-80 percent respectively (excluding emissions from natural sources). Conversion of land to farm production (particularly tropical forests) is the major agricultural source of CO_2 emissions while rice and livestock production are the principle sources of CH_4 emissions.

Soil Carbon: Depletion or sequestration of soil carbon is a potentially important source of agricultural greenhouse gas emissions. Plants use photosynthesis to remove CO_2 from the atmosphere and convert it to carbon which is stored in plant biomass. Left undisturbed, soils accumulate some of this carbon as organic matter through root growth and decay of crop plant materials. Tillage is used to loosen surface soil and subsurface material, improve aeration and water infiltration, and control weeds. All benefit crop growth in the short-term. Tilling, however, also increases the exposure of soils to oxygen thereby accelerating the conversion of soil organic matter to CO_2, which is released into the atmosphere. Over time then, tilling reduces both soil carbon levels and soil productivity.

Reductions in soil carbon levels in U.S. agricultural soil (between 30 and 50 percent over the last 100 years) may have been a significant component of the historic increase in atmospheric CO_2 levels.

Factors Shaping Industry Response

Agricultural production is an energy intensive industry. Agricultural chemicals, particularly nitrogen fertilizer, are energy intensive. Transportation of agricultural commodities to market would also be affected. Some components of the food processing sector are energy intensive but, overall, the sector is less energy intensive than overall manufacturing.

For every dollar of farm output, 12 cents is spent on energy with electricity accounting for 6 cents. This reflects the increasing reliance on electricity for operations such as grain handling and large-scale confined livestock production. Agricultural chemicals embody 6 cents of energy for each dollar of output, spent mainly on natural gas and electricity. Nitrogen fertilizer is among the most energy intensive chemicals and its availability is a key to high agricultural productivity. Energy cost increases would directly increase both agricultural production costs and agricultural chemical manufacturing costs.

Technology Trends and Options

The Climate Change Action Plan for the U.S. identified tree planting, research and outreach to help farmers better manage nitrogen use, methane capture from covered manure lagoons, and increased ruminant feed efficiency as opportunities to sequester carbon and reduce emissions of agricultural greenhouse gases.

Opportunities for further sequestering carbon in agriculture would include the following:

- Conversion of marginal cropland and pasture to forest: Forest growth currently offsets about 8 percent of total annual U.S. greenhouse gas emissions on a carbon equivalent basis. A number of studies have outlined the costs and economic benefits to U.S. agriculture resulting from strategies to mitigate U.S. greenhouse gas emissions by paying farmers to convert cropland and pasture to forest. Pulling the necessary quantities of land out of production, however, would raise land prices and would increase the cost of bidding out land out of production.

- Promoting the use of management practices that increase the quantity of carbon stored in agricultural soils: Studies suggest that these sinks could technically offset a majority of U.S. greenhouse gas emissions, but economic analysis of such possibilities is limited.

- Using biofuels to replace fossil fuels: Because the carbon released in the burning of biofuels would be taken back up by the next crop, replacing fossil fuels with biofuels offers a means of increasing the amount of carbon that is recycled in the production and use of energy. The IPCC (1996) has estimated that for the world's temperate regions as a whole, carbon emissions could be reduced by 85 to 493 million tons per year by allocating 8 to 11 percent of their cropland to biofuel crops. While the United State's share of this is not addressed, the IPCC notes that the best mitigation opportunities are in areas with good agricultural land and surplus production.

- Further efforts to alter livestock management practices to reduce methane emissions: The most promising opportunities for reducing methane emissions in U.S. agriculture are in new management practices for the feeding of livestock and the handling of livestock waste (particularly cattle).

Energy Supply Sectors

Electric Power Generation

Historically, demand for electricity and economic growth have been closely correlated. Over the last twenty years, U.S. demand for electricity grew by approximately three percent per year, but this rate of demand growth is expected to decrease between now and 2010, averaging slightly more than one percent per year.

With several hundred billion dollars worth of combined capital investments, electric power generation is one of the largest and most important economic sectors in the U.S. economy. The character of this industry has changed over time and is in the midst of another major restructuring. In 1995, FERC required open access to transmission for the purpose of wholesale competition. Currently over 80 percent of the states are moving toward electricity industry restructuring. Two broad trends can be noted. First, all the state decisions are leading to greater customer choice and second, there is a general trend to de-couple generation, transmission and distribution.

In addition to restructuring, the industry is undergoing a shift in the sources of generation. Nuclear energy is a carbon-free source of electricity that presently provides over 20 percent of U.S. electricity. Despite nuclear power's substantial contribution to today's electricity supply, no new nuclear power plants have been ordered by U.S. electricity generators since 1978. Although nuclear power generation was at an all-time high in 1995, the retirement of older plants and the lack of new nuclear projects will reduce nuclear in the future U.S. energy mix. Nuclear power plants are due to begin retiring in 2010 with most capacity retired by 2030. Fossil fuel power plants generated over 80 percent of U.S. electricity in 1970, but that share has fallen to about two-thirds as nuclear power's share has risen from virtually nil to about 22%; fossil generation is expected to return to about 80 percent over the next twenty years as the existing stock of nuclear plants are phased out.

Although the overall efficiency of fossil generation — the rate at which fossil energy is converted to electricity — has barely changed in the past 35 years, modest improvements are expected over the next twenty years as natural gas-fired generation doubles its share of total generation from about 15 percent today to over 30 percent. New natural gas-fired "combined cycle" power plants yield very high conversion efficiencies (>50 percent) by generating steam from the waste heat of advanced combustion turbines and using it to drive steam turbines.

Renewable energy is forecast to have high growth but remain a small part of the base. Excluding hydroelectric power, whose expansion possibilities are very constrained, renewable electricity generation is expected to double over the next twenty years but will still account for less that 2 percent of total electricity generation. The hydro share of the energy market was 4.4 percent in 1996.

As state-by-state restructuring takes place, several states have already mandated minimum levels of renewable energy through "renewable portfolio standards," including Vermont, Maine, and Arizona. Many other states are considering similar measures to accelerate the adoption of renewable generation technologies. These technologies have become more competitive over the last twenty years. Photovoltaics have dropped from 90 cents per kilowatt-hr to under 20 cents per kilowatt- hr; wind technology has dropped from 25 to 5 cents per kilowatt-hr. Cost reduction will continue to occur through R&D advances and through economies of scale as production rates increase.

Contribution to Greenhouse Gas Emissions

The electric power industry is the largest direct energy consumer in the United States. Electric generators are responsible for 35 percent of national emissions of carbon dioxide, with over 85 percent of electricity-related emissions coming from coal-fired plants.

	1995	Percentage of Total 1995 Emissions	2010	Percentage of Total 2010 Emissions
Petroleum	599	42%	730	42%
Natural Gas	318	22%	412	24%
Coal	507	36%	580	34%
Total	1424	100%	1722	100%

Source: DOE Annual Energy Outlook 1997

Factors Shaping Industry Response

Restructuring

Restructuring of the electric power industry offers a unique opportunity to mitigate future emissions of CO_2 from this sector. Many states are currently considering or adopting retail competition for their electric power markets. This trend may be accelerated with federal legislation. Retail competition may lower the price of electricity by as much as 20-25 percent in certain regions and change the fuel mix of generation. Restructuring without new environmental policies is expected to favor the expanded use of existing coal plants. These plants are largely depreciated, and hence can generate electricity for low incremental cost. To mitigate the environmental impacts of competition and maintain the environmental benefits of current state level renewable energy and demand side management programs, a number of options have been adopted or are under consideration. These include:

- A "portfolio standard" for renewable energy: this would require that all generators meet a specified level of renewable generation either by undertaking such projects themselves or purchasing "credits" from others who have.

- A social benefit fund: Revenues from a charge on transmission service are used to subsidize energy efficiency projects, renewable, R&D, or low income consumers. California has adopted this approach.

- Information disclosure requirements: Generators could be required to disclose the emission profiles of their generation, facilitating the marketing of "green" (or, less polluting) electricity.

- Leveling of the playing field for air pollutant requirements: Many states are hesitant to adopt retail competition because they perceive that differing regional environmental requirements put their electric industry at a competitive disadvantage and will result in more pollution being transported into their states. Thus, additional environmental provisions to "level the playing field" - which could include greenhouse gas emission reductions - are currently being debated. Adaption of fuel neutral standards would promote utilization of lower emission systems.

- Special consideration for energy efficient and/or low emission technologies: This includes

advanced gas turbines and micro turbines for cogeneration and self-generation, fuel cells, and renewable technologies.

Distributed Generation

Distributed generation is the utilization of small power generation technologies dispersed through the distribution system to provide local power close to customers, thereby reducing investment in transmission and distribution resources and improving local reliability. This could include self-generation or cogeneration by industrial and building sectors and involve power sales back to the grid. Cost competitive technologies, such as smaller scale advanced gas turbines, are emerging which can compete economically with central station generation when full costs, including the avoided transmission and distribution expenditures, are considered. All of this will support the customer choice aspect of deregulation and lead to a reduction in cost of electricity for customers. The electric power producers will move from the concept of centralized power for economics of scale to providing energy services for customers. This will provide:

- economies of mass production of units
- smaller, cleaner generation
- fuel security through diversity of generation portfolio
- more options for customers to be green

Technology Trends and Options

Electric sector emissions can be reduced either by making generation less carbon intensive (e.g., conversion efficiency improvements, fuel switching, cogeneration, or renewables) or by reducing the amount of electricity demanded through increased penetration of more energy-efficient end-use technologies. Studies by the America Council for an Energy-Efficient Economy (ACEEE) show that there is a long-term potential to save about 25 percent of industrial electricity consumption at a cost that is significantly lower than the current cost of new generation units. For example, an industrial site which purchased coal-derived electricity generated at 35 percent efficiency could self-generate power in a cogeneration mode at 75-80 percent efficiency, selling power back to the grid and producing their own steam.

Many of the following technologies are projected to substantially increase their market share in the next decade.

- The next generation of natural gas technologies (including gas turbines and fuel cells) are projected to achieve energy conversion efficiencies of 70 percent or more by 2005.

- High efficiency coal-fueled power plants, such as integrated gasification combined cycle, are likely to realize efficiencies exceeding 55 percent and half the CO_2 emissions of current coal technologies.

- Renewable technologies - wind power, photovoltaics, solar thermal, and geothermal — have seen sharp cost reductions in the past two decades, some by a factor of ten.

- Options such as biomass gasification offer the ability to produce power with no net increase in CO_2 emissions. The growth of biomass offsets (sequesters) the CO_2 released in electric power production.

Petroleum

Contribution to Greenhouse Gases

Petroleum products are the leading source of carbon emissions from energy use. Petroleum accounted for 584 MMTC emissions in 1995, and this figure is predicted to increase to 718 MMTC by 2010. The majority (~80 percent) of petroleum emissions result from transportation use.

Factors Shaping Industry Response

Petroleum product demand is largely a function of the demand for transportation. Petroleum product consumption has been rising even though the amount of oil energy consumed per dollar of GDP has been falling since 1973. Oil energy per dollar consumed per dollar of GDP fell from 8,900 Btu/$ in 1973 to an estimated 5,100 Btu/$ in 1996, a drop of 43 percent. The ratio will remain at 5,100 Btu/$ of GDP in 1997.

Coal

Electric utilities are the dominant consumers of coal. Overall consumption by utilities grew from 17 percent (84 million short tons) in 1949 to an 88 percent share (829 million short tons) in 1995. According to industry analysts, coal energy consumption will move up 1 percent in 1997 to 20.6 quads and coal's share of the energy market will remain at 22.7 percent. Coal consumption is expected to increase in future years along with the demand for electricity.

Contribution to Greenhouse Gas Emissions

Coal has the highest carbon content per unit of energy among fossil fuels — as well as being a source of pollutants such as sulfur dioxide. It is used primarily in the electricity sector, where coal-fired plants currently account for approximately 56 percent of total U.S. electricity production. Coal is the second leading source of carbon emissions, and is projected to produce 579 MMTC in 2010, compared to 507 MMTC in 1995. Even without consideration of the issue of greenhouse gas emissions, most analysts project that the great bulk of capacity additions to electric utility plants from now until at least 2010 will be fueled with natural gas rather than coal. Thus, while most existing coal-fired plants are highly competitive suppliers of power that are dispatched ahead of gas-fired plants on the basis of lower fuel costs, fuel cost advantages cannot offset the substantially higher capital costs of a coal plant when new capacity is needed.

Factors Shaping Industry Response

In the stabilization scenario, coal production is lower than in the baseline. In contrast, the NEMS stabilization scenario run under assumptions that allow for substantial "overbuilding" (early retirement) of existing coal capacity suggests a substantially greater decline in coal use than the DRI energy model analysis. The reduction in coal use from baseline in 2010 is twice as great — 58 percent vs. 29 percent.

Several factors contribute to the difference in perspectives. Most importantly, the large reductions in end-use energy demand in the DRI energy model provide "room" to use more coal that is simply unavailable in the NEMS stabilization scenario. In addition, the NEMS involves a larger reduction to reach stabilization, putting additional pressure on coal, the most carbon-intensive fossil fuel.

Changes in coal use due to greenhouse must be considered in the context of overall industry trends that are projected in the absence of any climate change action — despite output growth, employment in coal mining in 1995 is already less than half of 1980 levels. Therefore, notwithstanding rising coal consumption in the baseline case, national coal employment is projected to fall substantially — reflecting the fact that coal production productivity (tons per hour) rises at a much faster rate than does coal consumption in all regions. There is also a continuing shift towards increased supply from regions where productivity is highest.

In the DRI energy model results, there is a smaller shift away from coal use (and production). However, DRI has even higher labor productivity growth assumptions than does NEMS, which by itself reduces employment over time in both the base and mitigation policy cases.

Nuclear Energy

While the performance of existing nuclear electric power plants reached record levels in 1992, the number of operating reactors has leveled off. High operating costs, waste disposal difficulties, and other problems pose major challenges to the further expansion of nuclear electric power.

The future contribution of nuclear power depends on three factors: economic retirements of existing plants prior to the end of their license period, re-licensing of existing plants to extend beyond a 40-year service life, and level of new capacity builds.

Factors Shaping Industry Response

The baseline cases in the two energy models each project a modest level of economic retirements, operator decisions against pursuing relicensing, and no construction of new plants. As a result, the projected contribution of nuclear power in 2020 is slightly more than half of its 1995 level. While the base cases are similar, the two models differ substantially in the stabilization case. In the DRI energy model stabilization case, nuclear generation follows the DRI base case path. However, in the NEMS case, re-licensing of nuclear plants becomes economically attractive, and premature economic retirements do not occur. As a result, nuclear generation does not fall from its 1995 level. In addition, the model suggests that new nuclear capacity could be added in the 2015 time frame given the modeled carbon permit values in the stabilization case.

It should be noted that the model does not account for issues of public acceptability and uncertainty regarding waste disposal that could present significant barriers to new nuclear investments. The anticipated shift to more competitive electricity markets, in which the cost of capital for new generation facilities will be higher than that applicable to regulated utilities, tends to make investment in capital-intensive technologies with long lead times, such as nuclear generation, less attractive. For these reasons, the prospects for new nuclear builds remain problematic. The models illustrate how different policy choices can lead to differing outcomes.

Natural Gas

Contribution to Greenhouse Gas Emissions

Of the fossil fuels, natural gas consumption and emissions are predicted to increase most rapidly through 2015, according to AEO 97. In 1995, carbon emissions from natural gas were 267 MMTC, and this figure is projected to increase to 310 MMTC in 2010 and 319 MMTC in 2015.

Factors Shaping Industry Response

Impacts of greenhouse gas emissions mitigation on the natural gas industry depend on the balance between the three available strategies in reaching the emissions reduction goal. Different modeling tools illustrate different possible futures:

- The DRI energy model shows a reduction in natural gas use relative to baseline on the order of 9 to 16 percent between 2005 and 2015.

- NEMS, despite simulating a somewhat larger reduction in carbon emissions from the energy sector, shows an increase in natural gas use relative to base of between 4 and 11 percent over this same period.

The dramatically different alternative futures illustrate the way in which emphasizing different energy strategies to reduce carbon emissions — energy efficiency versus fuel switching — will produce different results.

The key to cost-effective greenhouse gas reductions in 2010 lies in the large potential of developing and implementing energy efficiency technologies in each of the economic sectors. While the tendency has been on emphasizing those industries which would feel challenged by a U.S. climate change policy to reduce emissions, it is clear that many opportunities exist as well. For example, companies and individuals in the architectural field can benefit as new building designs are needed to improve efficiency in both the residential and commercial sectors. In addition, industries that manufacture items such as heating and air conditioning equipment, office equipment, automobile parts, industrial equipment, and lighting, to name only a small fraction of potential industries, may also benefit under a climate change policy due to increased demand for these products. Finally, industries involved in the development of renewable energy technologies will also be at an advantage as interest in solar, wind and other sources of energy grows.

Conclusion

From the above discussion, it is clear that the way in which resources are used by individual industries within each economic sector varies widely. This is not surprising given the vast array of goods and services produced by these industries. Because sectors are unique, a U.S. climate change mitigation strategy must be designed and implemented in a way that reflects a solid understanding and appreciation of the differing circumstances faced by U.S. industries. Policies which emphasize both flexibility and a productivity-led investment strategy to reduce carbon emissions will give each industry the ability to respond to individual policies in a way that both minimizes potential impacts and maximizes possible opportunities. In order to achieve this goal, future climate change policies must be based on the continued development and diffusion of cost-effective, energy efficient technologies.