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Climate Change Modeling [1]

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S	20	6	4	1

Economic Impacts of Kyoto

Energy Modeling Forum 16 Working Group
Meeting #1

May 14, 1998

Presentation by
Paul M. Bernstein and W. David Montgomery
Charles River Associates, Inc.
Thomas F. Rutherford
University of Colorado

CRA

Scope of MRT

Multi-region trade model

- Fully dynamic, general equilibrium model
- 7 Regions: Asia, EE/FSU, EU 15, OPEC, OOECD, ROW, and U.S.
- 30 year time horizon: 2000 - 2030
- One non-energy sector (Armington Trade Structure)
  manufacturing goods, imperfect substitutes
- Three fossil fuels (Full Trade)
  oil
  gas
  coal
  4 traded goods
- Backstop technology
- Emission trading among any set of regions

MPSG software
GCAP data base

CRA

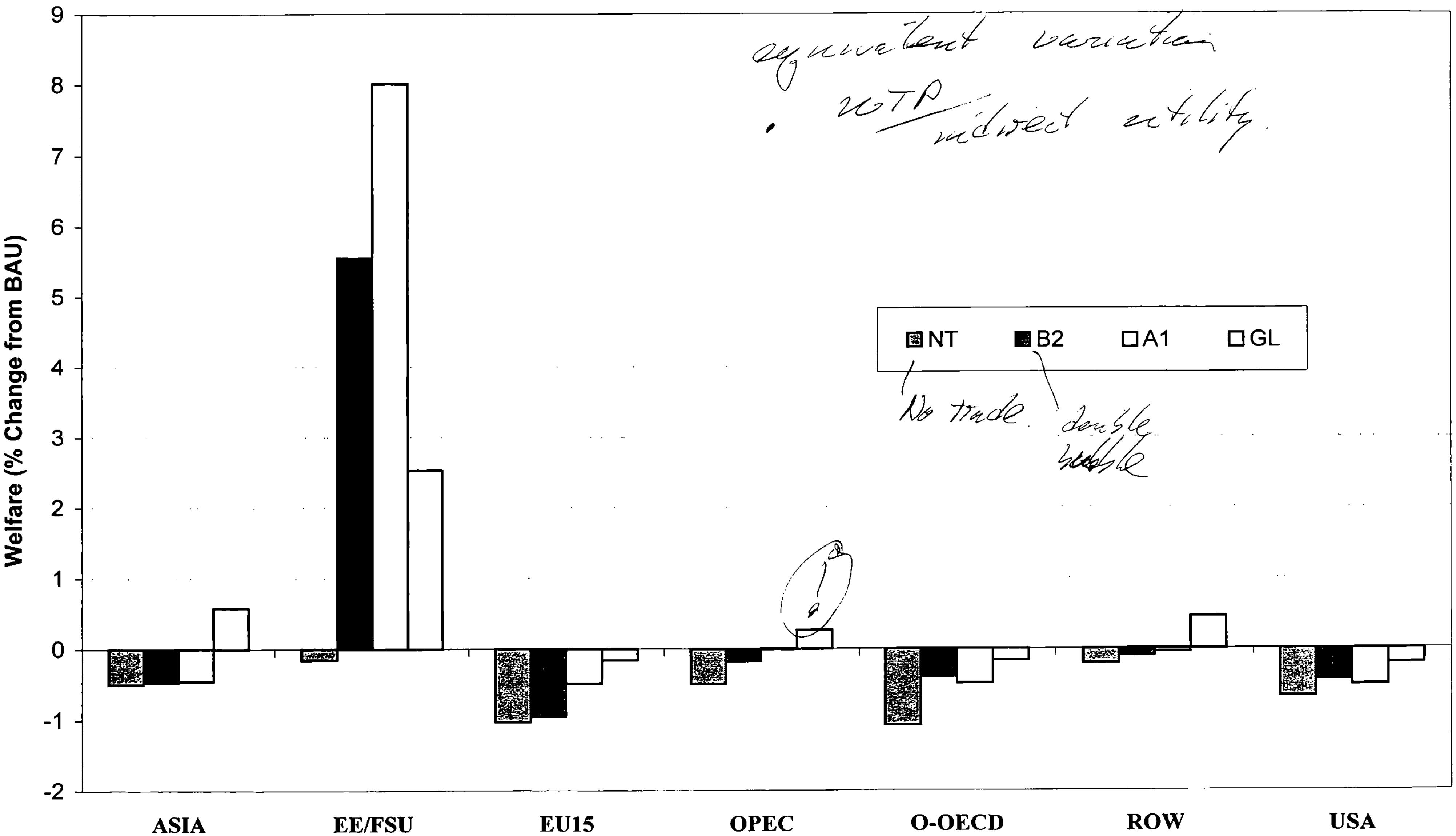
Scenarios and Sensitivity Analysis

- Trading blocs: EU only, Double Bubble, Annex 1, All countries
- Sink Potential: 0, 1/6, 2/3
- Other GHGs change to targets: -10%, 0, 10%
- Russia: hot air, no hot air trade
- Limits on trading: 50%, 30%, 10%
- Monopoly Trading

- No CDM.
- moved Russia to mkt prices by 2005 in baseline.

CRA

Infinite Horizon Welfare Under the Four Trading Regimes
(EMF Reference Case)



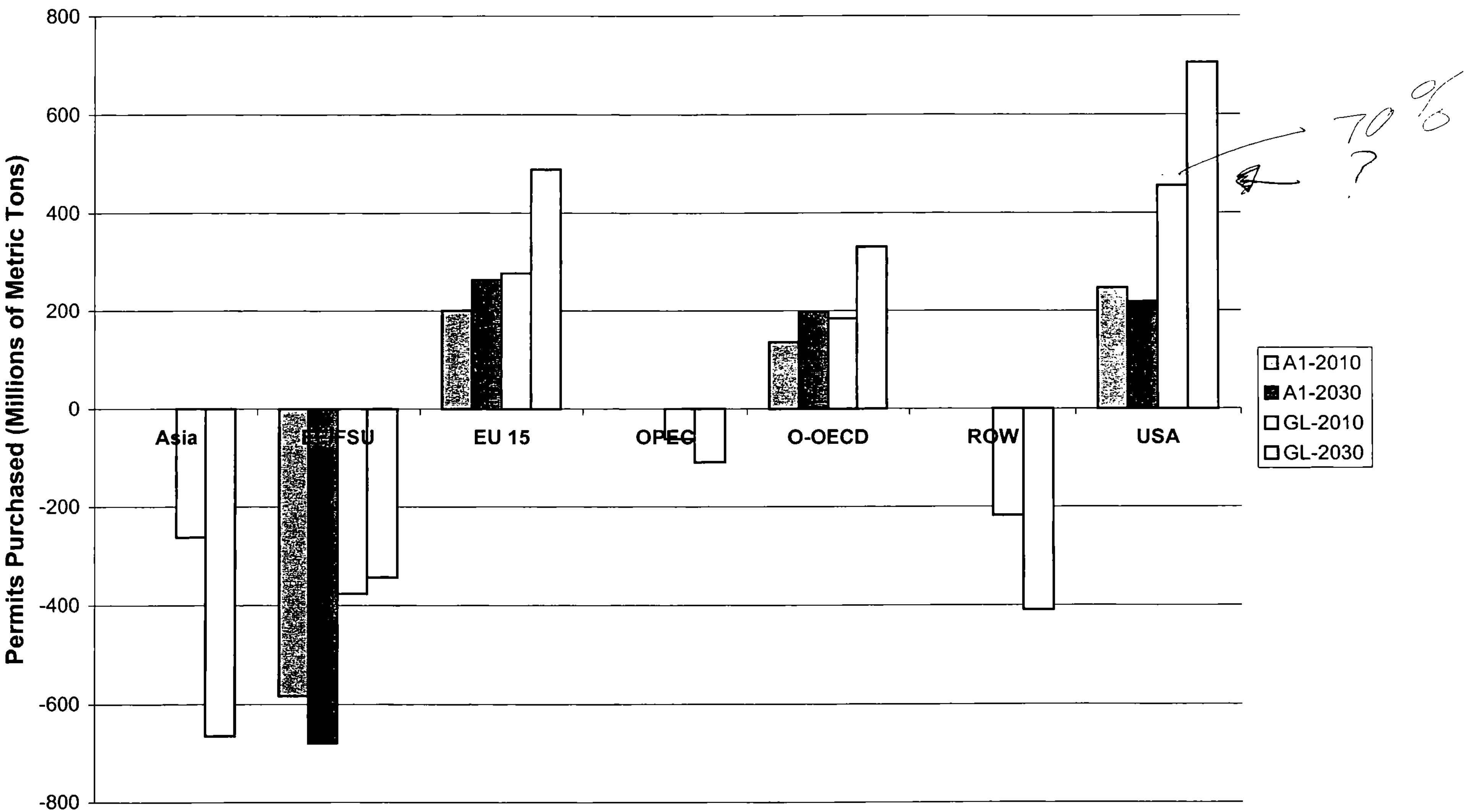
equivalent variation

WTP indirect utility

No trade

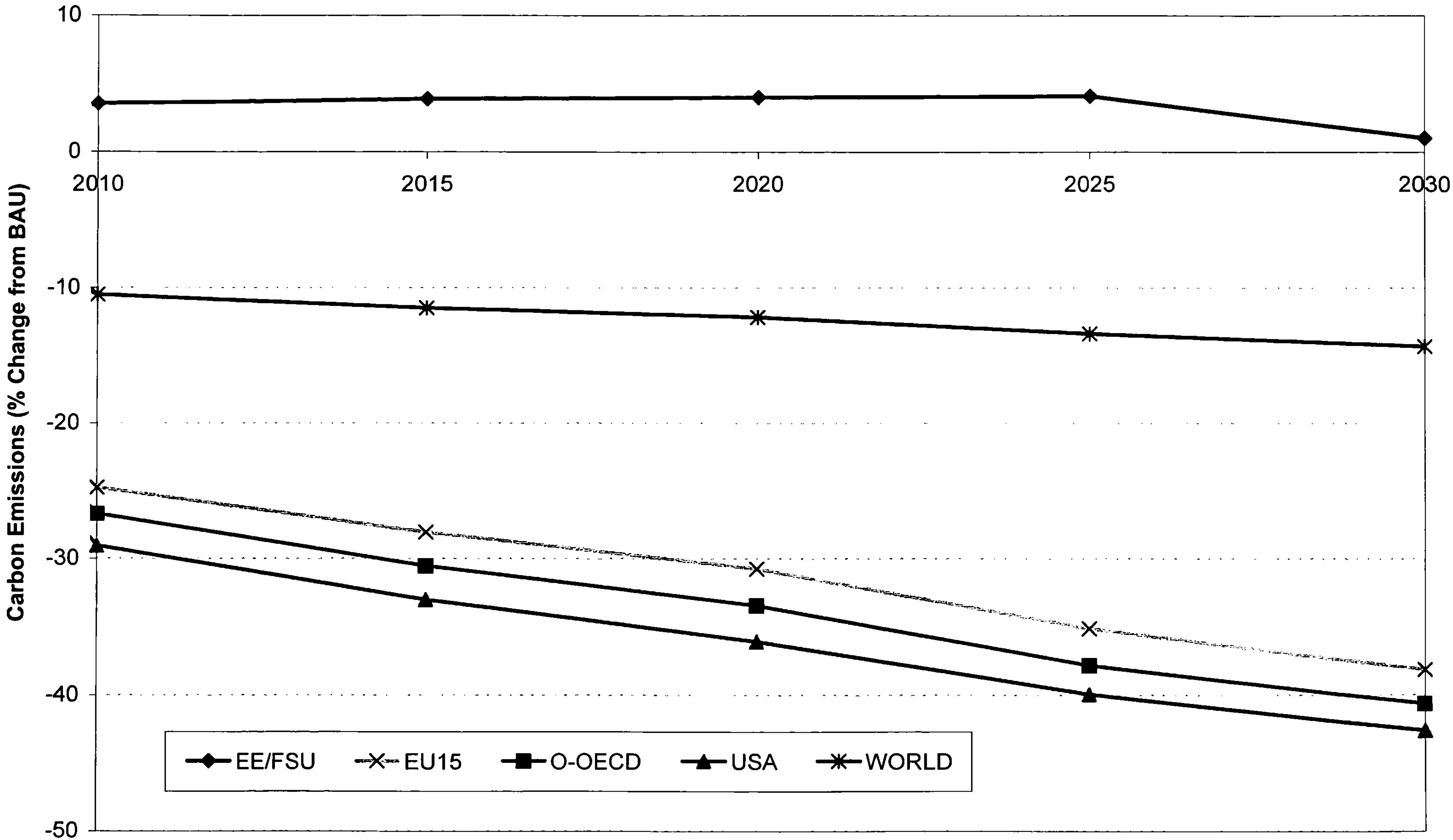
double bubble

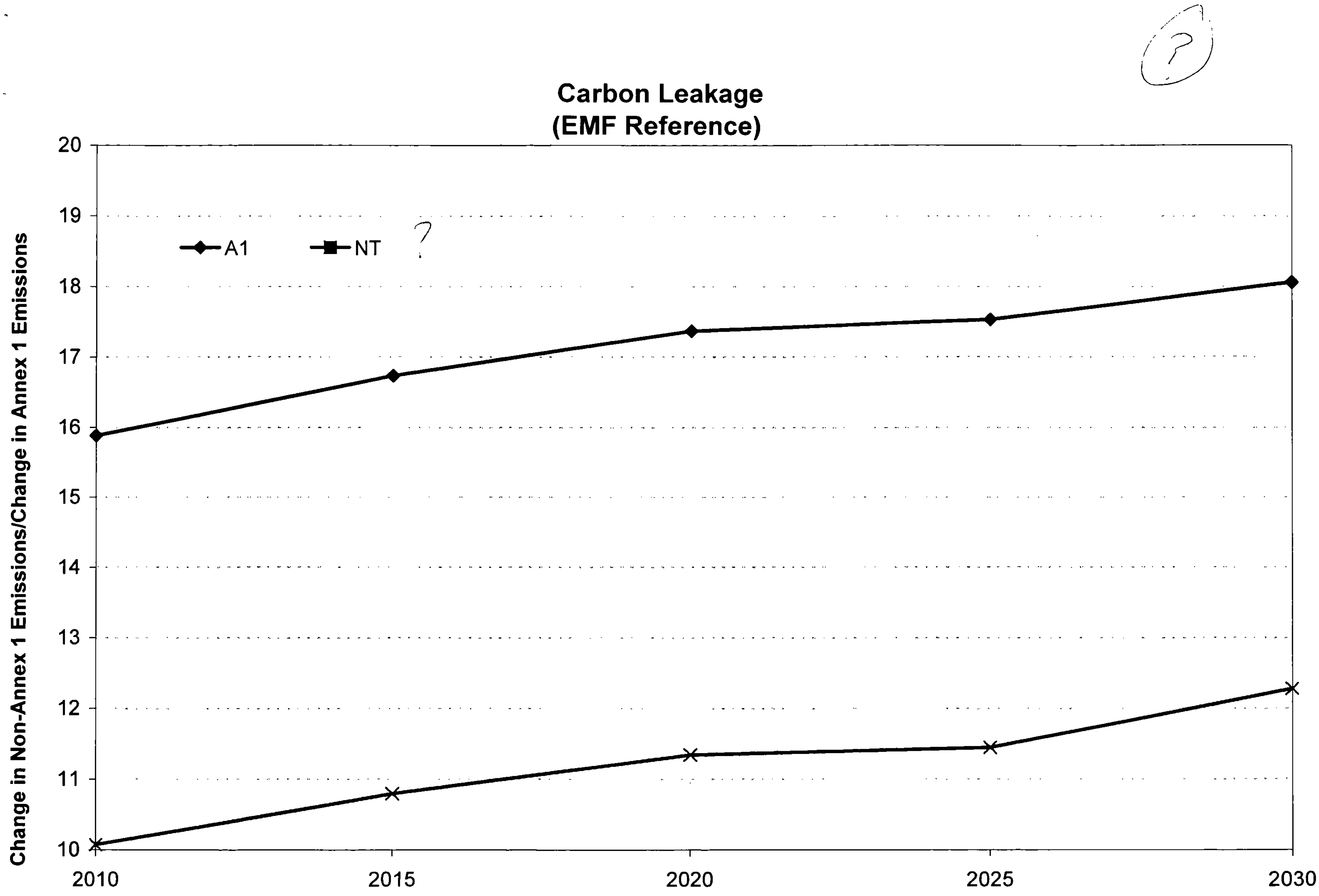
Trade in Emissions Permits (EMF Reference)



Δ Annex I
Δ Non Annex I

Carbon Emissions - Percent Deviation from BAU
(EMF Reference - No Trade Scenario)





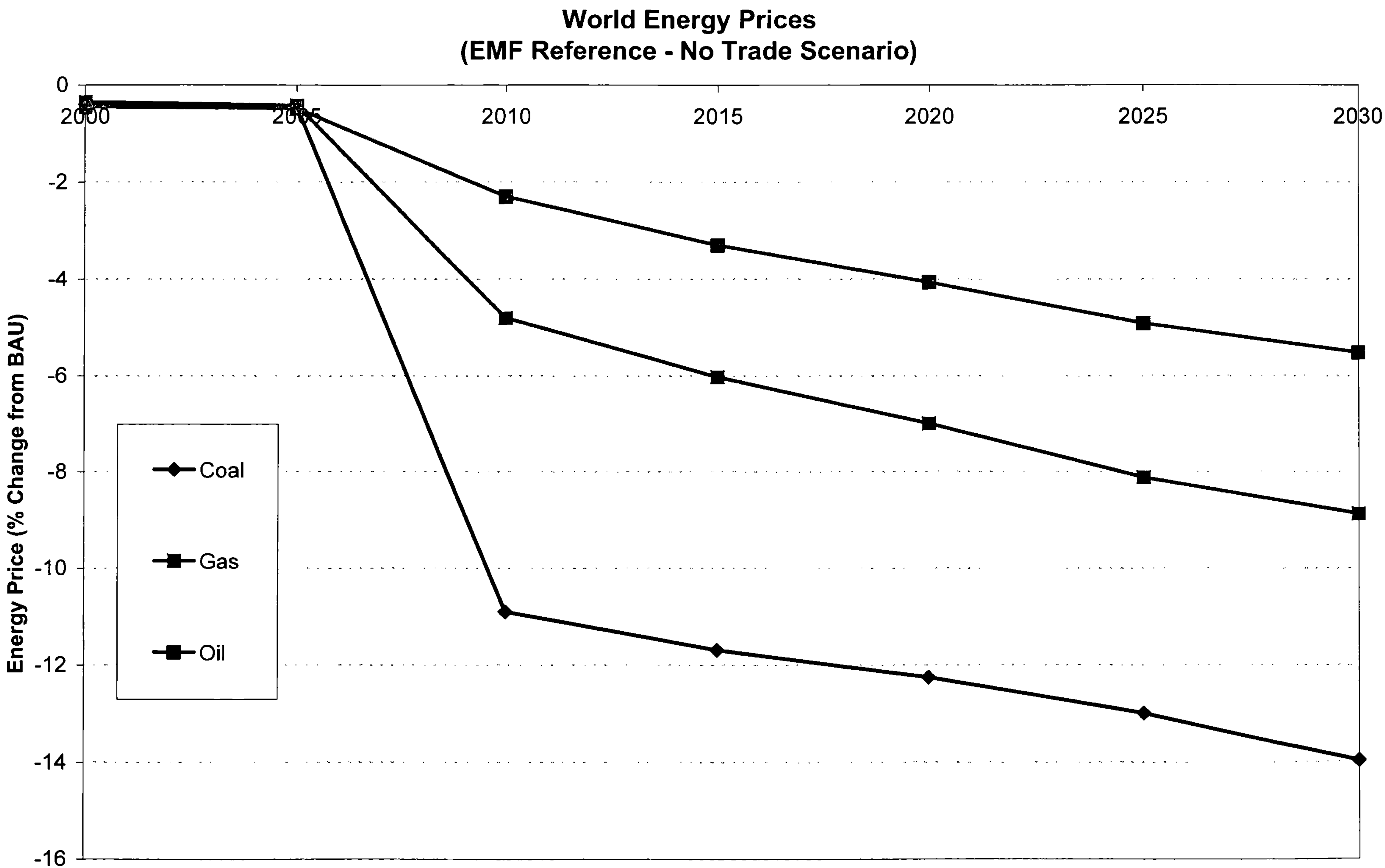
Carbon Leakage
(EMF Reference)
?
A1
NT
?
Change in Non-Annex 1 Emissions/Change in Annex 1 Emissions
20
19
18
17
16
15
14
13
12
11
10
2010
2015
2020
2025
2030

Permit
Price

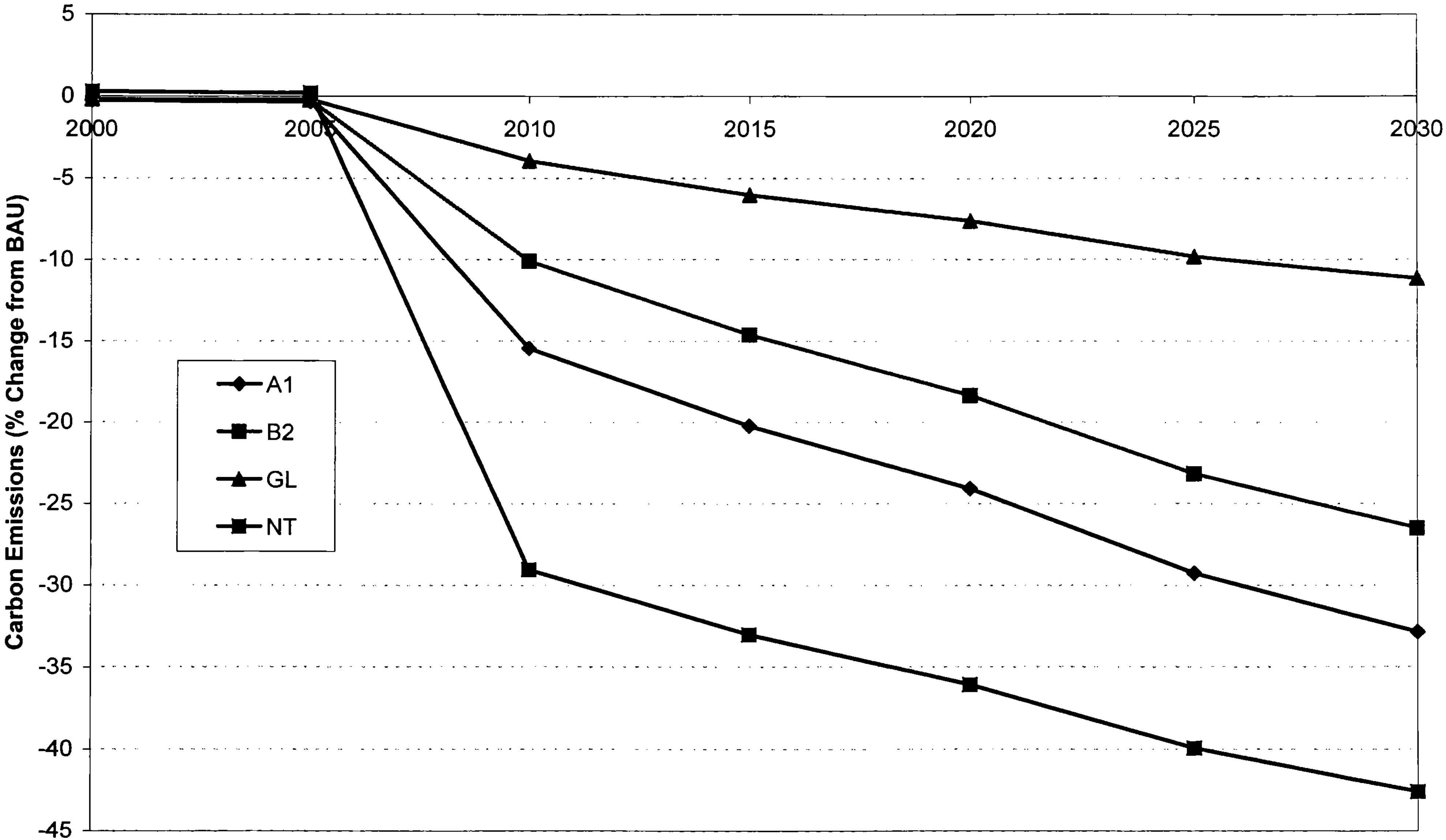
$20 Global

$50 B^2

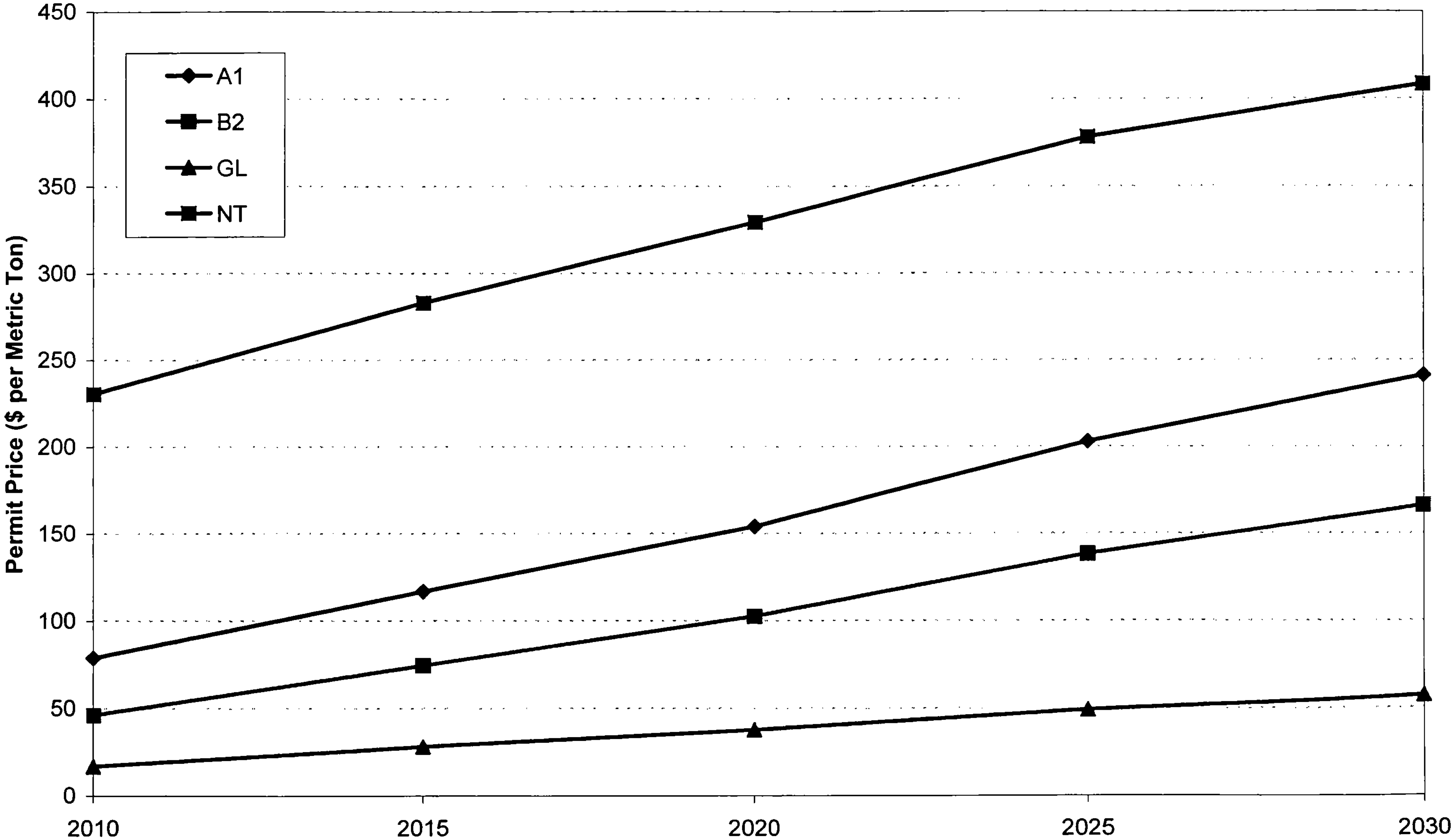
No plateau on prices

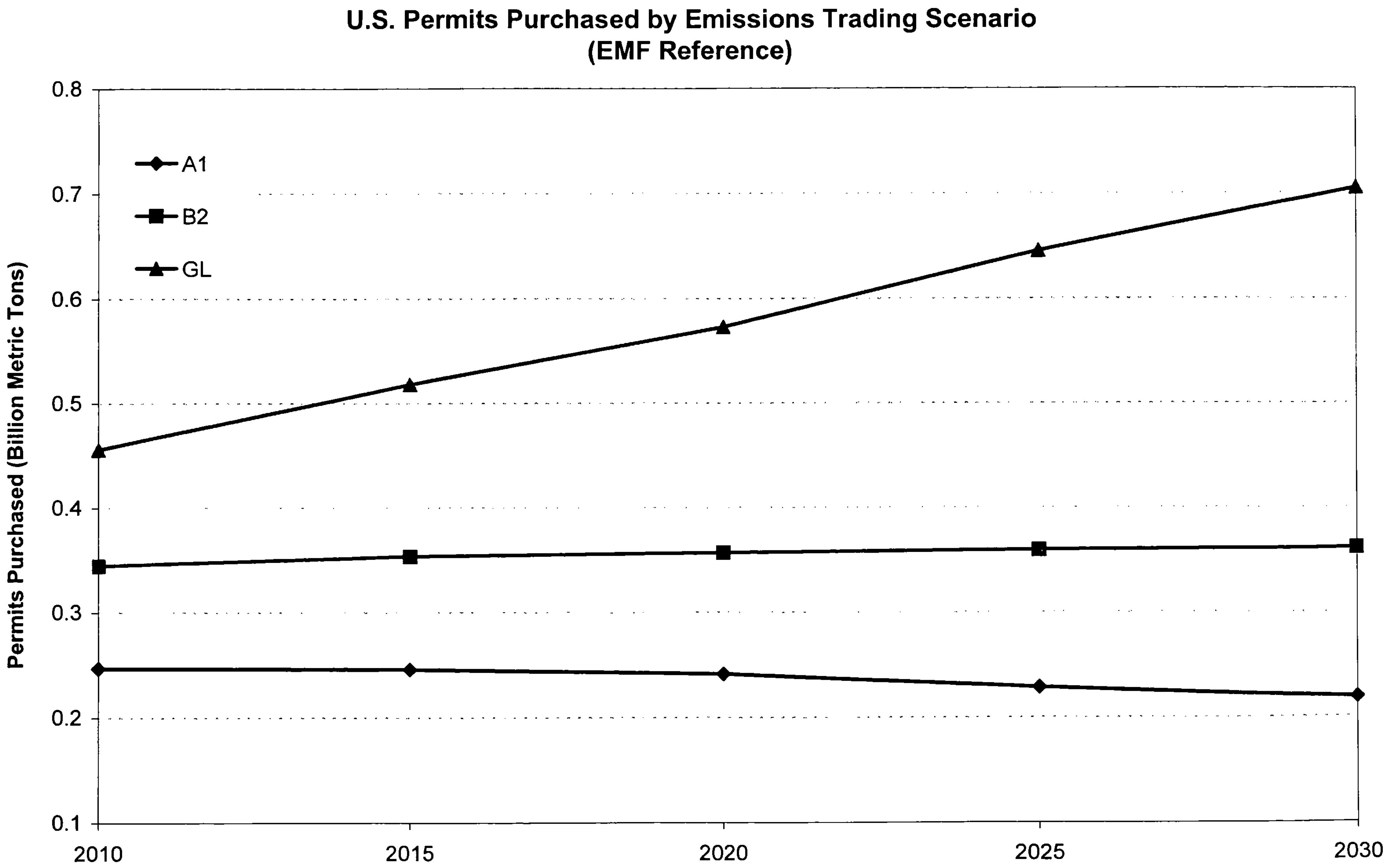

World Energy Prices
(EMF Reference - No Trade Scenario)
Energy Price (% Change from BAU)
0
-2
-4
-6
-8
-10
-12
-14
-16
2000
2005
2010
2015
2020
2025
2030
Coal
Gas
Oil

U.S. Carbon Emissions - Deviation from BAU by Trading Scenario (EMF Reference)

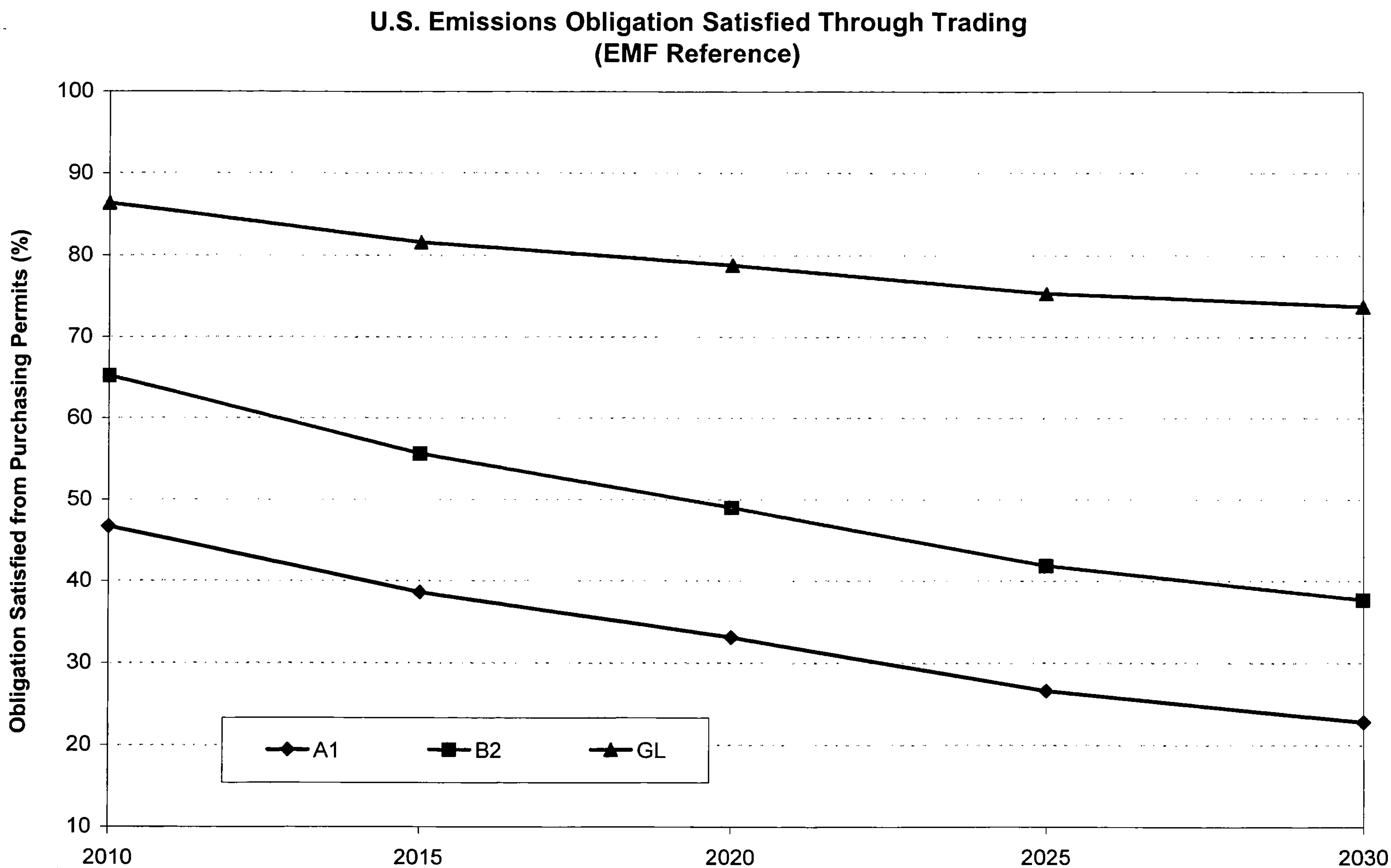


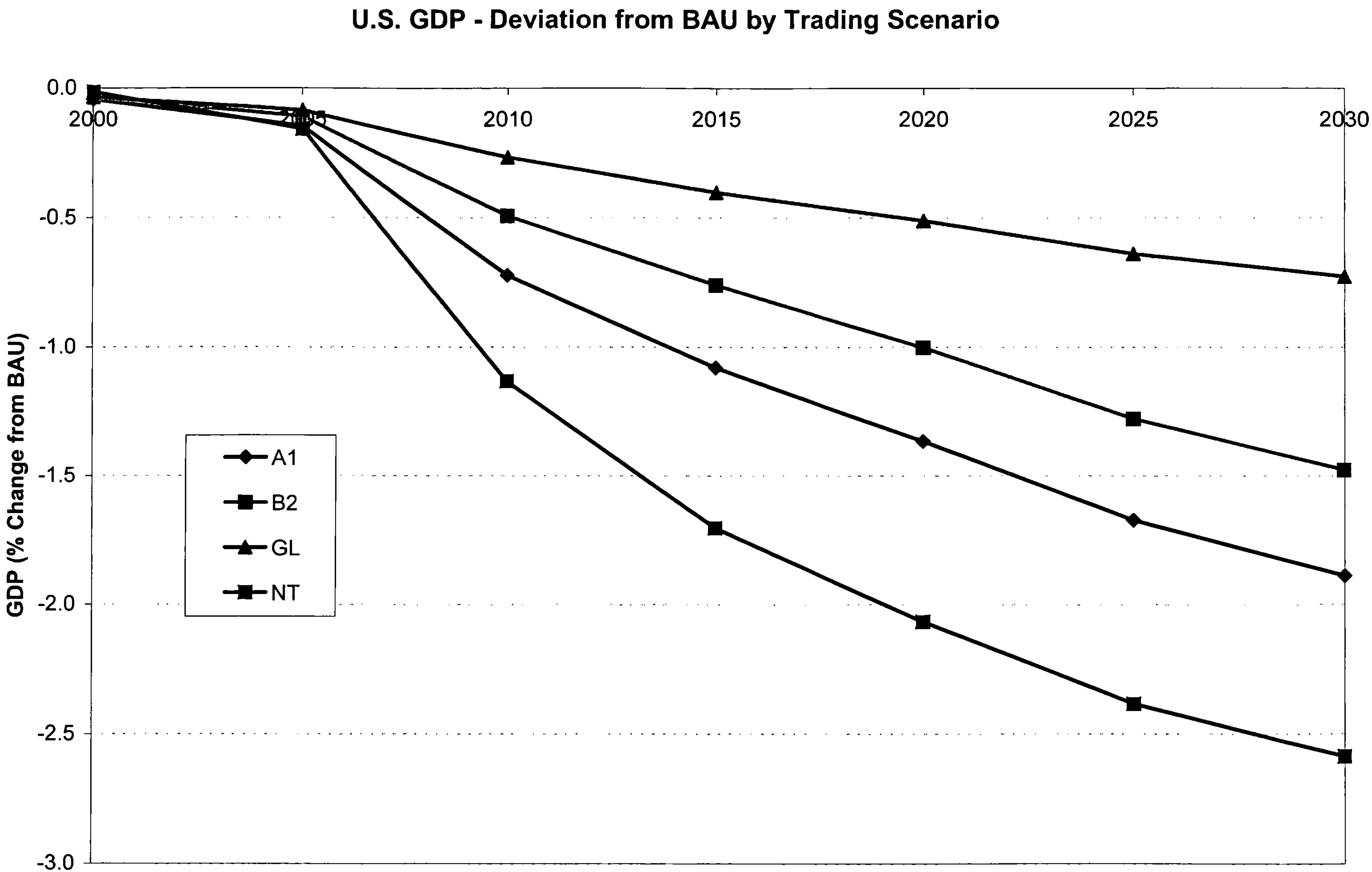
U.S. Carbon Permit Price by Emissions Trading Scenario



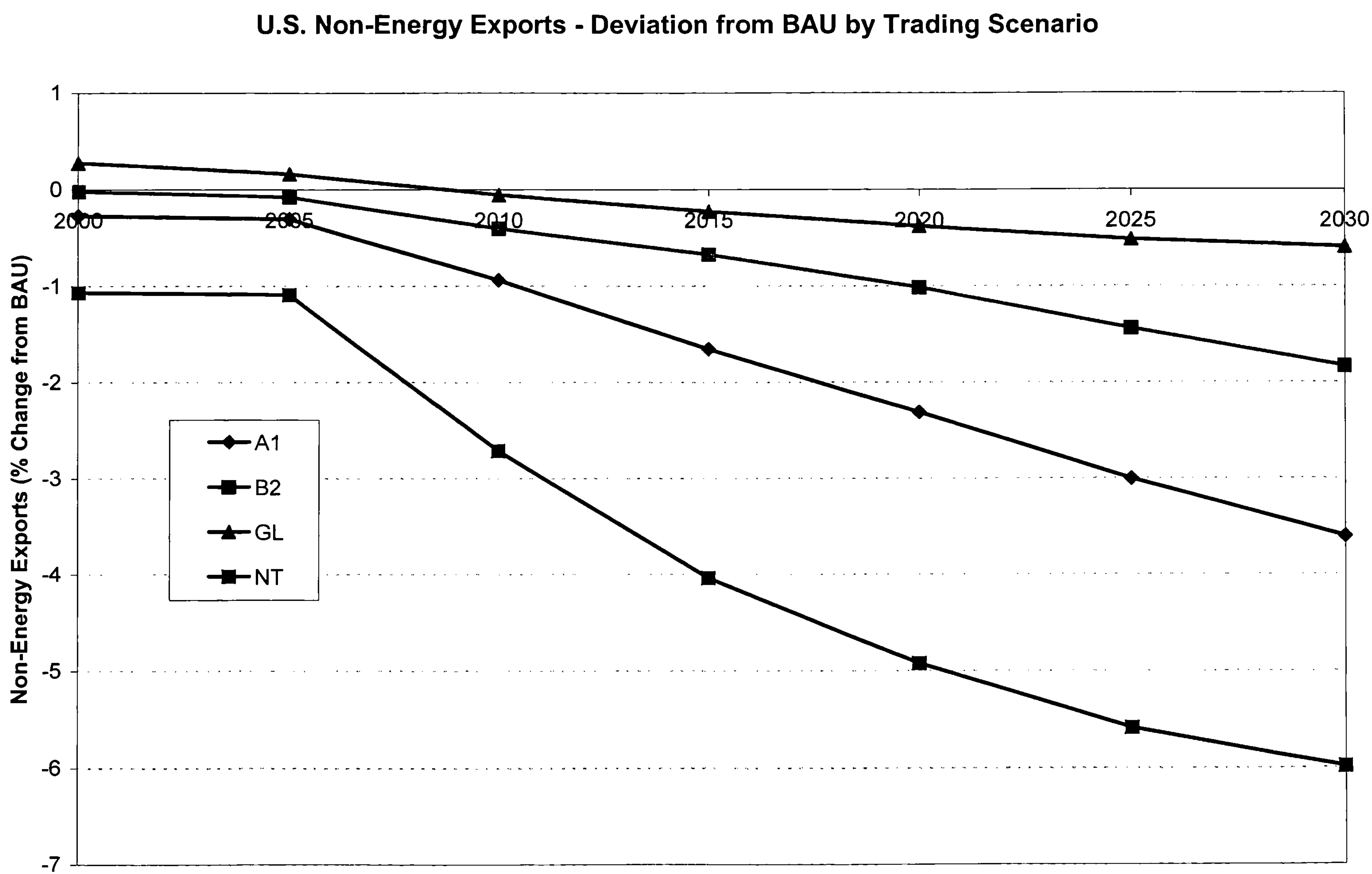


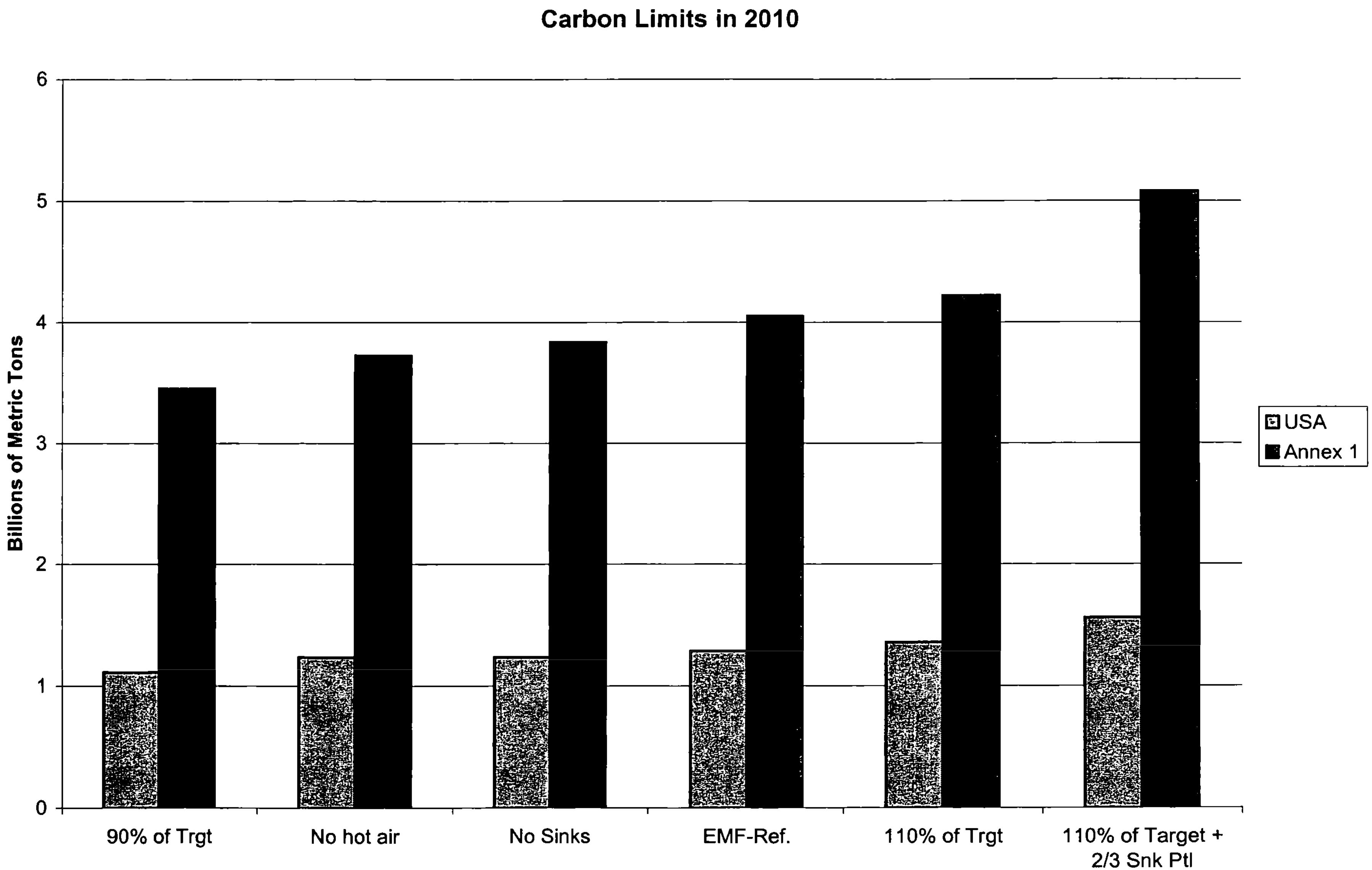
U.S. Permits Purchased by Emissions Trading Scenario
(EMF Reference)
Permits Purchased (Billion Metric Tons)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2010
2015
2020
2025
2030
A1
B2
GL


U.S. Emissions Obligation Satisfied Through Trading
(EMF Reference)
Obligation Satisfied from Purchasing Permits (%)
100
90
80
70
60
50
40
30
20
10
2010
2015
2020
2025
2030
A1
B2
GL

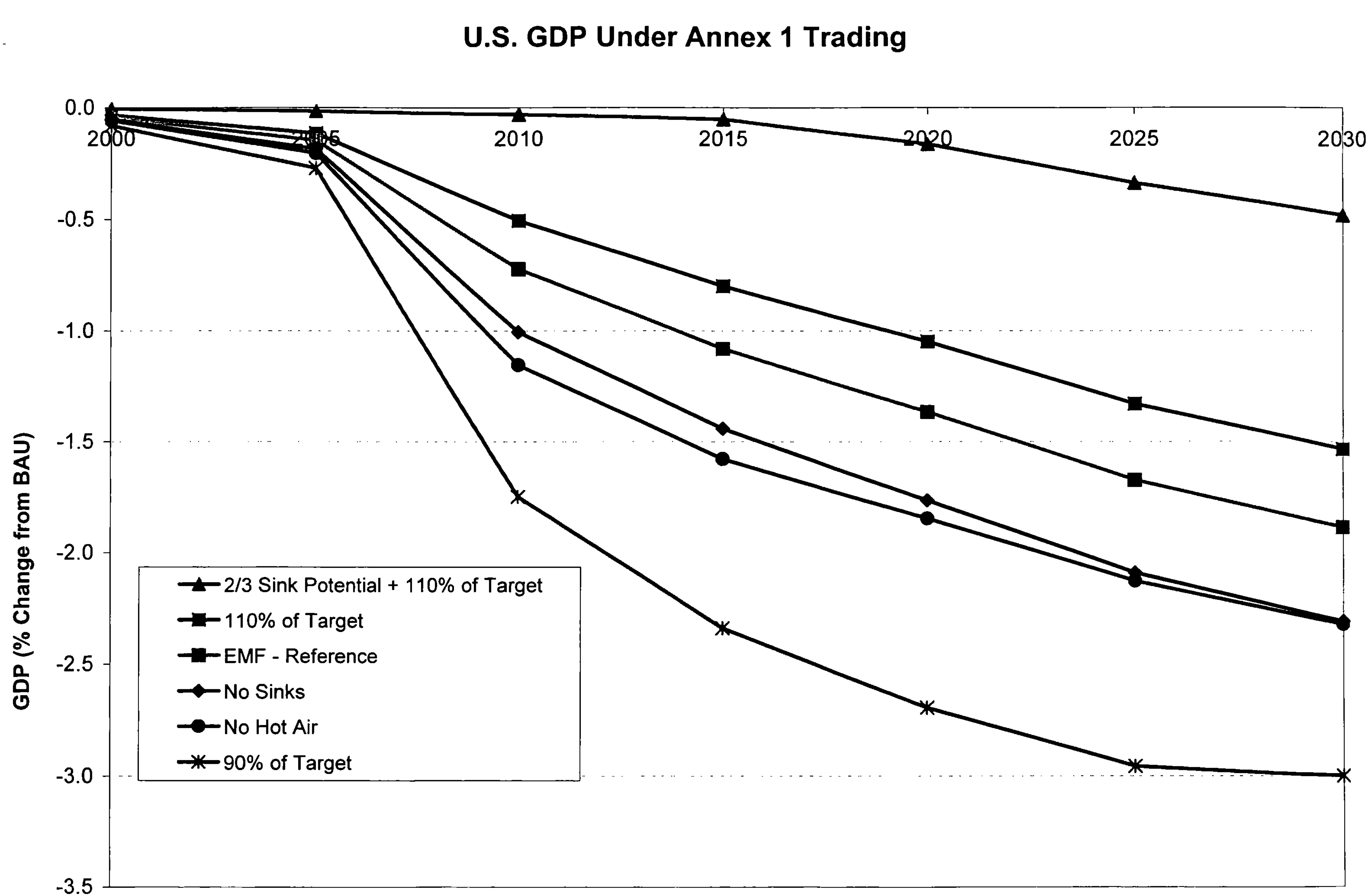


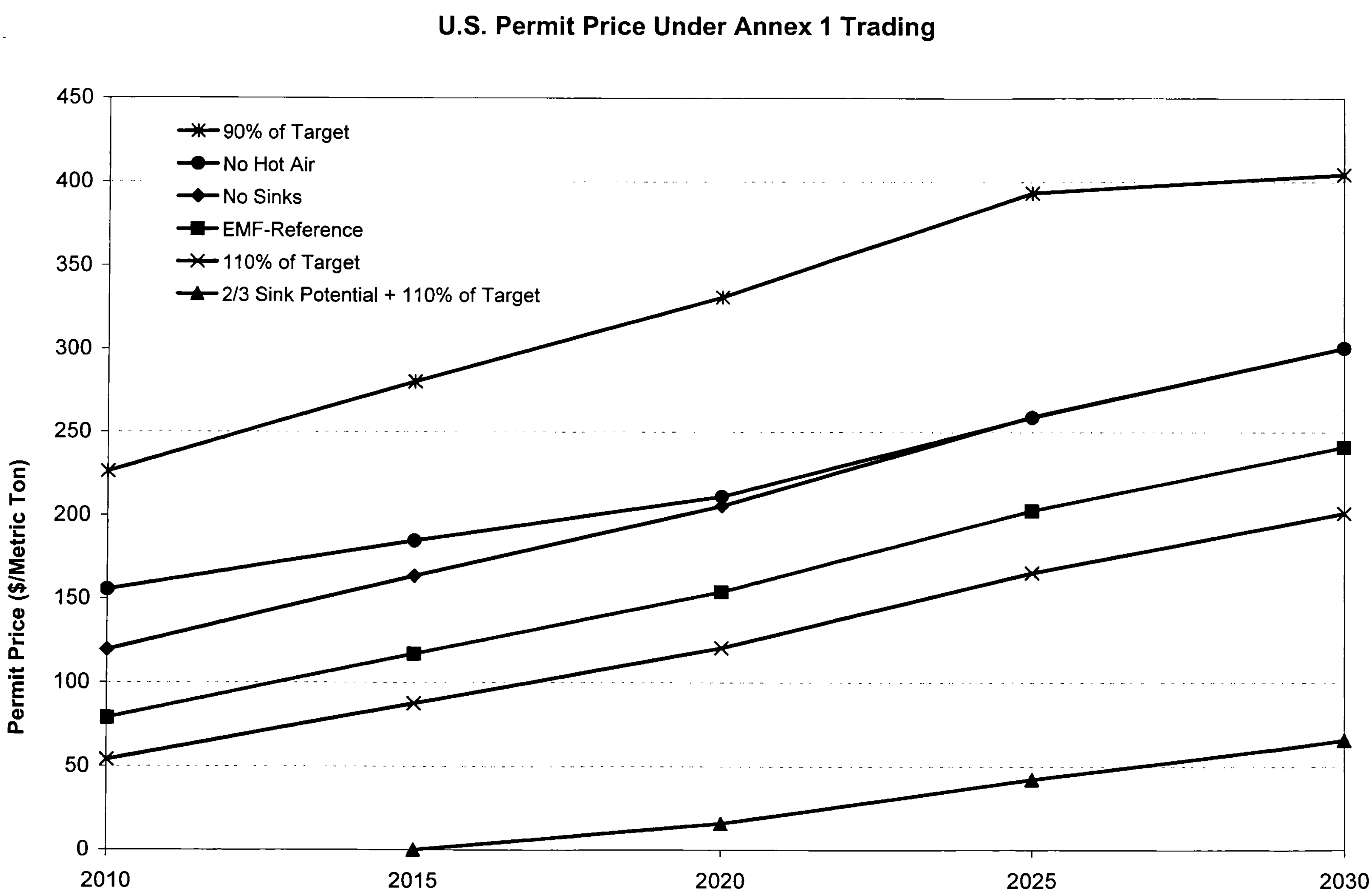
U.S. GDP - Deviation from BAU by Trading Scenario
GDP (% Change from BAU)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
2000
2005
2010
2015
2020
2025
2030
A1
B2
GL
NT


U.S. Non-Energy Exports - Deviation from BAU by Trading Scenario
Non-Energy Exports (% Change from BAU)
1
0
-1
-2
-3
-4
-5
-6
-7
2000
2005
2010
2015
2020
2025
2030
A1
B2
GL
NT

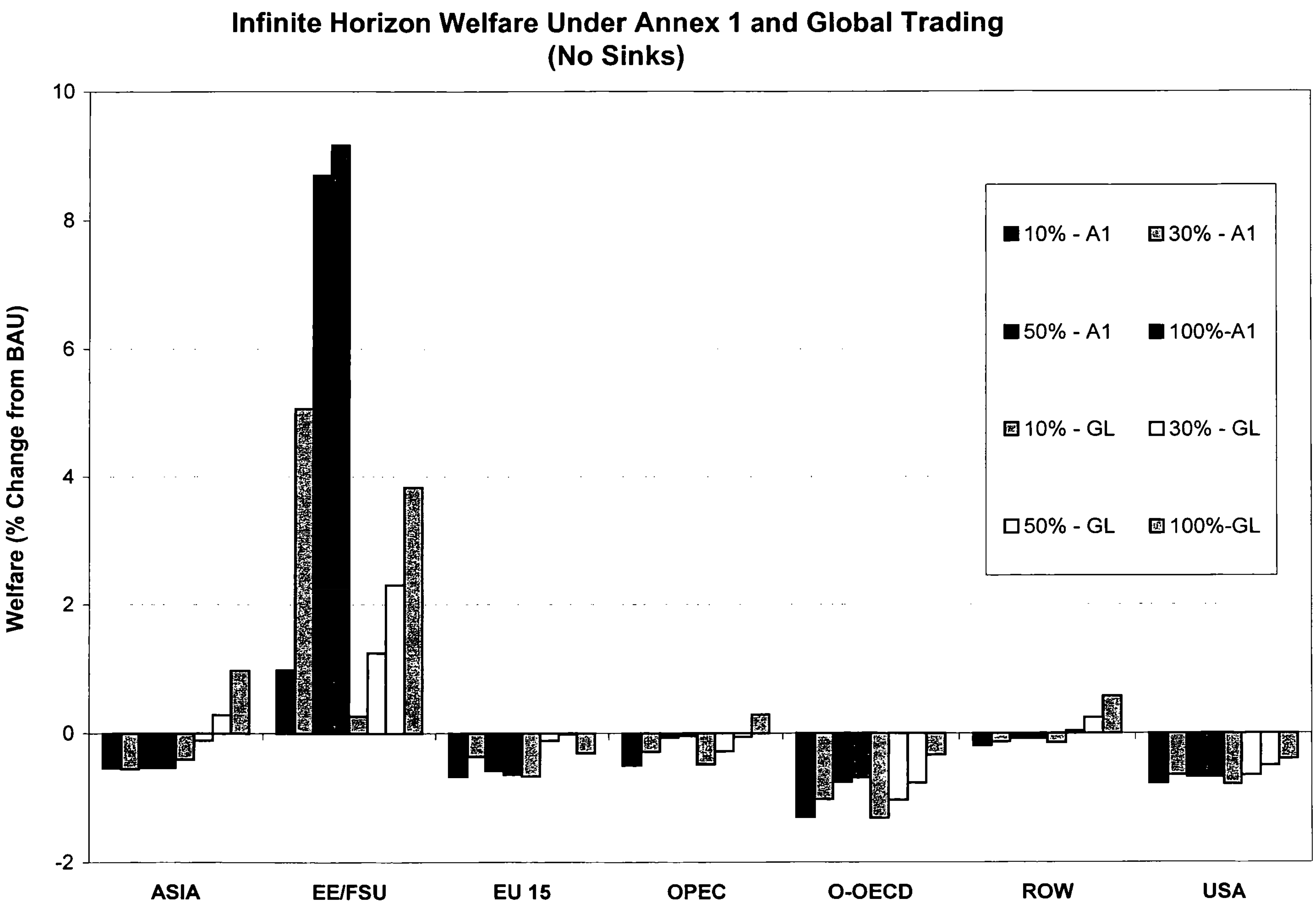


Carbon Limits in 2010
Billions of Metric Tons
6
5
4
3
2
1
0
USA
Annex 1
90% of Trgt
No hot air
No Sinks
EMF-Ref.
110% of Trgt
110% of Target + 2/3 Snk Ptl

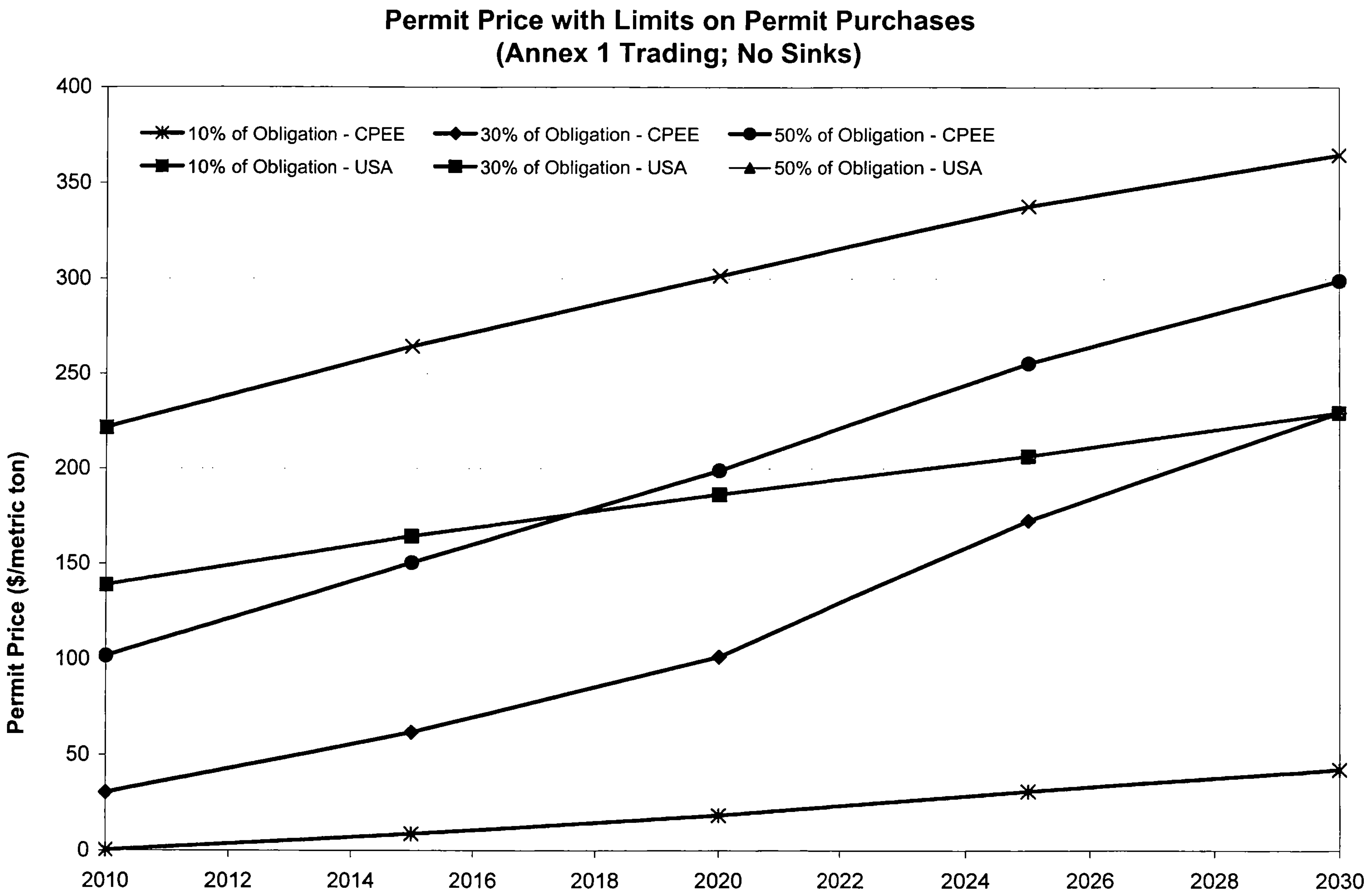

U.S. GDP Under Annex 1 Trading
GDP (% Change from BAU)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
2000
2005
2010
2015
2020
2025
2030
2/3 Sink Potential + 110% of Target
110% of Target
EMF - Reference
No Sinks
No Hot Air
90% of Target



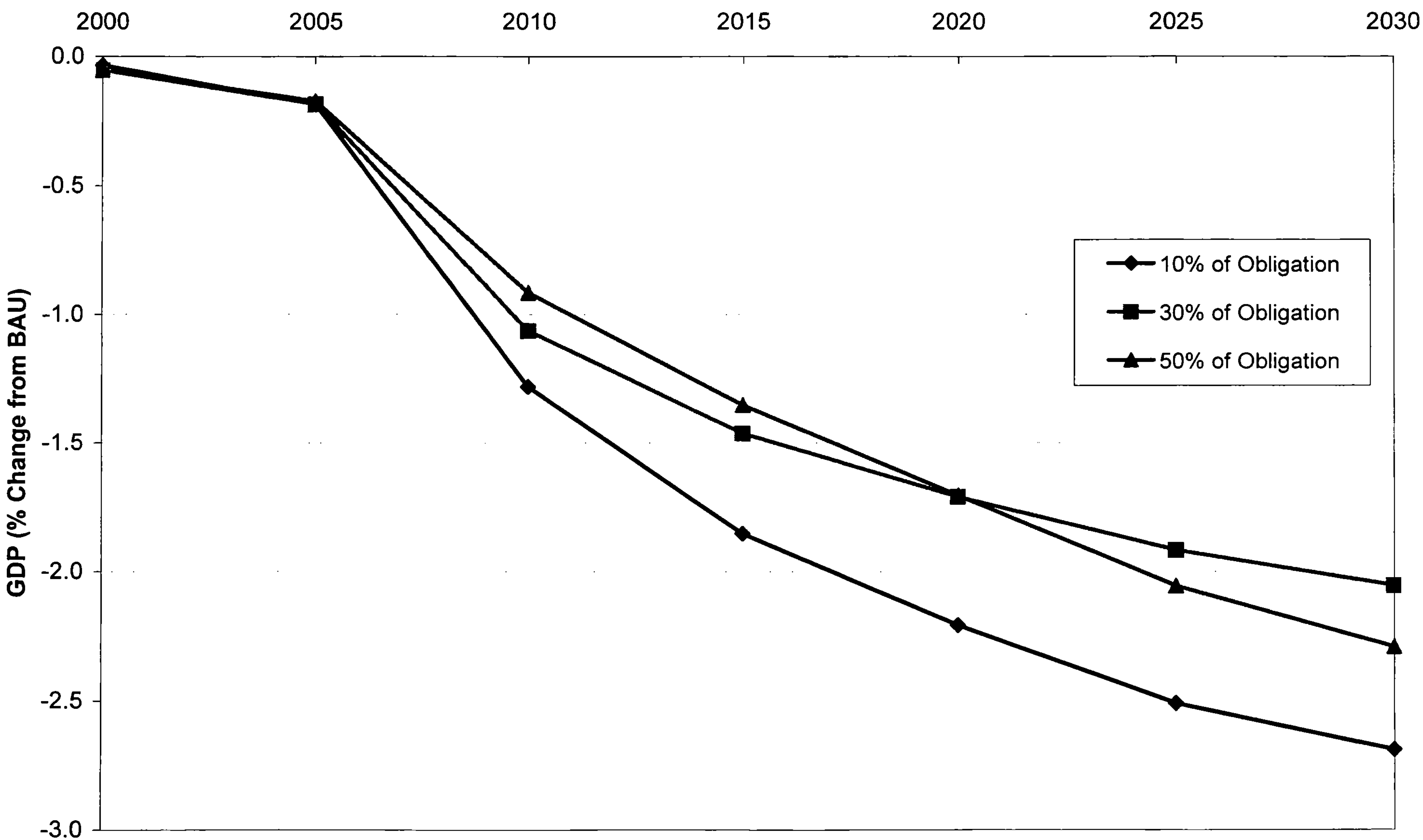
U.S. Permit Price Under Annex 1 Trading
90% of Target
No Hot Air
No Sinks
EMF-Reference
110% of Target
2/3 Sink Potential + 110% of Target
Permit Price ($/Metric Ton)
0
50
100
150
200
250
300
350
400
450
2010
2015
2020
2025
2030

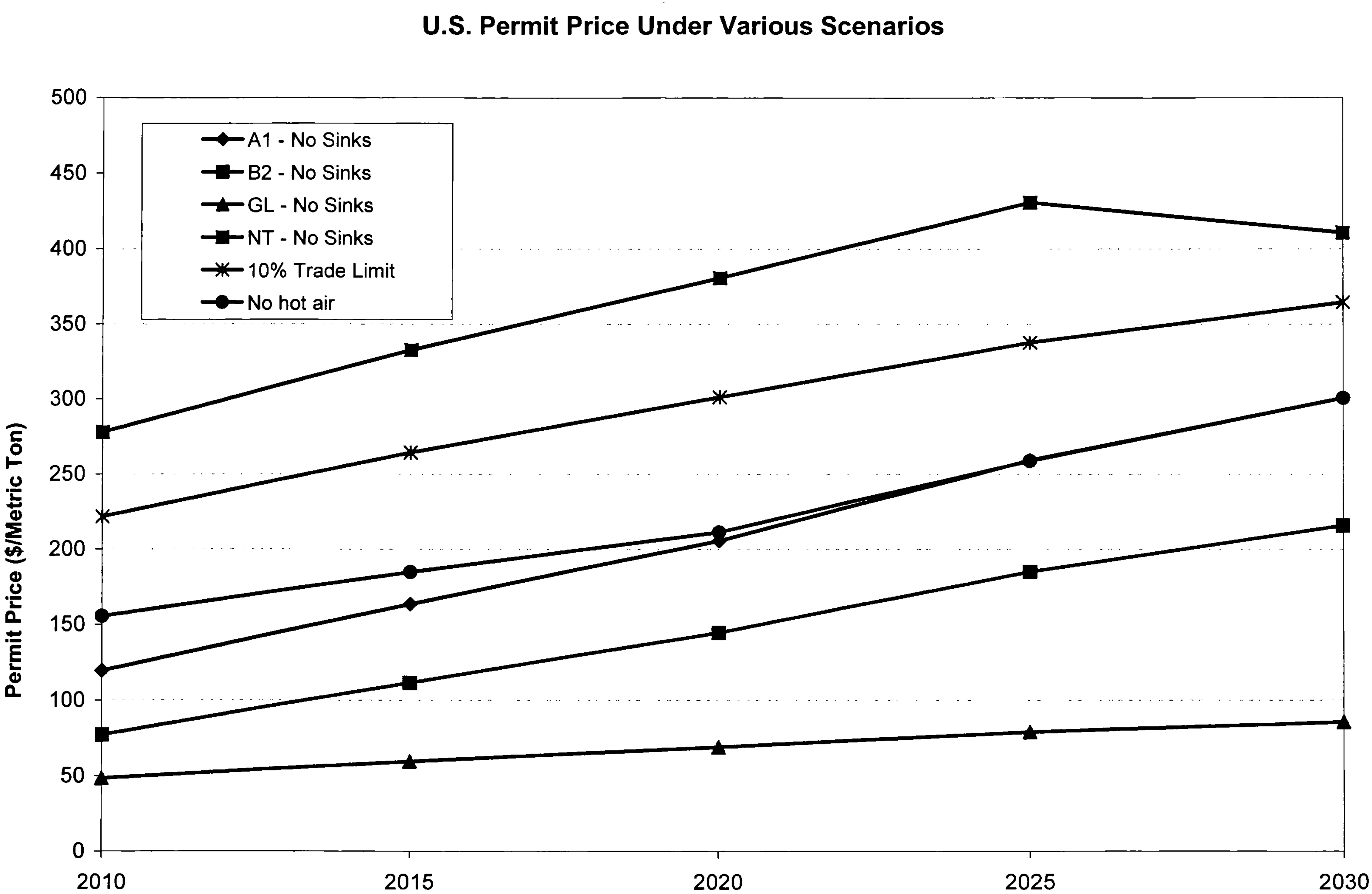


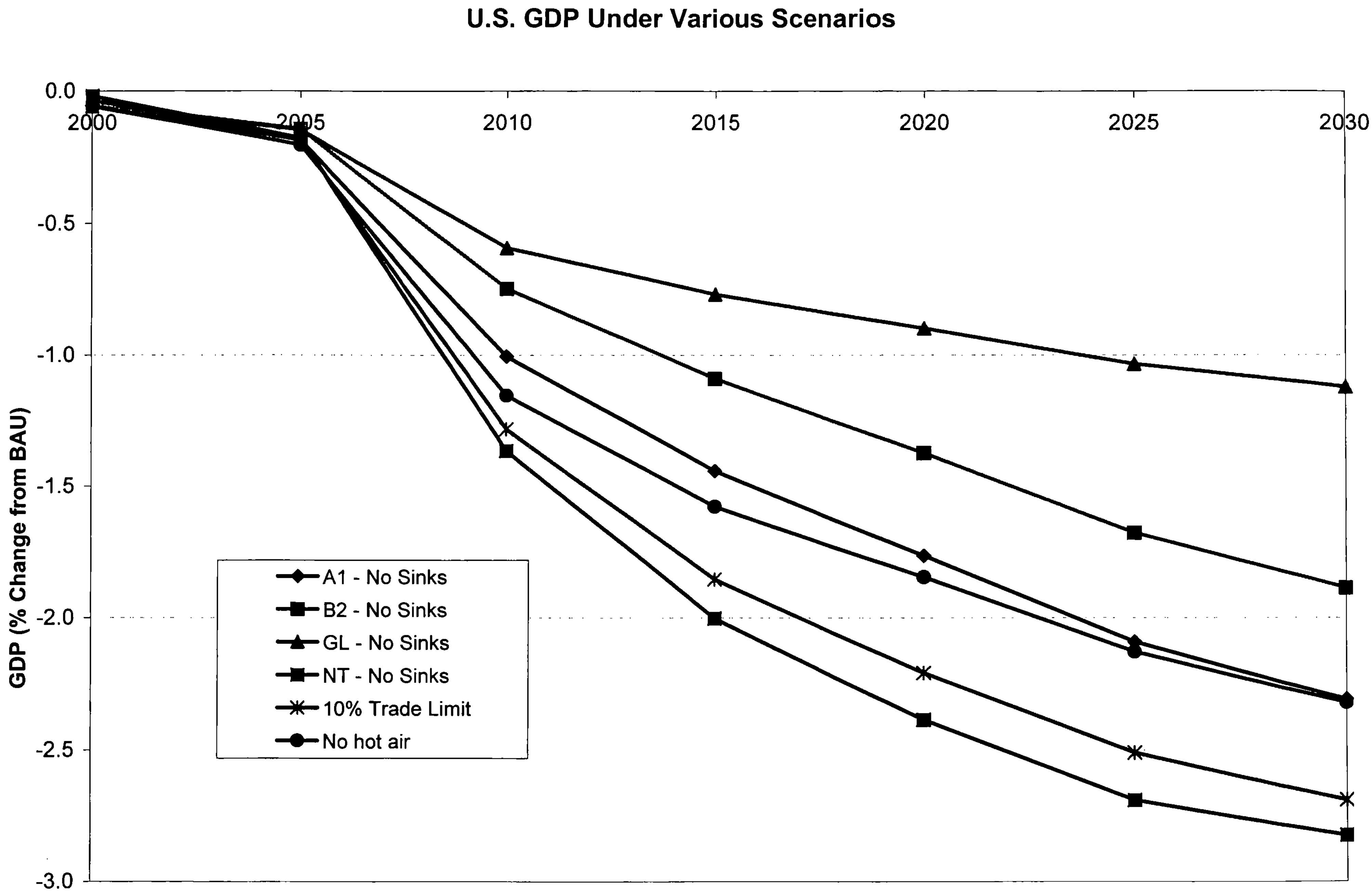
Infinite Horizon Welfare Under Annex 1 and Global Trading
(No Sinks)
Welfare (% Change from BAU)
10
8
6
4
2
0
-2
ASIA
EE/FSU
EU 15
OPEC
O-OECD
ROW
USA
10% - A1
30% - A1
50% - A1
100%-A1
10% - GL
30% - GL
50% - GL
100%-GL


Permit Price with Limits on Permit Purchases
(Annex 1 Trading; No Sinks)
10% of Obligation - CPEE
30% of Obligation - CPEE
50% of Obligation - CPEE
10% of Obligation - USA
30% of Obligation - USA
50% of Obligation - USA
Permit Price ($/metric ton)
400
350
300
250
200
150
100
50
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030

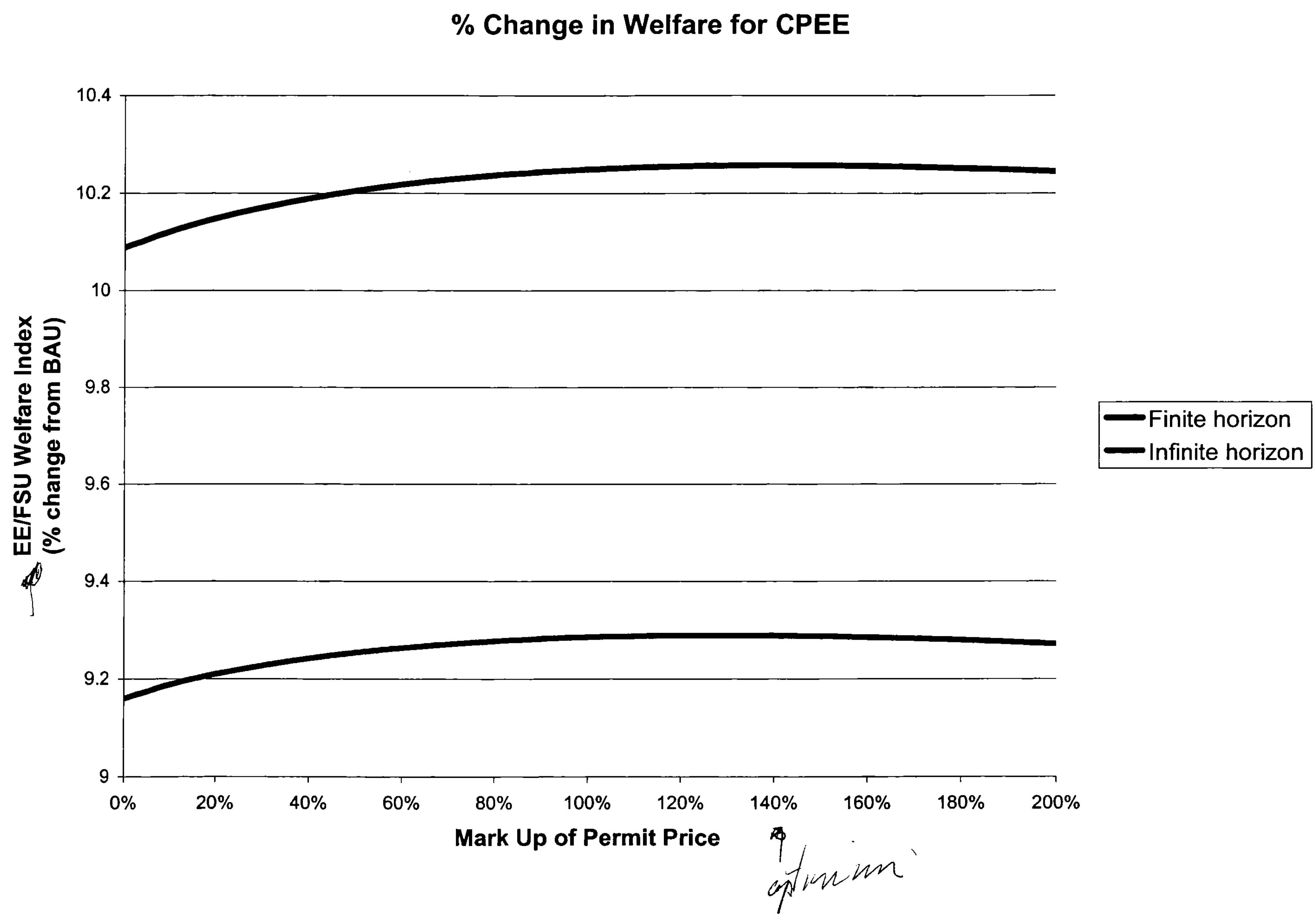
U.S. GDP under Different Trading Limits (Annex 1 Trading; No Sinks)



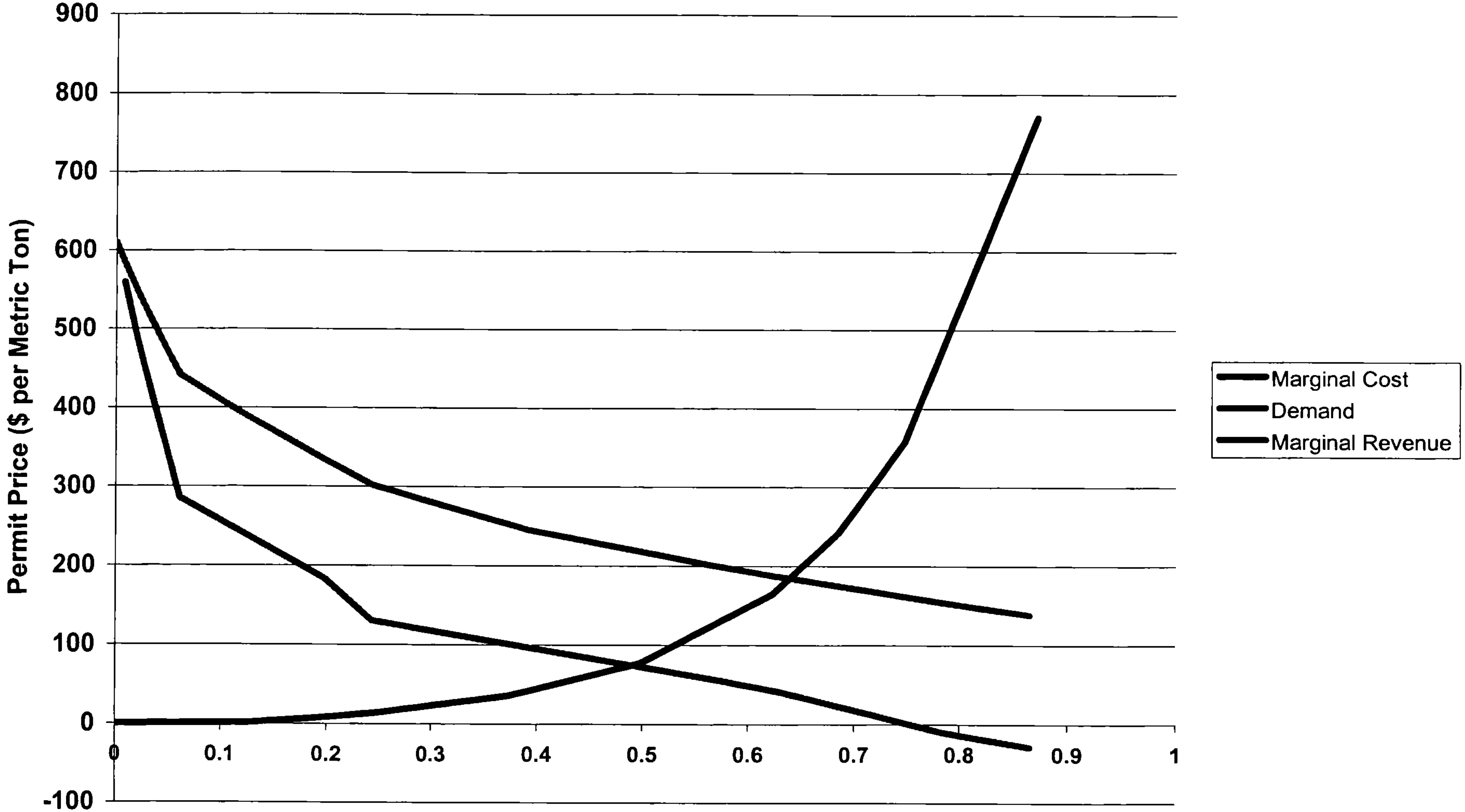

U.S. Permit Price Under Various Scenarios
Permit Price ($/Metric Ton)
500
450
400
350
300
250
200
150
100
50
0
2010
2015
2020
2025
2030
A1 - No Sinks
B2 - No Sinks
GL - No Sinks
NT - No Sinks
10% Trade Limit
No hot air



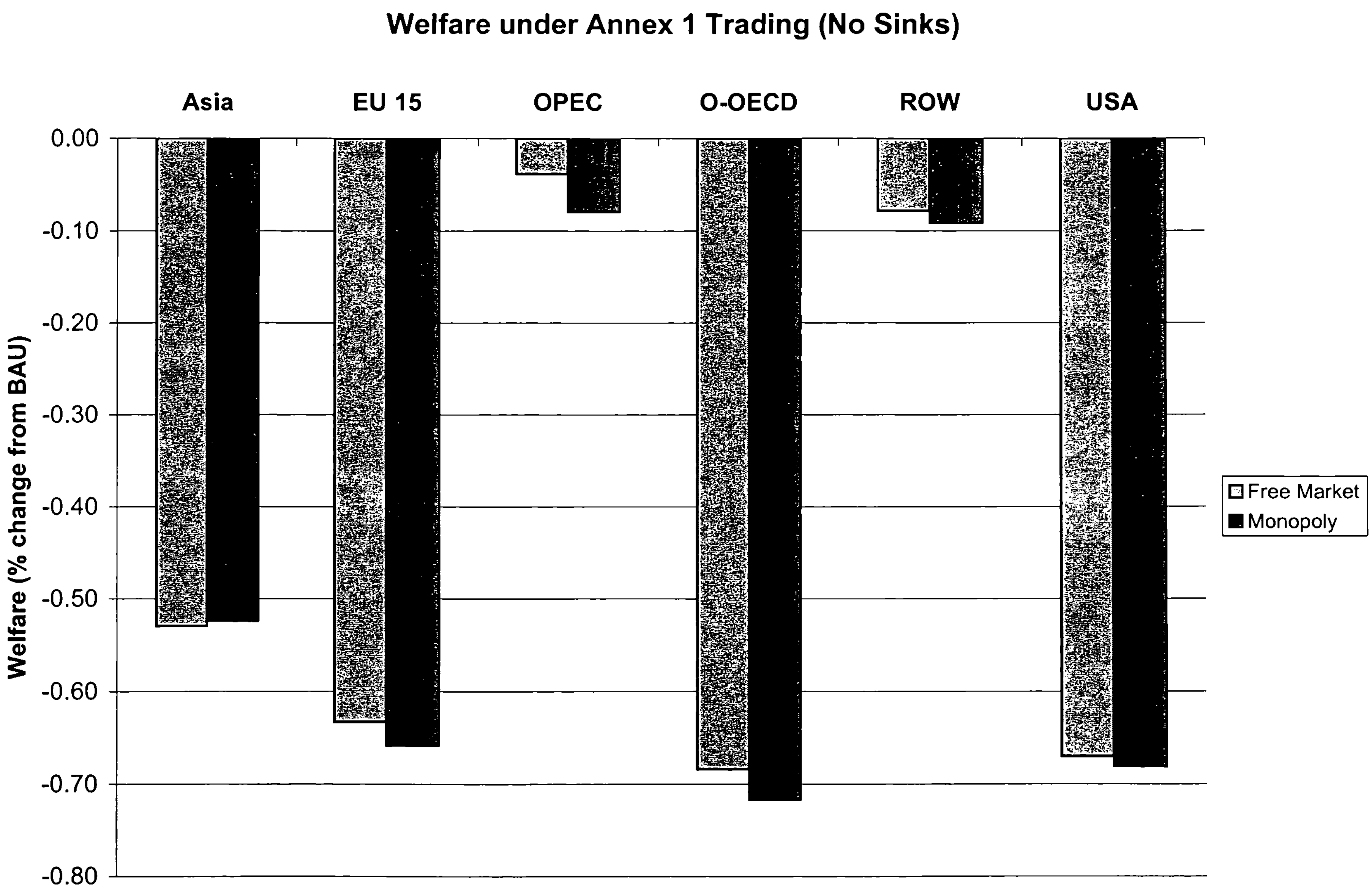
U.S. GDP Under Various Scenarios
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
2000
2005
2010
2015
2020
2025
2030
GDP (% Change from BAU)
A1 - No Sinks
B2 - No Sinks
GL - No Sinks
NT - No Sinks
10% Trade Limit
No hot air

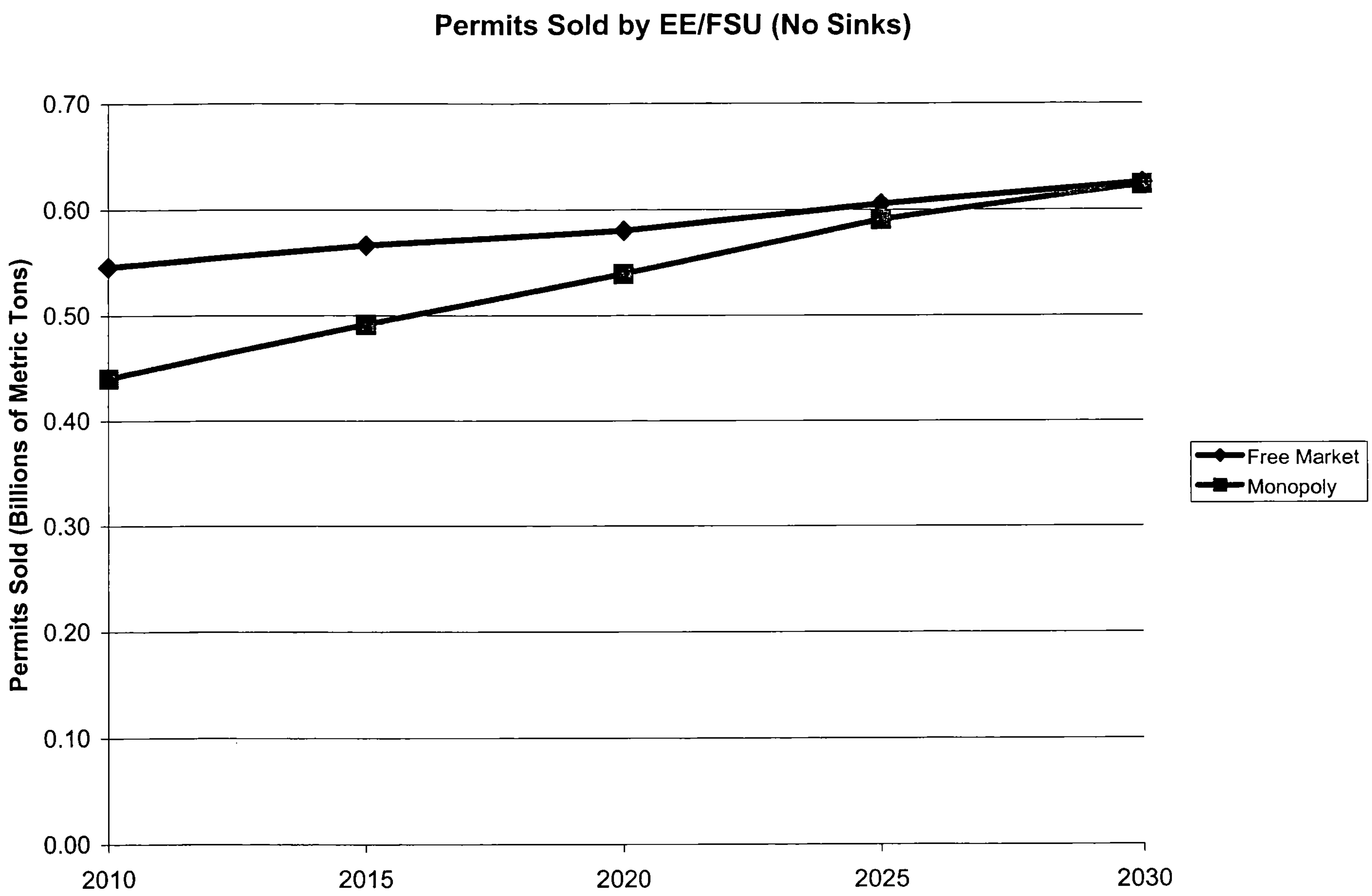

% Change in Welfare for CPEE
10.4
10.2
10
9.8
9.6
9.4
9.2
9
EE/FSU Welfare Index
(% change from BAU)
0%
20%
40%
60%
80%
100%
120%
140%
160%
180%
200%
Mark Up of Permit Price
Finite horizon
Infinite horizon
optimum

Permit Price Under Monopolistic and Free Market Competition
(Partial Equilibrium Solution)

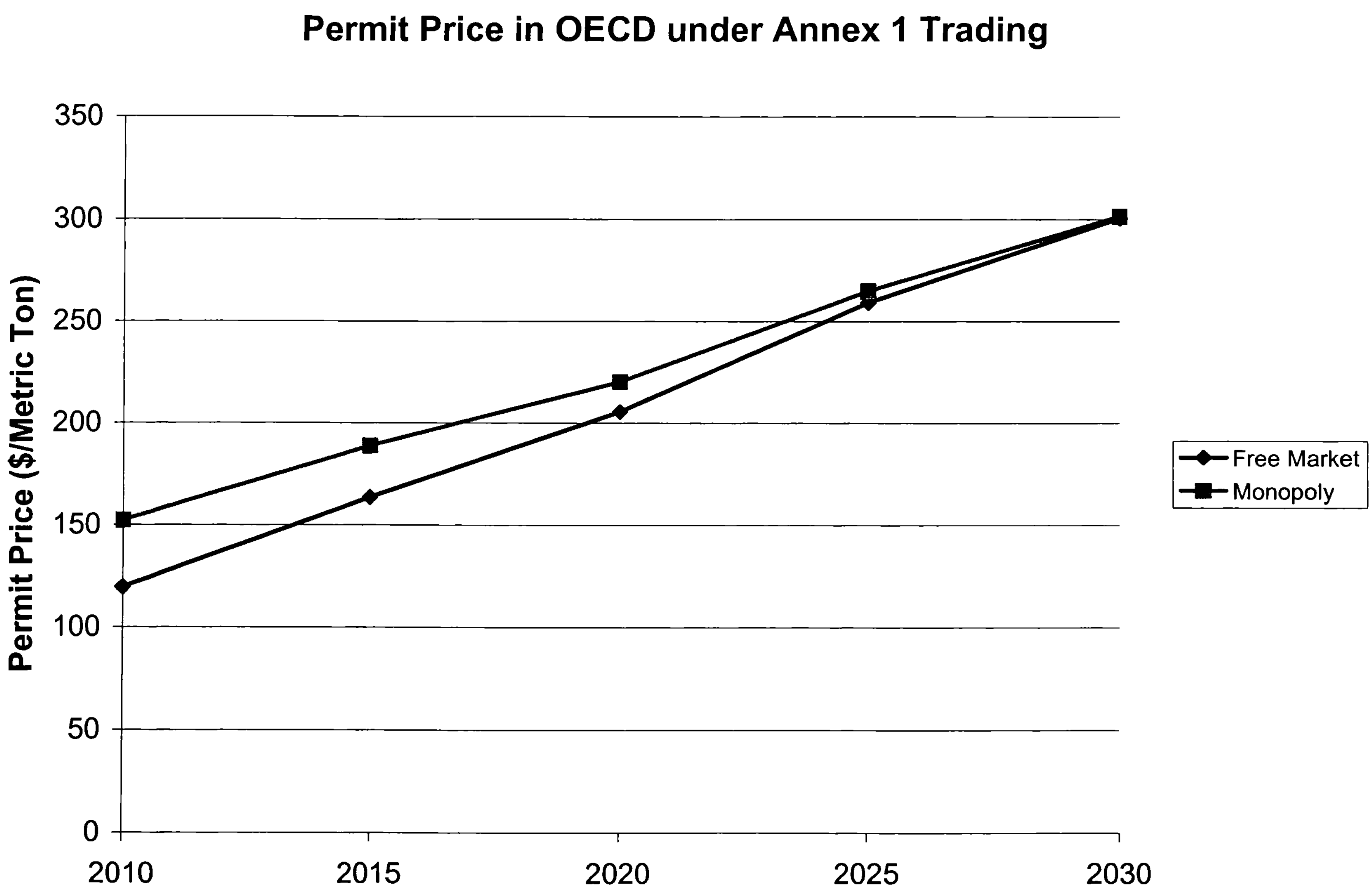


General Equilibrium Solution: Free Market: $120/tone and 0.55 Billion tonnes sold
Monopolistic Competition: $150/tonne and 0.44 Billion tonnes sold


Welfare under Annex 1 Trading (No Sinks)
Asia
EU 15
OPEC
O-OECD
ROW
USA
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
-0.80
Welfare (% change from BAU)
Free Market
Monopoly

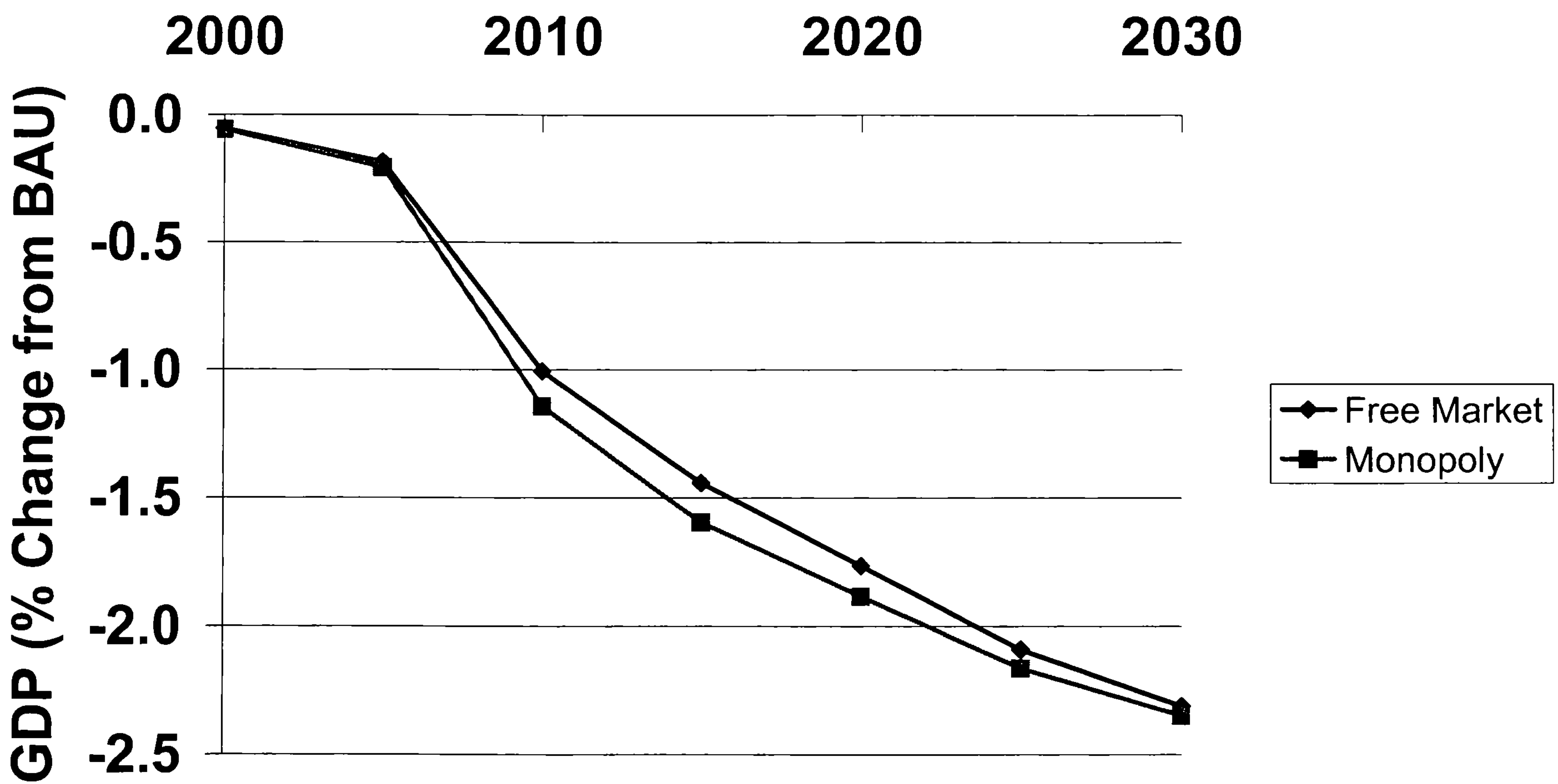


Permits Sold by EE/FSU (No Sinks)
Permits Sold (Billions of Metric Tons)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2010
2015
2020
2025
2030
Free Market
Monopoly



Permit Price in OECD under Annex 1 Trading
Permit Price ($/Metric Ton)
350
300
250
200
150
100
50
0
2010
2015
2020
2025
2030
Free Market
Monopoly

U.S. GDP under Annex 1 Trading
(No Sinks)



- oil price leakage 10%
- shift in energy-intensive industries = 20%

demand curve not correct
- other welfare triangles
- investment losses

- GDP loss ≈ 2 × resource cost.

-

Trade Structure of the MIT EPPA Model

Henry D. Jacoby and Zili Yang
MIT Joint Program on the Science and Policy of Global Change

Yale-NBER Workshop on International Trade and Climate Change

Snowmass, 12 August 1998

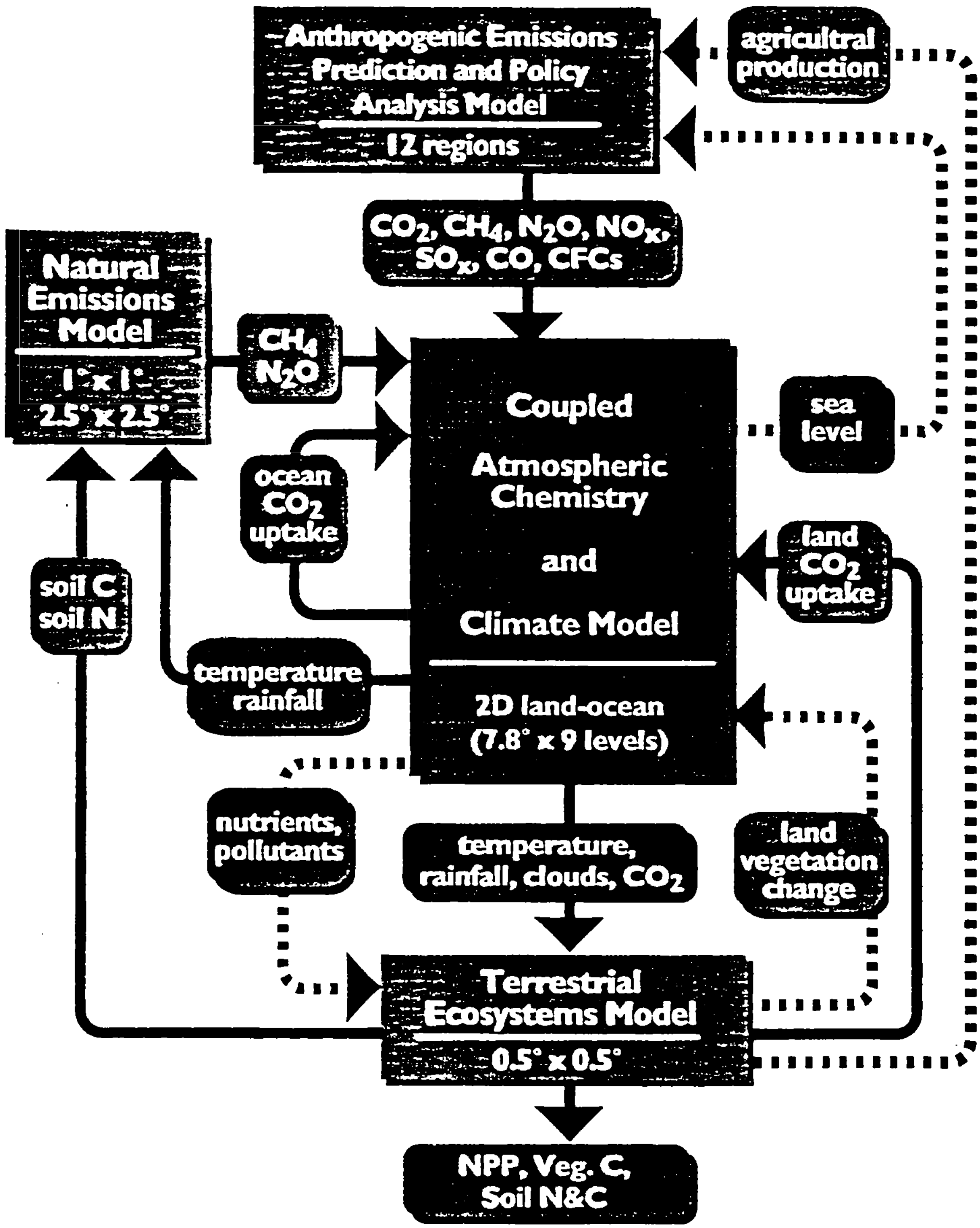
The Trade Structure of EPPA

- Purpose and history
- General model characteristics
- Trade formulation
- Sample applications
- Trade-related issues in current revision

Purpose and History of EPPA

- Multiple purposes in the MIT IGSM
  - Long-term driver of climate analysis
  - Studies of other gases
  - Cost analysis of policies
- GREEN origin, and revisions
  - GREEN SAMs still in use
  - GAMS/MPSGE $\Rightarrow$ many revisions
- New version in preparation
  - Conversion to GTAP
  - Other changes

The MIT Global System Model



10/96

General Model Characteristics

Model dimensions

Production structure

- CES nesting
- Vintaging options
  - Five vintages
  - Control of malleable fraction of old vintage

Alternative solution methods

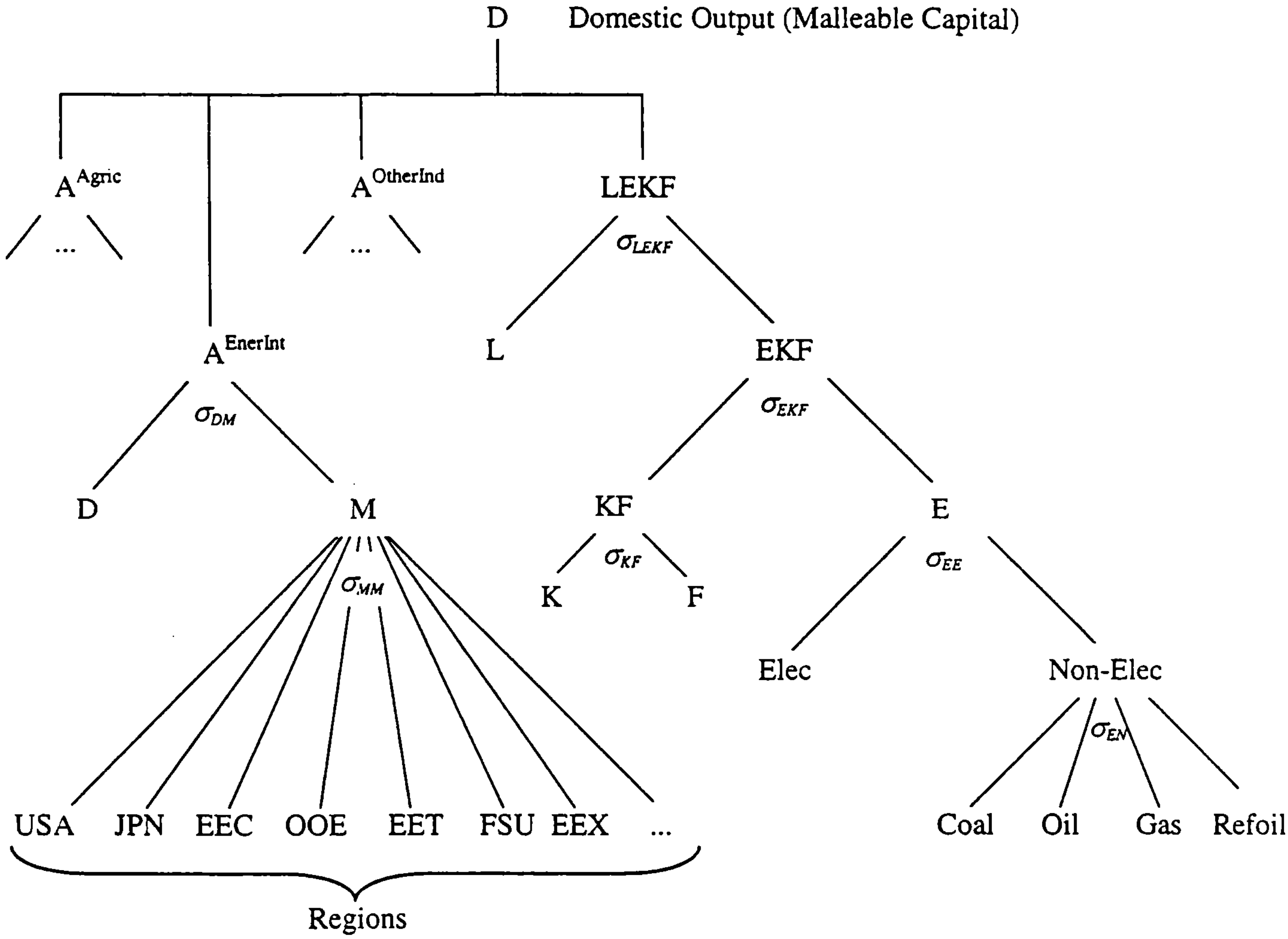
- Recursive dynamic (myopic)
- Forward-looking savings (parallel Ramsey)

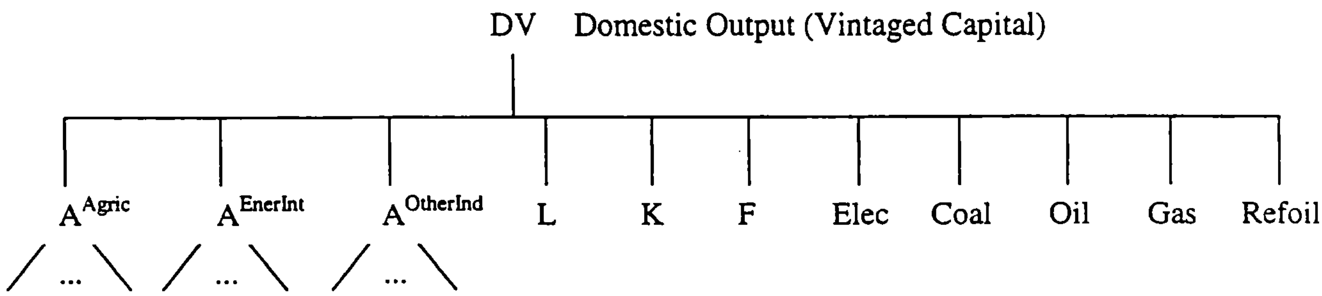
DIMENSIONS OF THE EPPA MODEL

Production sectors	**Consumer sectors**
Non-Energy	1. Food and beverages
1. Agriculture	2. Fuel and power
2. Energy-intensive industries	3. Transport and communication
3. Other industries and services	4. Other goods and services
Energy	
4. Crude oil	
5. Natural gas	**Primary Factors**
6. Refined oil	1. Labor
7. Coal	2. Capital (by vintage)
8. Electricity, gas and water	3. Fixed factors for each fuel, land in ag.
Future Supply Technology	
9. Carbon liquids backstop	
10. Carbon-free electric backstop	

Regions (and abbreviations)		**Gases (and chemical formulae)**	
1. United States	USA	1. Carbon Dioxide	CO_2
2. Japan	JPN	2. Methane	CH_4
3. European Community	EEC	3. Nitrous Oxide	N_2O
4. Other OECD	OOE	4. Chlorofluorocarbons	CFC
5. Central and East Europe	EET	5. Nitrogen Oxides	NO_x
6. The former Soviet Union	FSU	6. Carbon Monoxide	CO
7. Energy-exporting LDCs	EEX	7. Sulfur Oxides	SOx
8. China	CHN	8. Hydrofleurocarbons	HFC
9. India	IND	9. Perfleurocarbons	PFC
10. Dynamic Asian Econ's	DAE	10. Sulfur Hexafluoride	SF_6
11. Brazil	BRA		
12. Rest of the World	ROW		

EPPA Production Structure





Trade Formulation

All goods traded, energy and non-energy

- Oil & gas are Heckscher-Ohlin
- All others are Armington (2 levels)

No cost of international transport

Trade closure

- No financial markets
- Net foreign saving $\Rightarrow$ 0 over 5 periods

Trade in emissions permits

- Same trade closure applies
- Permit sale or purchase $\Rightarrow$ IM-EX gap

Sample Applications
(Not from a common case)

- Explore trade aspects of policy
  - Welfare effects of OECD/Annex I restriction
  - Carbon leakage
  - Terms of trade
  - Volume of permit trade
- Diagnosis of model behavior
  - Selected import-export changes

Figure 3. Regional Economic Impacts of a Sample QELRO Proposal Computed from Runs of the EPPA Model

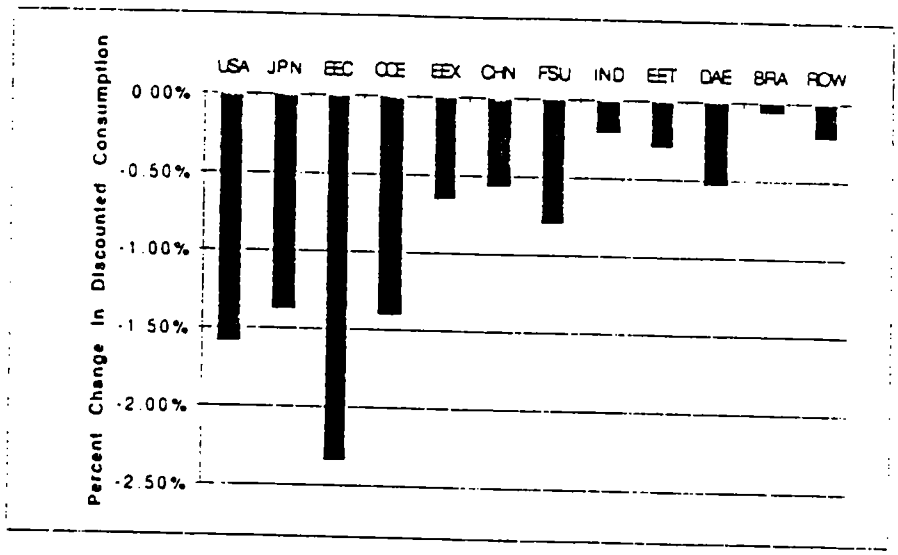
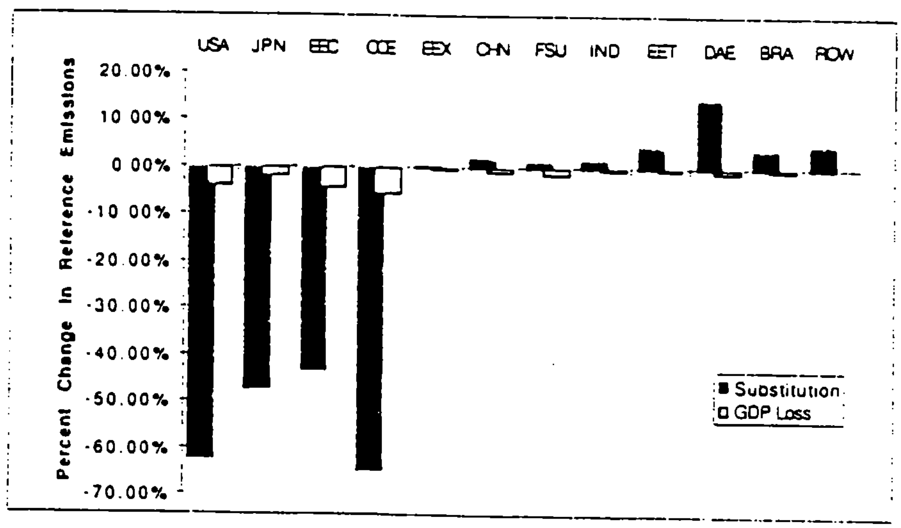
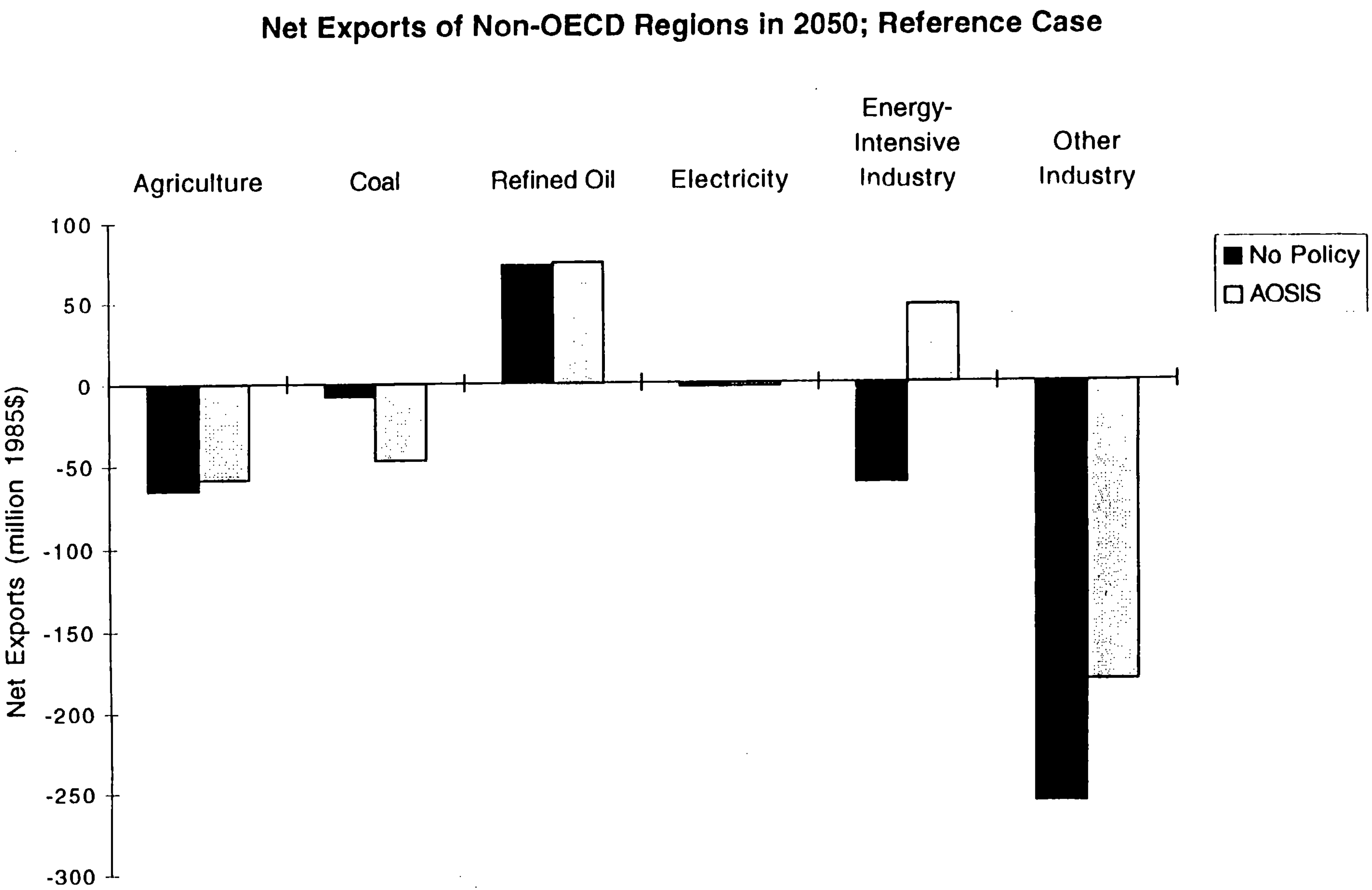


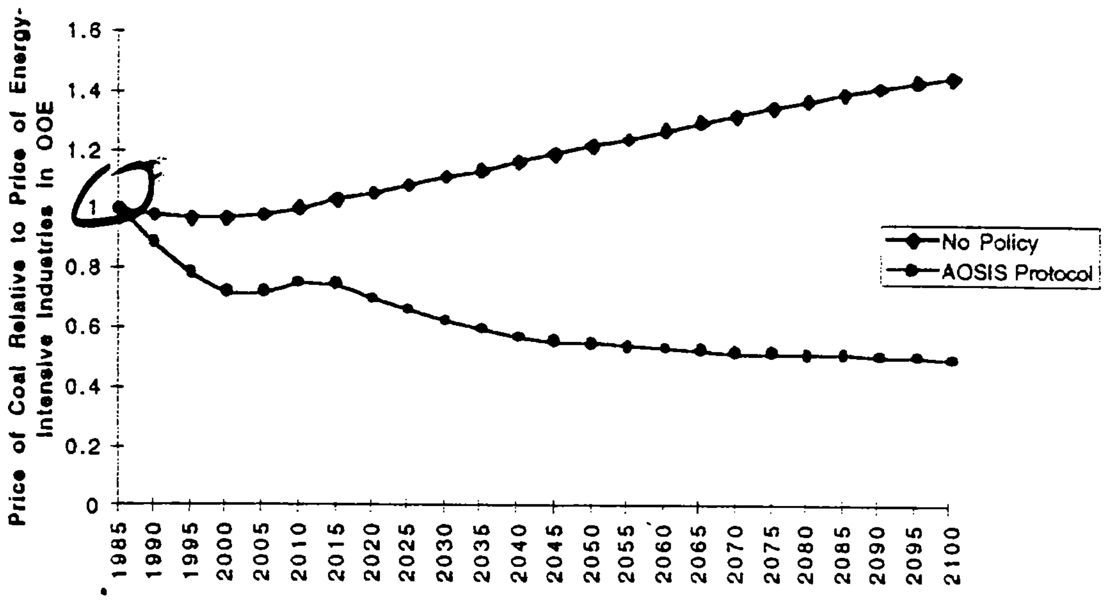
Figure 4. Percentage Change in Carbon Emissions Between 2000 and 2100 due to Substitution Effects and GDP Loss Resulting from a Sample QELRO Proposal



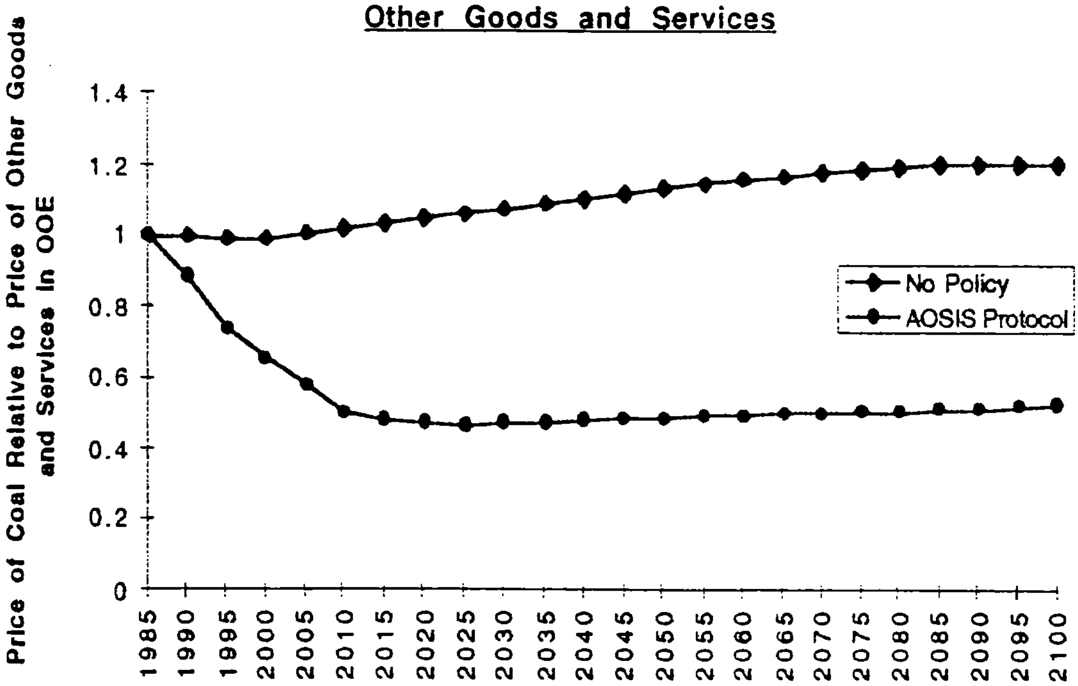

Net Exports of Non-OECD Regions in 2050; Reference Case
Agriculture
Coal
Refined Oil
Electricity
Energy-Intensive Industry
Other Industry
100
50
0
-50
-100
-150
-200
-250
-300
Net Exports (million 1985$)
No Policy
AOSIS

Price of Coal Relative to Selected Other Goods, with and without AOSIS Protocol, in Other OECD Region

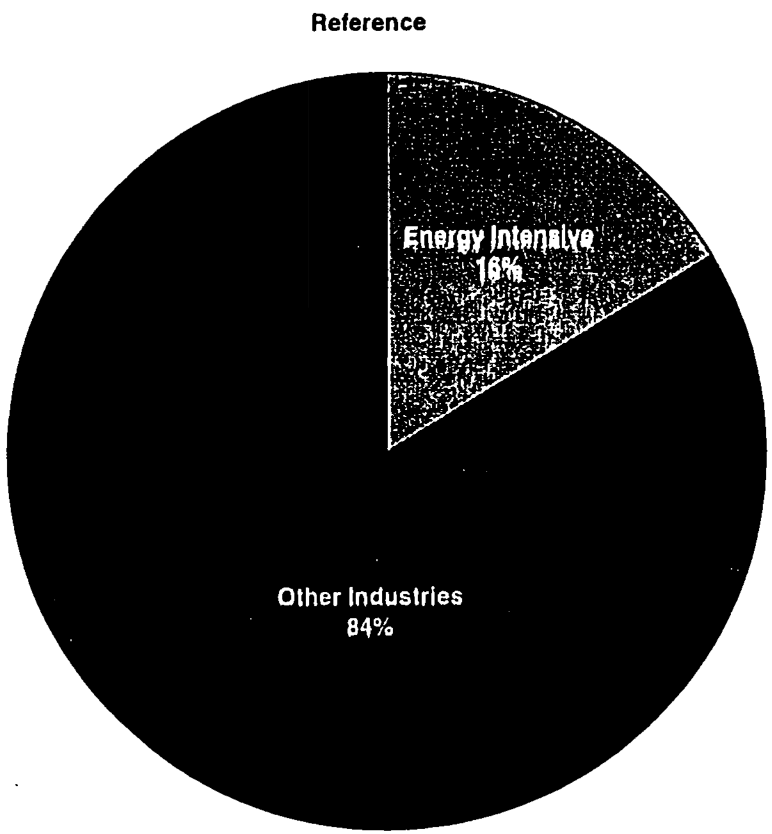
Energy-Intensive Industries

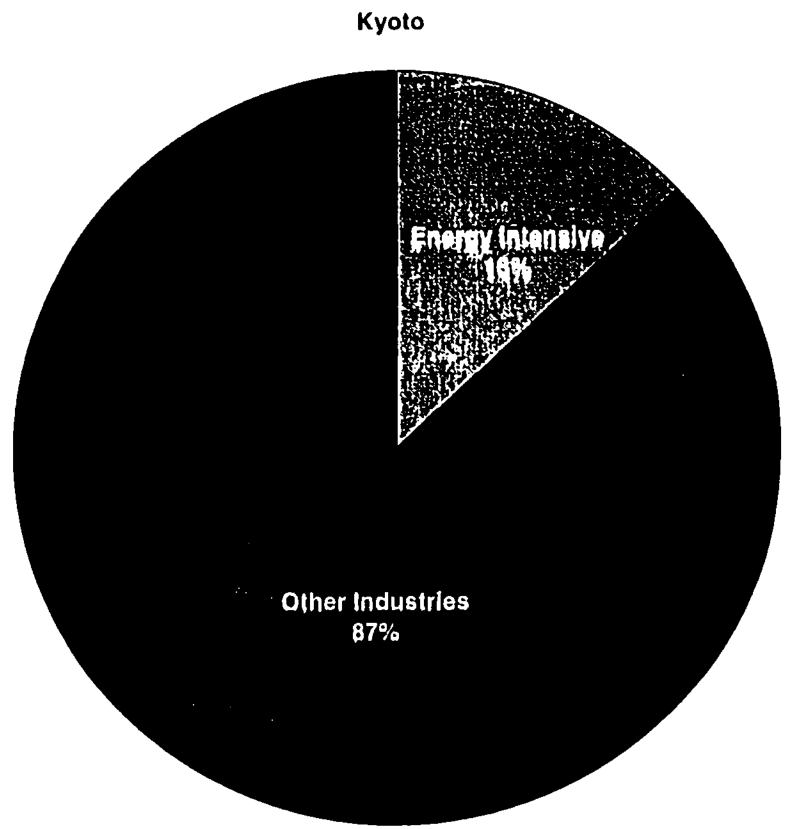


Other Goods and Services

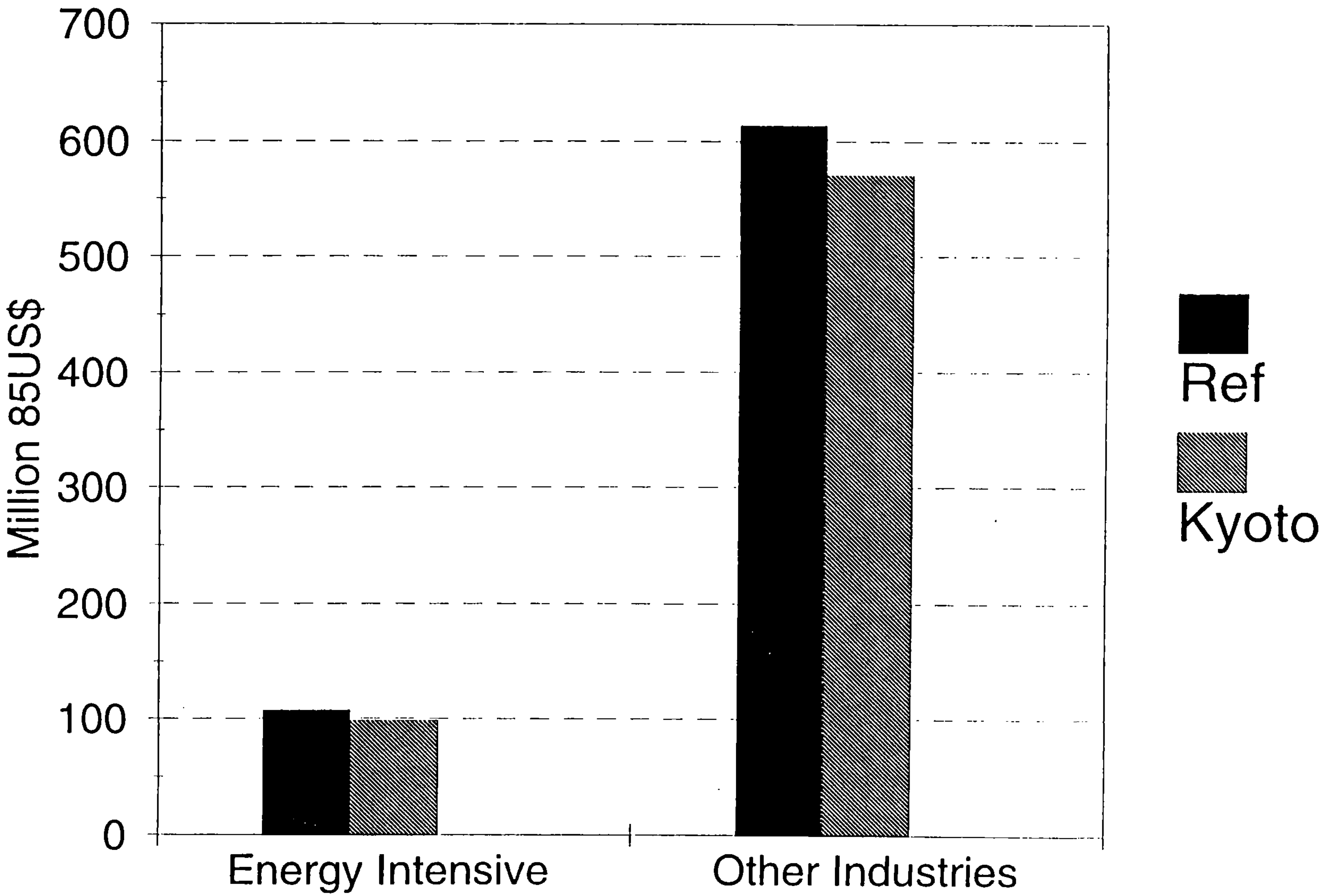


Selected Exports of JPN in 2010





Selected Imports of EEX in 2010



Trade-Related Issues in Current EPPA Revision

- Sectoral/regional dimensions
- Trade closure
  - As is?
  - Simple debt accounting, with constraints?
  - Other?
- Borrowing and banking in permit trade
- Cost function for natural gas trade

American
Petroleum
Institute

Implications of the Kyoto Protocol Targets for OECD Countries

Policy Analysis and Strategic
Planning Department

Research Study #093
May 1998

Implications of the Kyoto Protocol Targets for OECD Countries

Rayola S. Dougher[a]

Russell O. Jones[b]

Research Study #093
May 1998

[a]Senior Policy Analyst, American Petroleum Institute. [b]Research Manager, American Petroleum Institute. *The contents of this paper are for the purposes of study and discussion of government legislative or regulatory proposals and do not necessarily represent the views of the American Petroleum Institute or any of its members.*

Document prepared for publication by Lisa Ewing, Staff Assistant, American Petroleum Institute.

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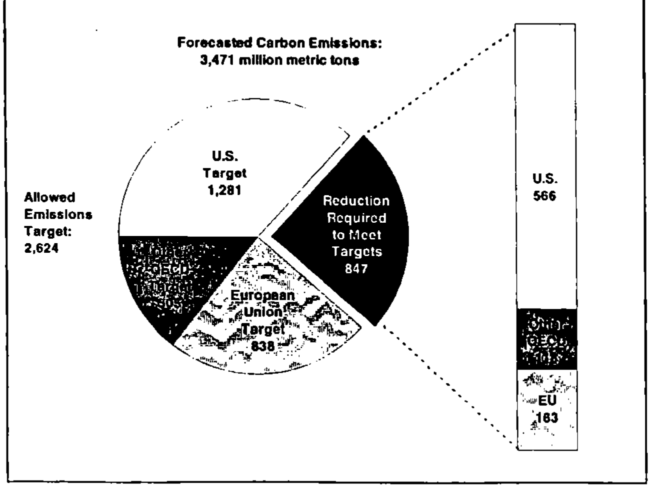
Executive Summary

The proposed Kyoto Protocol establishes aggressive targets and timetables for limiting greenhouse gas emissions for developed countries. Although a few developed nations would be allowed to increase their emissions above 1990 levels during the 2008-2012 period, most developed nations would be required to limit greenhouse gas emissions to between 6 and 8 percent below 1990 levels.

The figure below, ES-1, provides an overview of the Kyoto commitments for OECD countries. The pie on the left represents the baseline or business-as-usual forecasted carbon emissions of the OECD countries in the year 2010. It shows that in order to meet the Kyoto protocol targets, emissions must be reduced by 847 million metric tons from the total forecasted for the OECD of 3,471 million metric tons.

Sections of the pie show the amount of carbon emissions allowed for countries or groups of countries under the Kyoto Protocol. The bar on the right shows the reductions in carbon emissions required of these countries or regions in order for them to meet their targets. For example, in order for the U.S. to meet its target allowance of 1,281 million metric tons in the year 2010, its emissions must be reduced by 566 million metric tons. This represents a reduction of 31 percent from the U.S. government's business-as-usual baseline forecast of 1,847 million metric tons in the year 2010.

Figure ES-1
The OECD's Forecasted Carbon Emissions in the Year 2010, the Kyoto Targets and Required Reductions



In comparison, the 15-member nations of the European Union need to reduce their emissions by 163 million metric tons in order to reach a target total of 838 million metric tons. This reduction is 16 percent less than the 1,001 million metric tons forecasted for the region. Similarly, the other member countries of the OECD would be required to reduce their emissions by 118 million metric tons from a forecasted total of 623 million metric tons, or by 19 percent.

This study addresses the question: How difficult will it be to meet these reduction targets? The analysis begins with a review of pre-Kyoto commitments which indicates that few countries are likely to meet their early emission limitation commitments. Six of nine countries appear likely to exceed their commitments made prior to 1991 by wide to very wide margins. Only two small countries may meet these early commitments. Similarly, compared to government emission projections, only three of twenty-one OECD countries are expected to meet the Framework Convention on Climate Change's aim of limiting emissions to 1990 levels by 2000. This provides an important indication that meeting emission limitation goals is more difficult than thought.

This study uses a unique means of evaluating the ease or difficulty of meeting the Kyoto targets for most OECD countries. The approach taken is neither the traditional macroeconomic or general equilibrium modeling approach, nor the engineering technology approach. Rather, this study takes a simpler but more intuitive approach using the Kaya Identity. This algebraic identity breaks the factors that determine carbon emissions down into four key components: the carbon content of energy used in the economy, the energy intensity of economic activity, per capita gross domestic product (GDP), and population. In equation form the Kaya Identity is:

$$C = C/E * E/GDP * GDP/Population * Population$$

where C equals carbon emissions and E equals energy use.

This approach, covering 35 years of history plus government projections through 2010, provides a yardstick to evaluate how much behavior must be altered from current and expected behavior, and how this compares to past experience, especially the effort to limit energy use (and thereby carbon emissions) during the energy crisis years of 1974-1986.

Under this approach, the only way to reach the Kyoto targets with domestic actions is to change one or more of the key factors affecting carbon emissions, identified by the Kaya Identity, so that significant reductions can occur. Two approaches are used to put the magnitude of the effort into perspective. The first holds all factors but one constant. The second looks at past maximum changes in the Kaya Identity components.

For example, if the effort to achieve the Kyoto target focused *only* on the energy/GDP component of the Kaya Identity—the component that reflects energy intensity—then the U.S. energy/GDP ratio would have to decline during 2001-2010 at the rate of 4.5 percent annually. This is more than twice the rate of change which occurred during the energy crisis years—a time when fossil fuel prices quadrupled—and about 5 times the rate of change forecasted, indicating massive required changes in how energy is used in the U.S.

If, instead, the effort to achieve the Kyoto target focused *solely* on changing the carbon content of energy, then the U.S. would be required to reduce its carbon/energy ratio at a rate far beyond historical experience or forecasted expectations. The degree of change in the fuel mix which would be required to bring about such declines in the carbon/energy ratio is hard to imagine given existing energy sources and substitution possibilities. For example, even if the U.S. could theoretically substitute lower carbon content natural gas for all of the higher carbon content coal, oil and other combustibles forecasted for the year 2010, the U.S. would still fall short of its Kyoto target.

If reductions in energy intensity are no greater than governments forecast, and the mix of fuels and rate of population growth does not significantly differ from expectations, then the Kaya Identity makes it clear that profound reductions in economic growth would be required to meet the Kyoto targets. For example, the U.S. gross domestic product in 2010 would have to be 31 percent below projected levels to achieve the Kyoto target.

If economic growth is not to be sacrificed and the mix of fuels and energy efficiency improvements are the same as governments forecast, then under the Kaya Identity formulation, all of the effort to reduce emissions would fall on population size reductions. Short of draconian new policies to limit immigration and lower birth rates, it is unrealistic to assume any significant effort to reach the Kyoto targets would come through reduced population growth. It is this population growth, however, which fuels much of the future growth in carbon emissions in the U.S. Between 1990 and 2010 the U.S. population is forecasted to increase by 20 percent whereas Europe's is expected to grow only about 5 percent. This makes U.S. emission reduction targets that much more difficult to meet.

Finally, even if the maximum past changes in each Kaya Identity component which resulted in limiting carbon emissions were somehow to reoccur simultaneously for the next decade, the U.S. would still fall far short of its Kyoto target. Nevertheless, reproducing the maximum historic changes would come at a heavy cost. Past reductions in the amount of carbon emitted per unit of energy and the amount of energy used per dollar of GDP required rapidly expanding nuclear power, deregulation of natural gas, quadrupling U.S. fossil fuel energy prices, a host of government funded efficiency programs, and a 50 percent reduction in the growth rate of GDP per capita.

The European Union would just fall short of meeting its Kyoto target under their own maximum historic effort scenario, even if growth in per capita GDP is cut in half. Japan would achieve the Kyoto target under their maximum historic effort scenario, but not without a drastic reduction in their per capita GDP growth rate.

Clearly, the U.S. is not alone in requiring a major effort to meet the commitments made in Kyoto. Meeting the Kyoto Protocol targets would require major changes in how most countries use energy, and perhaps what energy is used and how fast economic growth occurs. Based on the Kaya Identity analysis, it appears highly unlikely that the Kyoto targets could be met by domestic action without major new policies to limit energy use. It is highly likely that these policies would have significant adverse impacts on the rate of growth in per capita GDPs.

This analysis concludes that major changes would be required to reach the Kyoto target. This raises serious questions about the claims that the Kyoto Protocol targets are "realistic."

I. Introduction

The proposed new Kyoto Protocol establishes very aggressive targets and timetables for limiting greenhouse gas emissions for developed countries. Although a few developed nations would be allowed to increase their emissions above 1990 levels during the 2008-2012 period, most nations would be required to limit greenhouse gas emissions to between 6 and 8 percent below 1990 levels.

The framing of these targets is a misleading indicator of the extent to which emissions of greenhouse gases would have to be constrained. In the U.S., for example, government projections of carbon emissions, in the absence of new policies to limit those emissions, exceed the Kyoto Protocol target by 44 percent in 2010 and 56 percent in 2020. Phrased differently, the U.S. would have to reduce its carbon emissions by 31 percent from a 2010 business-as-usual projection to meet the Kyoto target. In contrast, greenhouse gas emissions in developing countries are allowed to grow unconstrained under the Kyoto Protocol.

This study provides a concise and transparent means of evaluating the ease or difficulty of meeting the Kyoto targets for most Organization for Economic Co-operation and Development (OECD) countries.[1] The approach taken is not a traditional macroeconomic modeling approach. That approach asks the question, what price must be put on carbon emissions, and therefore fossil fuel use, either through a carbon tax or an equivalent tradable permit system to meet the Kyoto targets. A strength of the macroeconomic approach, sometimes called a "top-down" approach, is that it evaluates a policy — increased energy costs that alter the behavior of businesses and individuals. At the same time, however, the top-down approach does not provide highly detailed information on exactly how businesses and individuals would alter their behavior and the equipment they purchase.

Another approach not taken is the traditional engineering technology approach like that presented in recent U.S. national laboratory studies. Such studies seek in general to identify the types of equipment changes needed to limit emissions for industries, commercial establishments, homes, and transportation systems. A strength of the "bottoms-up" approach, as it is sometimes called, is that it identifies the quantity of alternative technologies that must be installed to limit emissions to some target level. An important weakness of the bottoms-up approach is that it has difficulty explaining why businesses and individuals do not already use specific technologies and, more importantly, what policies would be required to alter the behavior of individuals and businesses so as to achieve the emission reduction targets.

This study takes a simpler but more intuitive approach and provides a way to compare the *level of effort* or amount of change required to meet the Kyoto emissions targets with current projections of emissions as well as past periods when emissions were significantly constrained. That is, this approach provides a yardstick to evaluate how much behavior must be altered from current and expected behavior, and how this altered behavior compares to past experience, especially the effort to limit energy use (and thereby carbon emissions) during the energy crisis years of 1974-1986.

In the U.S., for example, carbon emissions in 1986 equaled those in 1973. This 13-year period is about the same length as the period between now and the end of the Kyoto target period for limiting emissions. How does the effort required to limit emissions between now and 2008-2012 compare to the effort to limit energy use over the 1974-1986 period? And how do the U.S. efforts compare with the efforts of other OECD countries?

This study uses an algebraic identity to provide the necessary yardstick to make these comparisons. In the "Kaya Identity,"[2] carbon emissions depend entirely on the carbon content of energy used in the economy, the energy intensity of economic activity,

[1] The 21-member countries of the OECD reviewed in this report include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States.

[2] The Kaya Identity has been used in a number of analyses. An early reference is: Kaya, Y., "Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios," paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris, France, 1990.

per capita economic activity and population. As such, the Kaya Identity does not identify or evaluate specific policies. Rather, it evaluates the extent of change required to reach a specific target.

Chapter II provides background on the December 1997 Kyoto Protocol agreement, including an evaluation of two major earlier efforts to limit carbon emissions — efforts that largely failed. Chapter III explains the Kaya Identity approach and applies the methodology to the United States. Chapters IV and V extend the analysis to the other OECD countries. Chapter VI looks at the Kyoto targets in light of past maximum changes in Kaya Identity components. Chapter VII summarizes the results. Appendices A and B provide information on emissions projections, as well as detailed data on the average annual percent changes in carbon emissions and the Kaya Identity factors affecting these emissions for each of the 21-member OECD countries.

II. The Kyoto Protocol and Previous Commitments

A. Overview

In December 1997, in Kyoto, Japan, more than 150 countries concluded negotiations under the Framework Convention on Climate Change (FCCC) on proposed new stringent limitations on developed country emissions of greenhouse gases. The Kyoto Protocol, as the proposed new treaty is called, was in fact the culmination of negotiations initiated in mid-1995 at the First Conference of Parties to the Framework Convention on Climate Change. And the 1995 meeting was the first meeting of the countries that had ratified the FCCC, which itself was negotiated in 1992.

While the Protocol is a complex document, a key component specifies targets and timetables for emission limitations on six anthropogenic greenhouse gases from developed countries, the so-called Annex I countries. A focus of the negotiations was on carbon dioxide (CO_2) emissions from the use of fossil fuels — coal, natural gas, and petroleum. The proposed Protocol places no limits on greenhouse gas emissions from developing countries.

The carbon emissions targets for most Annex I countries are between 6 and 8 percent below 1990 emissions levels, although a few countries are allowed to exceed their 1990 level emissions. The timetable for reaching targeted levels is 2008-2012. While the terminology may make the targets sound modest, they are not. For the U.S., for example, basecase or reference case carbon emission projections by the U.S. Energy Information Administration for 2010, a little over a decade from now, are 44 percent greater than would be allowed under the Kyoto Protocol.

Before addressing the implications of the Kyoto Protocol for OECD countries, it is important to remember that this is not the first effort to put limits on greenhouse gas emissions. In fact, the Kyoto Protocol is the third in a series of commitments to limit greenhouse gas emissions.

The first set of commitments were made during the 1988-1990 period. Although there were some discussions within the European Community as a whole, the commitments at that time were primarily made by individual countries. The second set of emissions commitments or aims were made primarily in conjunction with the drafting, signing, and ratification of the Framework Convention on Climate Change in the 1991-1995 period. The proposed Kyoto Protocol, as noted, is the result of negotiations covering the 1995-1997 period. Reviewing the apparent success or failure to meet these earlier commitments provides a very useful perspective in evaluating the proposed new Kyoto Protocol emission limitation targets.

B. Early Emission Reduction Commitments

Climate Change Policy Initiatives, published in 1992 by the International Energy Agency/OECD, provides a useful summary of early national commitments to limit greenhouse gas emissions, particularly carbon emissions from the use of fossil fuels. Table II-1 summarizes the early commitments identified in that source.

The table also compares these emission targets with recent emissions projections that are variously referred to as "business-as-usual", or "reference case" or "base case" projections.[3] These terms refer to projections that take into account all existing specific government policies that impact future emissions. They do not take into account additional policies that might be implemented in the future, perhaps in response to the Kyoto Protocol.

The commitments listed in Table II-1 reflected early concerns about potential global warming which were expressed, for example, at an international meeting in Toronto in 1988. This 1988 meeting led to an "Action Plan of the Toronto Conference" which discussed a target of returning national emissions to 20 percent below 1988 levels by 2005. At the time, there was little in-depth analysis of the actions required and resulting economic impacts that would follow the implementation of such a policy.

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[3] The emissions history and projections are described in greater detail elsewhere in this report (see Appendix A). But in essence, the EU country projections are from the EU Directorate General for Energy (DG XVII) *Energy in Europe — European Energy to 2020: Scenario Approach;* the U.S. projection is derived from the U.S. Energy Information Administration *Annual Energy Outlook 1998*, and the projections for other OECD countries are from *Energy Policies of IEA Countries — 1997 Review*, published by the International Energy Agency/OECD. A brief comparison of the EU and IEA projections is contained in Appendix A.

Table II-1
Early Emission Reduction Commitments — Success or Failure?

Country	Date Made & Type of Commitment	Target	Emissions Projections Relative to Target
Austria	1988 Action Plan of Toronto Conference	80% of 1988 levels in 2005	Exceed target by 51%
Denmark	1990 Action Plans	80% of 1988 levels in 2005	Exceed target by 35%
Germany	1990 Interministerial Working Group	72.5% of 1987 levels in 2005	Exceed target by 31%
Luxembourg	1990 Goal	80% of 1990 levels in 2005	Meet target
Netherlands	1990 NEPP-Plus Plan	96% of 1989/90 in 2000	Exceed target by 8%
Norway	1989 Preliminary	100% of 1989 levels in 2000	Projection not available
Switzerland	1990 Federal Council Action	100% of 1990 levels in 2000	Below target by 3%
Australia	1990 Planning Target	80% of 1988 levels in 2005	Exceed target by 82%
New Zealand	1990 Climate Change Programme	80% of 1990 in 2005	Exceed target by 40%

Sources: Commitments: International Energy Agency/OECD, *Climate Change Policy Initiatives*, 1992.
Projections: See discussion in text and Table II-2.

Prior to 1991, six of the countries listed in Table II-1 made national commitments to limit emissions in 2005 to 20 percent or more below the levels reached in 1988, 1989 or 1990. Three of them made commitments to return emissions to at or slightly below 1989 or 1990 levels by 2000.

How many of these nine countries appear likely to meet these early commitments to limit carbon emissions? Compared to current "reference case" projections it appears that:

- five of the six nations with year 2005 targets of 20 percent or more below 1987 to 1990 levels will exceed their early targets by very wide margins ranging from 30 percent to 80 percent. These countries are Austria, Denmark, Germany, Australia and New Zealand;

- Luxembourg may meet its aggressive target of 20 percent below 1990 levels by 2005, but it is important to note that Luxembourg's 1990 level emissions were only about 1 percent of those of Germany;

- Netherlands' emissions likely will exceed the much less aggressive early target which was 4 percent below 1989/90 levels in 2000 by about 8 percent;
- Switzerland may succeed in limiting its emissions to slightly below its less aggressive target of 1990 levels in 2000; and
- no comparable projection was available to make a judgment whether or not Norway might meet its early commitment.

In sum, six of the nine countries appear likely to exceed their early commitments by wide to very wide margins, the smallest country might meet its commitment, one country may have emissions somewhat below its early commitment, and for one country data are not adequate to make a judgment. While these countries still have some time to implement additional and more stringent policies to further constrain emissions, it also must be acknowledged that the commitments in question were made seven or more years ago. In sum, for most of the countries in Table II-1, the policies enacted to date have not been adequate to meet these early emission limitation commitments.

In retrospect, these early commitments simply offer a good example of the difficulty of reducing carbon emissions at a future date to levels significantly below a past date while population and economic activity are increasing. For example, three countries in Table II-1 made commitments to limit emissions in 2005 to 20 percent below 1988 levels. While carbon emissions were pledged to decline 20 percent over the 17-year interval, population in Austria, Denmark and Australia is projected to increase by 8 percent, 2 percent, and 22 percent, respectively. And for economic standards of living to increase, economic activity (GDP) must increase more than population. And that is the case. For Austria, Denmark and Australia, real GDP is projected to increase 54 percent, 46 percent, and 62 percent, respectively. Reducing emissions by 20 percent while population is increasing 2 percent to 22 percent and GDP is increasing 50 percent to 60 percent was clearly a task far more difficult than those making the commitments appreciated.

C. The Emission Limitation Aims of the UN Framework Convention on Climate Change

In the early 1990s, a series of international negotiations on climate change led to the signing of the United Nations Framework Convention on Climate Change (FCCC) in June, 1992. One hundred and fifty-four countries signed the Framework Convention at the UN conference on the Environment and Development in Rio de Janeiro. After receiving the required ratification by 50 countries, including the United States, the Framework Convention entered into force on March 21, 1994, becoming international law for all Parties (countries) that had ratified it. The first official meeting of the Parties of the FCCC was held in Berlin in 1995.

The Framework Convention established a number of legally binding commitment for all Parties to the Convention. These generally non-intrusive obligations included, but were not limited to:

- preparation of national inventories of anthropogenic greenhouse gas emissions;
- development of programs to mitigate effects of greenhouse gases and promote measures of adaptation to climate change;
- technology co-operation;
- sustainable management of greenhouse gas sinks and reservoirs;
- integration of climate change considerations in the formulation of other policies;
- scientific research to reduce scientific uncertainties about possible climate change;
- exchanges of information.

Additionally, the Framework Convention established a number of legally binding obligations that fell only on the so-called Annex I nations. Annex I (a list of countries in the Framework Convention) includes the OECD countries except Mexico, the members of the European Union,[4] and eleven ex-Soviet Bloc countries sometimes referred to as "countries in transition" to market economies.

Key among the obligations of Annex I countries, but not the developing nations, is an obtusely formulated aim to limit greenhouse gas emissions. Article 4.2(a) of the Framework Convention states that each Annex I Party shall take policies and measures to limit its anthropogenic emissions of greenhouse gases. These policies and measures:

- "will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions..."
- "recognizing that the return by the end of the present decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol would contribute to such modification...."

And Article 4.2(b) states that each Party shall detail policies and measures:

- "with the aim of returning individually or jointly to their 1990 levels of these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol."

Clearly, the Framework Convention did not establish a specific target and timetable for a reduction in Annex I country greenhouse gases. Equally clear, however, was an emphasis on one of the greenhouse gases, carbon dioxide, as well as a target, 1990 level emissions, and a timetable, the end of the present decade, i.e., the year 2000.

Prior to and after the negotiation, signing, and ratification of the Framework Convention, many Annex I Parties made national commitments to limit their greenhouse gas emissions and or their carbon dioxide emissions to 1990 levels by the year 2000.

[4] The 15-member countries of the European Union include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom.

For the United States, this commitment was made on April 21, 1993, with the plan to achieve this commitment being issued as *The Climate Change Action Plan* in October 1993. The text box provides a quotation from that *Action Plan*.

The Climate Change Action Plan

Today, I reaffirm my personal, and announce our nation's commitment to reducing our emissions of greenhouse gases to their 1990 levels by the year 2000. I am instructing my administration to produce a cost-effective plan...that can continue the trend of reduced emissions. This must be a clarion call, not for more bureaucracy or regulation or unnecessary costs, but instead for American ingenuity and creativity, to produce the best and most energy-efficient technology."

President Clinton
April 21, 1993

After the Framework Convention was signed, the International Energy Agency/OECD developed an updated summary of national commitments or aims for limiting carbon dioxide and/or greenhouse gas emissions. This update was published as *Climate Change Policy Initiatives - 1994 Update - Volume I - OECD Countries.*

As summarized in the IEA/OECD 1994 update, most OECD Annex I parties established national commitments or aims to limit carbon dioxide and/or greenhouse gas emissions to 1990 levels by 2000, although the commitments were made in somewhat varying forms. While the European Union as a whole made a commitment to limit emissions to 1990 levels in 2000, individual EU members made a variety of commitments, some of which allowed growth in emissions. And until very recently there was no explicit attempt to reconcile the sum of the various national commitments with the overall EU commitment. Other nations, like Japan, made commitments in the form of per-capita emissions goals.

Table II-2 provides a comparison of recent governmental projections of carbon dioxide emissions for 2000 with 1990 level emissions for OECD countries. For the OECD countries as a whole, year 2000 emissions are projected to exceed the 1990 target by about 12 percent, or about 340 million metric tons carbon. This total excludes Iceland, Norway and Turkey, because comparable governmental projections of energy consumption and carbon emissions were not available.

Compared to the EU's own projections, total EU emissions are expected to exceed 1990 levels in the year 2000 by about 4 percent. Only Luxembourg, the smallest by far of the countries, appears likely to have emissions substantially below the year 2000 target.

Germany's year 2000 emissions are expected to be slightly below 1990 levels, in large part because of the unification with East Germany after 1990, and the subsequent closure of many highly inefficient old East German production facilities and the elimination of subsidized energy. However, Germany has a self-proclaimed aim of reducing carbon emissions from energy to 25 percent to 30 percent below 1987 levels by 2005 (with 1987 levels being about 4 percent larger than 1990 levels). Compared to the EU's projections, Germany will fall far short of this goal.

Compared to the EU projection, carbon emissions in Great Britain will exceed 1990 levels in year 2000 by about 3 percent. Under some other projections, the UK's emissions fall somewhat below 1990 levels in 2000. In either case, approximately reaching the year 2000 target is largely due to policy shifts that allowed and promoted the use of natural gas in electricity generation. This one-time switch from coal to gas in electricity generation significantly lowered the path of future carbon emissions.[5]

Japan's carbon emissions, and those of Australia, Canada, New Zealand and the U.S. are projected to exceed 1990 levels in 2000 by 8 percent to 23 percent.

In summary, only three of the twenty-one OECD countries for which forecasts are available are expected to meet the aim of limiting carbon emissions in year 2000 to 1990 levels. Two of those countries are among the four smallest countries reviewed, and the third, Germany, achieves the target largely because of reunification.

[5] See note in Table II-2 and Appendix A for discussion of alternative projections.

Table II-2
OECD Carbon Emissions: Comparison of 1990 and Projected Year 2000 Emissions
(million metric tons carbon)

Country	1990 Emissions as the 2000 Target	Projected Year 2000 Emissions	Difference	% Difference
Austria	17.6	19.5	1.9	11%
Belgium	30.7	31.6	0.8	3%
Denmark	15.1	18.3	3.2	21%
Finland	17.3	22.3	5.0	29%
France	109.7	116.6	6.9	6%
Germany	274.0	267.3	-6.7	-2%
Great Britain	162.3	167.9	5.6	3%
Greece	19.5	22.0	2.4	13%
Ireland	9.0	10.1	1.2	13%
Italy	113.1	123.8	10.7	9%
Luxembourg	2.8	2.3	-0.6	-20%
Netherlands	48.1	49.3	1.2	3%
Portugal	13.0	15.9	2.9	23%
Spain	60.5	63.4	2.9	5%
Sweden	18.6	21.9	3.3	18%
European Union Total	911.3	952.1	40.8	4%
Switzerland	12.7	12.4	-0.4	-3%
Australia	73.8	90.6	16.8	23%
Canada	126.1	143.1	16.9	13%
Japan	306.2	330.0	23.7	8%
New Zealand	7.3	8.2	0.9	12%
U.S.	1,377.1	1,621.5	244.4	18%
Total All Countries	2,814.7	3,157.8	343.1	12%

Sources: See description in text. Includes carbon dioxide, measured in metric tonnes carbon, from fossil fuels plus 50 percent of carbon from combustibles and other solid fuels. 1990 data calculated from IEA/OECD *Energy Balances of OECD Countries* using IPCC suggested methodology. Year 2000 data calculated from government projections showing 1990 data and year 2000 projections, linked to the OECD *Energy Balances* data.

Iceland, Norway, and Turkey are not included because comparable governmental energy and emissions projections were not available. It should be noted that Turkey has requested that it be removed from the Annex I obligations under the Framework Convention on Climate Change.

As noted in Appendix A, alternative projections for 2000 and 2010 exist. For example, IEA projections have emissions in some countries substantially higher (Finland, Greece and Ireland). Germany's emissions are somewhat lower. Emissions for Great Britain are lower in 2000, but about the same in 2010.

Many factors contribute to the failure to meet this aim of the Framework Convention on Climate Change. Even though nations adopting the Framework Convention's emissions aim introduced a wide variety of policies to limit emissions,[6] policies must be stringent enough to offset population and economic growth. Compared to a target of keeping year 2000 emissions at 1990 levels, the population in both the EU and Japan is projected to increase about 3 percent and GDP about 24 percent. In the U.S., Australia and Canada, population is projected to increase 10 percent to 12 percent, while GDP is projected to increase 20 percent to 35 percent.

An even more useful perspective, however, is gained by taking a more detailed look at the underlying economic and energy use factors that link carbon emissions and energy use with fundamental economic factors. These include population growth and increases in per capita gross domestic product (GDP) which tend to increase emissions, reductions in the energy intensity of GDP which tend to slow carbon emission growth, and changes in a nation's fuel mix which can push emissions upward or downward. However, before assessing these factors in detail, the emission limitation commitments made under the proposed Kyoto Protocol are reviewed.

[6] A useful perspective on these policies is available in the IEA/OECD publication *Climate Change Policy Initiatives - 1994 Update*.

D. Kyoto Protocol Targets and Timetable

The proposed Kyoto Protocol to the Framework Convention on Climate Change, agreed to in December 1997, set new greenhouse gas emission targets and timetables for Annex I nations. This proposed protocol was the result of an intensive two-year round of negotiations that culminated in all-night negotiating sessions before agreement was reached.

The ground rules for the negotiating process were established at the First Conference of Parties, the first meeting of the countries that ratified the Framework Convention, in 1995. A decision document referred to as the "Berlin Mandate" specifies key findings and ground rules, such as:

- the emission limitation obligations contained in the 1992 Framework Convention "are not adequate" and the Parties of the Conference agree "to begin a process to enable it to take appropriate action for the period beyond 2000..." (see Adoption of Decisions section)
- the negotiating process will aim "to set quantified limitation and reduction objectives [for developed country/other Parties included in Annex I] within specified time-frames, such as 2005, 2010 and 2020, for their anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol...." (see Section II)
- the negotiating process will "not introduce any new commitments for Parties not included in Annex I...." (see Section II)
- the negotiating process should be completed "as early as possible in 1997 with a view to adopting the results at the third session of the Conference of the Parties." (see Section III).

The end result of this negotiating process, the proposed Kyoto Protocol, establishes a "commitment period" covering 2008-2012. During this period, emissions of anthropogenic greenhouse gases (in carbon dioxide equivalents) in each country should not exceed five times a certain percentage of that country's emissions in 1990 (three small volume but potent greenhouse gases use 1995 as a base year). Because the commitment period centers on 2010, comparisons of projections for 2010 with 1990 levels provide a useful barometer of how easy or how difficult it will be for countries to meet their targets. The specific targets for the Annex I countries, as a percentage of 1990 levels emissions, are summarized in Table II-3.

Table II-3
Kyoto Protocol Emission Limitation Targets for 2008-2012

As % of 1990 Level	Country/Region
110%	Iceland
108%	Australia
101%	Norway
100%	New Zealand Russian Federation* Ukraine*
95%	Croatia*
94%	Canada Japan Poland*
93%	United States
92%	EU countries as a total (targets for individual EU countries to be specified by the EU within an EU "bubble") Bulgaria* Czech Republic* Estonia* Hungary* Latvia* Liechtenstein Lithuania* Monoco Romania* Slovakia* Slovenia* Switzerland

*Ex-Soviet Bloc countries — in transition to market economies

The Kyoto Protocol also established a number of other mechanism that in principle could influence the level of emissions reductions required in a specific country. However, as indicated below, the significance of these mechanisms is difficult to determine at this time. These mechanisms include:

Emissions Trading: Article 3.10 of the Kyoto Protocol allows countries to trade their "emission reduction units", thereby altering their national emission reduction targets upward or downward. However, Article 17 indicates that the Conference of Parties shall define the relevant "principles, modalities, and rules and guidelines, in particular for verification, reporting and accountability for emissions trading." Trading is also supposed to be "supplemental to domestic actions...."

Hence, the Kyoto Protocol in theory allows trading but contains no rules for trading. Presumably, no trading can occur until such rules exist, and those rules also could be subsequently altered. Until rules exist, it is difficult to develop any credible estimates of how large such trading might be. When such rules might be developed is problematic, given the diverse and strongly held views about trading that were expressed in the negotiations leading to the protocol and prevented the inclusion of trading rules in the protocol.

Other Gases: The Kyoto Protocol covers the "aggregate anthropogenic carbon dioxide equivalent emissions" of six greenhouse gases, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) The first three gases use a 1990 base year and the last three gases use a 1995 base year for the 2008-2012 emission limitation targets. For most countries, carbon emissions make up the bulk of total carbon dioxide equivalent emissions.[7] To the extent that other gases do not meet their emission limitation targets, emissions of carbon dioxide from fossil fuels would have to be reduced even more for a country to meet its overall target.

Bubbles, Meeting Targets Jointly, and Joint Implementation: Article 3 allows Parties in Annex I to meet their targets "individually or jointly" in the aggregate. This allows the EU countries to operate under the long-declared EU "bubble" — individual country emissions can be above or below the 92 percent of 1990 level target as long as the EU aggregate achieves the targeted level. However, other countries also could agree to meet their combined aggregate target jointly. The Protocol also allows "joint implementation" among Annex I countries. These are project specific emission reduction efforts undertaken by one Party in another Annex I country.

Sinks: Sinks refers to the ability of plants to pull carbon from the atmosphere as they grow, thereby sequestering carbon. The Kyoto Protocol appears to require that changes in emissions, relative to 1990 levels, from direct human-induced land use changes and forestry activities which impact this sequestration be counted. Whether including sinks increases a nation's emission reduction target or decreases the target depends on the nature of land use change, afforestation, reforestation, deforestation, etc.

This formulation might cause difficulty for countries with growing populations. The population in the U.S., for example, is expected to increase by about 50 million people between 1990 and 2010. This implies direct human induced land-use changes for roads and housing, etc. that tend to reduce sequestration of carbon. Unless other programs exist to offset any such reduced sequestration, then greater reductions in anthropogenic emissions of the six greenhouse gases would be required for a nation to meet its overall emissions limitation target. Again, the rules for this category of emissions have yet to be written, and their poten-

[7] The U.S. *Climate Action* Report, also known as the "Second National Communication" under the FCCC, summarizes U.S. emissions. Carbon emissions account for 85 percent of total carbon equivalent emissions, followed by methane (11 percent), nitrous oxide (2 percent) and small amounts of HFCs, PFCs and SF6s. However, between 1990 and 1995, HFC and PFC emissions increased more than 60 percent.

Table II-2
OECD Carbon Emissions: Comparison of 1990 and Projected Year 2000 Emissions
(million metric tons carbon)

Country	1990 Emissions as the 2000 Target	Projected Year 2000 Emissions	Difference	% Difference
Austria	17.6	19.5	1.9	11%
Belgium	30.7	31.6	0.8	3%
Denmark	15.1	18.3	3.2	21%
Finland	17.3	22.3	5.0	29%
France	109.7	116.6	6.9	6%
Germany	274.0	267.3	-6.7	-2%
Great Britain	162.3	167.9	5.6	3%
Greece	19.5	22.0	2.4	13%
Ireland	9.0	10.1	1.2	13%
Italy	113.1	123.8	10.7	9%
Luxembourg	2.8	2.3	-0.6	-20%
Netherlands	48.1	49.3	1.2	3%
Portugal	13.0	15.9	2.9	23%
Spain	60.5	63.4	2.9	5%
Sweden	18.6	21.9	3.3	18%
European Union Total	911.3	952.1	40.8	4%
Switzerland	12.7	12.4	-0.4	-3%
Australia	73.8	90.6	16.8	23%
Canada	126.1	143.1	16.9	13%
Japan	306.2	330.0	23.7	8%
New Zealand	7.3	8.2	0.9	12%
U.S.	1,377.1	1,621.5	244.4	18%
Total All Countries	2,814.7	3,157.8	343.1	12%

Sources: See description in text. Includes carbon dioxide, measured in metric tonnes carbon, from fossil fuels plus 50 percent of carbon from combustibles and other solid fuels. 1990 data calculated from IEA/OECD *Energy Balances of OECD Countries* using IPCC suggested methodology. Year 2000 data calculated from government projections showing 1990 data and year 2000 projections, linked to the OECD *Energy Balances* data.

Iceland, Norway, and Turkey are not included because comparable governmental energy and emissions projections were not available. It should be noted that Turkey has requested that it be removed from the Annex I obligations under the Framework Convention on Climate Change.

As noted in Appendix A, alternative projections for 2000 and 2010 exist. For example, IEA projections have emissions in some countries substantially higher (Finland, Greece and Ireland). Germany's emissions are somewhat lower. Emissions for Great Britain are lower in 2000, but about the same in 2010.

Many factors contribute to the failure to meet this aim of the Framework Convention on Climate Change. Even though nations adopting the Framework Convention's emissions aim introduced a wide variety of policies to limit emissions,[6] policies must be stringent enough to offset population and economic growth. Compared to a target of keeping year 2000 emissions at 1990 levels, the population in both the EU and Japan is projected to increase about 3 percent and GDP about 24 percent. In the U.S., Australia and Canada, population is projected to increase 10 percent to 12 percent, while GDP is projected to increase 20 percent to 35 percent.

An even more useful perspective, however, is gained by taking a more detailed look at the underlying economic and energy use factors that link carbon emissions and energy use with fundamental economic factors. These include population growth and increases in per capita gross domestic product (GDP) which tend to increase emissions, reductions in the energy intensity of GDP which tend to slow carbon emission growth, and changes in a nation's fuel mix which can push emissions upward or downward. However, before assessing these factors in detail, the emission limitation commitments made under the proposed Kyoto Protocol are reviewed.

[6] A useful perspective on these policies is available in the IEA/OECD publication *Climate Change Policy Initiatives - 1994 Update.*

D. Kyoto Protocol Targets and Timetable

The proposed Kyoto Protocol to the Framework Convention on Climate Change, agreed to in December 1997, set new greenhouse gas emission targets and timetables for Annex I nations. This proposed protocol was the result of an intensive two-year round of negotiations that culminated in all-night negotiating sessions before agreement was reached.

The ground rules for the negotiating process were established at the First Conference of Parties, the first meeting of the countries that ratified the Framework Convention, in 1995. A decision document referred to as the "Berlin Mandate" specifies key findings and ground rules, such as:

- the emission limitation obligations contained in the 1992 Framework Convention "are not adequate" and the Parties of the Conference agree "to begin a process to enable it to take appropriate action for the period beyond 2000..." (see Adoption of Decisions section)
- the negotiating process will aim "to set quantified limitation and reduction objectives [for developed country/other Parties included in Annex I] within specified time-frames, such as 2005, 2010 and 2020, for their anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol...." (see Section II)
- the negotiating process will "not introduce any new commitments for Parties not included in Annex I...." (see Section II)
- the negotiating process should be completed "as early as possible in 1997 with a view to adopting the results at the third session of the Conference of the Parties." (see Section III).

The end result of this negotiating process, the proposed Kyoto Protocol, establishes a "commitment period" covering 2008-2012. During this period, emissions of anthropogenic greenhouse gases (in carbon dioxide equivalents) in each country should not exceed five times a certain percentage of that country's emissions in 1990 (three small volume but potent greenhouse gases use 1995 as a base year). Because the commitment period centers on 2010, comparisons of projections for 2010 with 1990 levels provide a useful barometer of how easy or how difficult it will be for countries to meet their targets. The specific targets for the Annex I countries, as a percentage of 1990 levels emissions, are summarized in Table II-3.

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The Kyoto Protocol also established a number of other mechanism that in principle could influence the level of emissions reductions required in a specific country. However, as indicated below, the significance of these mechanisms is difficult to determine at this time. These mechanisms include:

Emissions Trading: Article 3.10 of the Kyoto Protocol allows countries to trade their "emission reduction units", thereby altering their national emission reduction targets upward or downward. However, Article 17 indicates that the Conference of Parties shall define the relevant "principles, modalities, and rules and guidelines, in particular for verification, reporting and accountability for emissions trading." Trading is also supposed to be "supplemental to domestic actions...."

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Other Gases: The Kyoto Protocol covers the "aggregate anthropogenic carbon dioxide equivalent emissions" of six greenhouse gases, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) The first three gases use a 1990 base year and the last three gases use a 1995 base year for the 2008-2012 emission limitation targets. For most countries, carbon emissions make up the bulk of total carbon dioxide equivalent emissions.[7] To the extent that other gases do not meet their emission limitation targets, emissions of carbon dioxide from fossil fuels would have to be reduced even more for a country to meet its overall target.

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This formulation might cause difficulty for countries with growing populations. The population in the U.S., for example, is expected to increase by about 50 million people between 1990 and 2010. This implies direct human induced land-use changes for roads and housing, etc. that tend to reduce sequestration of carbon. Unless other programs exist to offset any such reduced sequestration, then greater reductions in anthropogenic emissions of the six greenhouse gases would be required for a nation to meet its overall emissions limitation target. Again, the rules for this category of emissions have yet to be written, and their poten-

[7] The U.S. *Climate Action* Report, also known as the "Second National Communication" under the FCCC, summarizes U.S. emissions. Carbon emissions account for 85 percent of total carbon equivalent emissions, followed by methane (11 percent), nitrous oxide (2 percent) and small amounts of HFCs, PFCs and SF6s. However, between 1990 and 1995, HFC and PFC emissions increased more than 60 percent.

tial significance will depend critically on those rules.

Clean Development Mechanism: Article 12 establishes a means by which Parties may undertake project specific emission reduction activities in developing nations. Such projects can start as early as 2000 and generate emission reduction credits for the 2008-2012 period. However, the projects must be certified by an as yet to be established FCCC body and a share of the proceeds of the projects certified must be paid to that body. Again, the extent to which this mechanism may yield meaningful emission reductions during the 2008-2012 period is indeterminate at this time.

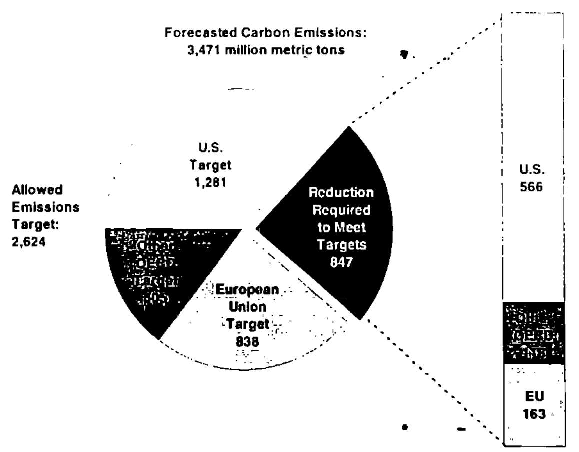
E. Emission Reductions Required by the Kyoto Protocol

While the remainder of this report goes into some detail about the nature of the emission limitation commitments contained in the Kyoto Protocol, and how easy or difficult it may be to meet these commitments, Figure II-1 provides a useful overview to these commitments for OECD countries/Annex I countries. As noted earlier, Iceland and Norway are not included because of data problems, and Turkey is not included because it has no emission limitation specified in the Kyoto Protocol.

The figure below provides an overview of the Kyoto commitments for OECD countries. The pie on the left represents the baseline or business-as-usual forecasted carbon emissions of the OECD countries in the year 2010. It shows that in order to meet the Kyoto protocol targets, emissions must be reduced by 847 million metric tons from the total forecasted for the OECD of 3,471 million metric tons.

Sections of the pie show the amount of carbon emissions allowed for countries or groups of countries under the Kyoto Protocol. The bar on the right shows the reductions in carbon emissions required of these countries or regions in order for them to meet their targets. For example, in order for the U.S. to meet its target allowance of 1,281 million metric tons in the year 2010, its emissions must be reduced by 566 million metric tons. This represents a reduction of 31 percent from the U.S. government's business-as-usual baseline forecast of 1,847 million metric tons in the year 2010.

Figure II-1
The OECD's Forecasted Carbon Emissions in the Year 2010, the Kyoto Targets and Required Reductions



In comparison, the 15-member nations of the European Union would be required to reduce their emissions by 163 million metric tons in order to reach a target total of 838 million metric tons. This reduction is 16 percent less than the 1,001 million metric tons forecasted for the region. Similarly, the other member countries of the OECD would be required to reduce their emissions by 118 million metric tons from a forecasted total of 623 million metric tons, or by 19 percent.

The question of how easy or how hard it may be to reach these emission reduction commitments has been the subject of significant debate and many analyses. The approach taken in this study is neither another macroeconomic simulation (sometimes referred to as a "top-down" study) nor an engineering/technology assessment (called a "bottoms-up" study). Rather, this study looks at the core variables that drive emissions:

- population,
- per capita gross domestic product,
- the energy intensity of GDP, and
- the carbon content of energy used in the economy.

In fact, carbon emissions cannot be changed from baseline projected levels without changing one or more of these four components of what is called the Kaya Identity. How these components change between now and 2010 determines carbon emissions in 2010 in the baseline or business-as-usual projection.

Comparing how much these components must change between now and 2010 to reach the emission levels mandated by the Kyoto Protocol, versus the changes in the business-as-usual projection, provides a revealing indication of how easy or hard it will be to achieve the Kyoto targets. Further, these changes also are compared with changes that occurred during the energy crisis years of 1973-1986, a period in which U.S. inflation adjusted fossil fuel prices quadrupled. As demonstrated in subsequent chapters, the reductions in fossil energy use required by the Kyoto Protocol emission targets are quite large, and would require changes in its determinants well in excess of those which occurred in most market economies during the energy crisis years.

III. Methodology and Illustration for the U.S.

A. Overview of the Kaya Identity[8]

Comparison of recent energy market forecasts through 2010 and beyond with carbon emission limitation targets and timetables contained in the proposed Kyoto Protocol reveals a strong disconnect between the world of energy market forecasting and the world of international climate change policy. For example, the U.S. Energy Information Administration's *Annual Energy Outlook 1998* reference case projects U.S. carbon emissions to be 44 percent above the Kyoto target for the U.S. in 2010 and 56 percent above in 2020.

The Kaya Identity decomposes carbon emissions in a way that allows comparison of past changes in key components affecting emissions with changes that would be required to meet the Kyoto Protocol's proposed emission targets. For example, the most dramatic alteration of U.S. carbon emissions trends in the past 35 plus years occurred during the 1974-1986 period, sometimes referred to as the energy crisis years. Although U.S. carbon emissions in 1985 and 1986 almost exactly matched emissions in 1973, the intervening years were marked by very large increases in real energy prices, rapid growth of nuclear power, numerous government programs to reduce energy use, and a 50 percent reduction in the rate of growth of per capita GDP. Over this period, the energy intensity of GDP declined an average of 2.1 percent per year.

The Kaya Identity provides a useful tool for characterizing past changes in key factors impacting carbon emissions and allows a comparison with the types of changes required to meet future emission targets. Under the Kaya Identity formulation, carbon emissions depend on the carbon content of energy used in the economy, the energy intensity of economic activity, per capita gross domestic product (GDP), and population. In equation form the Kaya Identity is:

$$C = C/E * E/GDP * GDP/Population * Population$$

where C equals carbon emissions and E equals energy use. For small to moderate changes in the Kaya components between any two years, the sum of the percent changes in each of the components (C/E, E/GDP, GDP/Population, and Population) closely approximates the percent change in carbon emissions between those two years.

The historical trends in the Kaya Identity components provide a reference point for evaluating current baseline projections of carbon emissions as well as the key economic, demographic and energy intensity factors leading to those emissions. More significantly, the past changes in the Kaya Identity components, especially during the period of the oil price shocks, can be compared with the extent of change required to meet emissions targets and timetables proposed in the Kyoto Protocol. To the degree that changes in energy intensity required to reach proposed targets, given other assumptions, are outside the scale of changes during the energy crisis years of the 1970's and 1980's, the viability of the proposed targets and timetables must be seriously questioned.

The Kaya Identity approach makes it clear that unless economic growth is significantly slowed from projected rates or large changes in the nation's fuel mix are made in the next decade, the effort required domestically (i.e., without emissions trading) to reach carbon emission limitation goals proposed by the Kyoto Protocol would be more than twice that required to limit energy use in the 1974-1986 period.

It should be noted that the Kaya Identity, by itself, says little about the nature of policies that would be required to reach the Kyoto targets. The Kaya Identity also does not evaluate the cost to the economy of what and how products are made and consumed. The Identity only provides a measure of the extent of change required to reach the target. *However, unless new policies alter economic and energy trends sufficiently so that the Kaya Identity requirements are met, the Kyoto targets will not be achieved.*

This chapter explains the application of the Kaya Identity by summarizing Kaya Identity information

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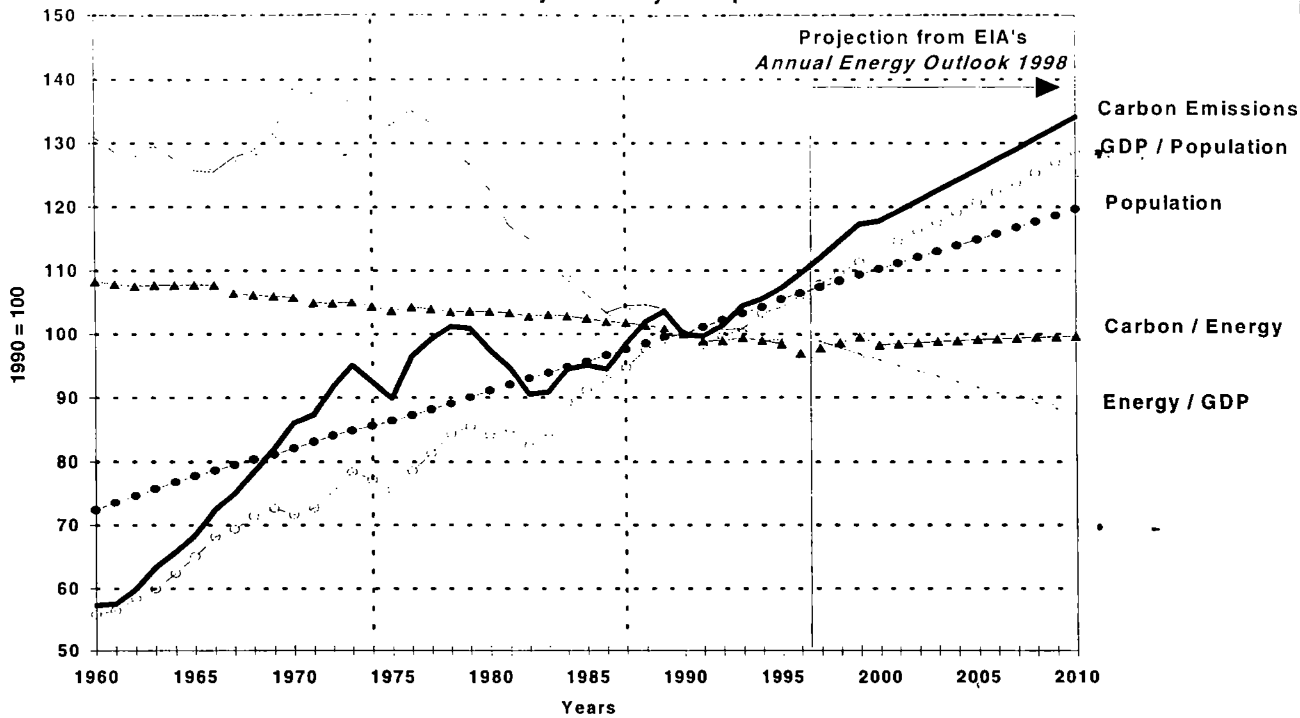
[8] This chapter updates and extends analysis presented in "Carbon Emissions — A Kaya Identity Perspective on Historic Emissions and Proposed Emission Reduction Targets and Timetables" by Russell Jones and Barbara Tierney, published in *International Energy Markets, Competition and Policy,* Conference Proceedings of the 18th Annual North American Conference of the U.S. Association for Energy Economics, and the International Association for Energy Economics, San Francisco, September, 1997.

Figure III-1
U.S. Kaya Identity Components



for the United States. This highlights historic trends as well as current energy business-as-usual (also referred to as reference case or baseline) projections into the next century. These results are then compared with the targets contained in the Kyoto Protocol for the U.S. Finally, an assessment is made of the effort that would be required to meet the target and timetable in light of historical experience. Subsequent chapters look at all OECD countries.

B. Kaya Identity Components: Historic Trends and Projections

1. Data

Energy data for 1960 - 1995 are available from the OECD's *Energy Balances of OECD Countries.* The data used here are for total primary energy and include: coal, crude oil and petroleum products (excluding non-energy use), natural gas, nuclear, hydro-power, geothermal, solar, wind & other, combustible renewables and waste, and other non-specified combustion (for electricity generation or heat).

The carbon content of these fuels is calculated following procedures suggested by the Intergovernmental Panel on Climate Change.[9] To allow for the possibility that some of the carbon in current combustible renewables and waste[10] is in fact being "recycled," that is, drawn from the atmosphere and then emitted during combustion, the carbon content of these fuels is counted as only half that suggested by the IPCC. As a practical matter, however, this adjustment has no material impact on the analysis because combustible renewables are such a small part of energy supplies.

Historic GDP data are drawn from the OECD *National Income Accounts - Main Aggregates* as well as from the U.S. *Economic Report of the President.* Population data are drawn from the OECD *Labour Force Statistics* and the U.S. *Economic Report of the President.* Data and projections for the 1995 - 2010 period are drawn from the U.S. Energy Information Administration's *Annual Energy Outlook 1998* reference case.

Figure III-1 provides a summary of the Kaya components for the U.S. as well as a projection using the

[9] See Part 1 of Volume 3 of the *Greenhouse Gas Inventory Reference Manual - IPCC Draft Guidelines for National Greenhouse Gas Inventories,* 1994.

[10] This category includes peat, wood, wood waste, municipal waste, vegetal waste, industrial waste and sulfite lies, but varies from country to country.

Table III-1
U.S. Kaya Identity Components
(average annual percent change)

	1960-1973	1974-1986	1987-1995	1996-2000*	2001-2010*
Carbon (Million Mt)	4.0%	0.0%	1.4%	1.9%	1.3%
Carbon/Energy	-0.2%	-0.2%	-0.4%	0.0%	0.1%
Energy/GDP	0.3%	-2.1%	-0.4%	-0.6%	-0.9%
GDP/Population	2.7%	1.3%	1.3%	1.7%	1.3%
Population	1.2%	1.0%	1.0%	0.9%	0.8%

Note: *Calculated using EIA, *Annual Energy Outlook 1998*, Reference case.

Energy Information Administration's *Annual Energy Outlook 1998* reference case. All data have been converted to index form with 1990 equal to 100. This date was chosen because international negotiations for limits on greenhouse gas emissions use 1990 levels as a common reference point.

Table III-1 provides summary statistics for five time periods within the 1960-2010 period illustrated in Figure III-1. As will become more apparent in the discussion below, the key criterion for the selection of the time periods in Table III-1 was the annual change in the energy/GDP ratio. For example, the energy/GDP ratio declined every year during the 1974-1986 period with the exception of one year (1976). The ratio even declined in 1986, despite the dramatic collapse of world oil prices in that year.

2. The 1960-1973 Period

The 1960-1973 period was characterized by fairly sustained U.S. economic growth. Population grew at 1.2 percent per year over this period, more rapidly than in any subsequent period. Per capita income (GDP/population) grew at an average annual rate of 2.7 percent over this period. Even though there was a mild economic recession lasting from April 1960 to February 1961, GDP per capita grew by 1.0 percent between 1960 and 1961. As seen in Figure III-1, the energy/GDP ratio declined somewhat during the first few years of the 1960-1973 period and then rose toward the end of the period. Over the entire period, the energy/GDP ratio increased at an average annual rate of 0.3 percent. Only the carbon content of energy (the carbon/energy ratio) showed a modest decline during this period. Overall, carbon emissions increased at an average annual rate of 4.0 percent between 1960 and 1973.

3. The 1974-1986 Period

This time period was marked by several important events and changes in underlying trends that had a dramatic impact on U.S. carbon emissions. First, energy prices increased substantially. Between 1959 and 1972, real crude oil prices (domestic first purchase price) stayed in a relatively narrow range of $1.74 to $2.18 per million Btu in real 1992 dollars.[11] Between 1972 and 1974, real oil prices increased from $1.74 to $3.08 per million Btu. Between 1978 and 1981, oil prices increased from $3.04 to $8.31 per million Btu. Prices then declined somewhat in real terms for a while and then fell substantially in 1986 to $2.68 per million Btu. Real wellhead natural gas prices followed a different upward pattern, increasing at a more measured pace from $0.57 per million Btu in 1973 to a peak of $3.18 in 1983. Coal prices, in real terms, more than doubled between 1971 and 1976.

Overall, the composite fossil fuel price for the U.S., in real 1992 dollars, roughly doubled between 1972 and 1976, and doubled again by 1981. During the 1981-1986 period, composite fossil fuel prices declined slowly and then much more rapidly, but in 1986 they were still double the pre-1973 levels in real terms. These price increases generated not only substantial market pressure for increases in energy efficiency, but also numerous government programs aimed at increasing energy efficiency, reducing overall energy use, and lowering oil imports.

The second major factor affecting carbon emissions was a significant slowing of economic growth —an event arguably not completely independent of the increases in energy prices. During the 1974-1986 period, three recessions jolted the economy, including back-to-back recessions in 1980 and in 1981/82. In all three of these recessions, U.S. GDP per capita declined on a year to year basis.

The third key factor impacting carbon emissions trends during this period was the growth of electricity generated from nuclear power. Between 1972

[11] Unless otherwise indicated, prices are from the U.S. Energy Information Administration, *Annual Energy Review 1995*, Table 3.1.

and 1978, U.S. nuclear power generation increased from 15 million TOE (tonnes of oil equivalent energy, as reported by the OECD) to 76 million TOE. Output declined to 69 million TOE in 1980, related to the Three Mile Island reactor accident, but then rebounded to 114 million TOE in 1986, or more than 6 percent of total U.S. primary energy. This trend had a major impact on the carbon content of overall U.S. energy use. Of all Kaya Identity components, the carbon/energy ratio has changed the least. The primary cause of the reduction in the carbon/energy ratio was the growth of nuclear power.

The Kaya Identity components shown in Table III-1 reflect these three factors quite clearly. First, the rate of increase in per capita GDP slowed dramatically. The average annual increase in GDP per capita over the 1960-1973 period was 2.7 percent, but over the 1974-1986 period the increase slowed by more than 50 percent, down to 1.3 percent per year. Second, the average annual change in the energy/GDP ratio changed from an increase of 0.3 percent per year over 1960-1973 to a decrease of 2.1 percent per year. This change reflected a quadrupling of real energy prices in the U.S., plus a host of government programs aimed at promoting increased energy efficiency. Third, driven primarily by the expansion of nuclear power, the carbon content of overall energy declined at a 0.2 percent annual rate, the same as the rate of decline in the 1960-1973 period.

These changes in the Kaya Identity components had a dramatic impact on U.S. carbon emission trends. Over the 1960-1973 period, U.S. carbon emissions increased every year, at an average rate of 4.0 percent. Starting from a level of 1.30 billion metric tons (MT) in 1973, carbon emissions initially declined to 1.24 million MT by 1975 and then increased to 1.39 billion MT in 1978, and then declined back to 1.30 billion MT in 1986, the same level as 1973.

As summarized in Table III-1, the average annual change in carbon emissions in the 1974-1986 period was 0.0 percent. This period is a useful reference point for evaluating the level of effort that would be required to meet targets and timetables for emission limits negotiated in the Kyoto Protocol.

Compared to the previous time period when carbon emissions were increasing at an average rate of 4.0 percent per year, the 0.0 percent growth rate in carbon emissions over 1974-1986 was achieved with a roughly 20 percent reduction in the rate of population growth, a 50 percent reduction in the growth rate of GDP per capita, no change in the rate of reduction in the carbon/energy ratio, and a large change from a 0.3 percent per year *increase* in the energy intensity of GDP to an average annual 2.1 percent *reduction* in the energy intensity of GDP.

4. The 1987-1995 Period

This period was significantly less volatile than the 1974-1986 period, and carbon emissions increased at an average rate of 1.4 percent per year. The population growth rate was the same as in the preceding period. There was one recession, from July 1990 to March 1991, and the average annual change in per capita GDP was 1.3 percent, matching the rate of increase in the 1974-1986 period. Inflation adjusted composite fossil fuel prices in 1987 were $2.05 per million Btu, about double that in 1972 but half that in 1981. With some volatility, prices trended downward and by 1995 had fallen to $1.39 per million Btu, about one-third greater than the 1972 level.

The energy/GDP ratio continued to fall at an average annual decline of 0.4 percent. The rate of decline was less than one-fifth that experienced during the 1974-1986 period (-2.1 percent). However, the carbon content of overall energy use declined at a faster rate than in either of the preceding two time periods. Several factors contributed to this trend. Again, nuclear power increased its share of total U.S. primary energy, from a little over 6 percent in 1985 to about 9 percent in 1995. There were some increases in geothermal and other non-carbon energy sources, but there was a bigger decline in the share of crude oil and petroleum products in total primary energy, from about 39 percent in 1986 to a little over 35 percent in 1995, reflecting the lagged impact of the earlier high prices. Also, natural gas increased its share of total primary energy by about two percentage points over the period. This increase was due in part to the deregulation of wellhead natural gas markets and the resulting low prices for natural gas.

5. The 1996-2000 and the 2001-2010 Periods

While the data in Figure III-1 and Table III-1 reflect the reference case projection in the Energy Information Administration's *Annual Energy Outlook 1998* through 2010, the short 1996-2000 period is included here for a pragmatic reason. The Kyoto Protocol climate change negotiations on greenhouse gas emission limitations came to a conclusion in December 1997. Even with this completed negotiation, it is unknown when, or even if, the Kyoto Protocol will be ratified by the required number of national governments to enter into force as an international

No El. Rest.

treaty with the force of law on those countries ratifying it. Some have speculated that it might be three to five years before enough countries ratified the Protocol to bring entry into force.

With this outlook, it is unlikely that U.S. emission trends would be significantly altered prior to 2000, given the time requirements of treaty approval, development of national implementing programs, drafting of necessary laws and regulations, and the process of obtaining necessary Congressional approval. Efforts to significantly alter the emissions path from the assumed EIA baseline probably would take effect only after that date. Therefore, it is useful to use the year 2000 as a reference point to calculate the level of effort required to achieve emission limitation targets.

Additionally, looking at the EIA reference case projection in two time periods provides a useful perspective. For example, compared to a 1.4 percent annual average increase in U.S. carbon emissions over the 1987-1995 period, the average annual change over 1996-2000 projection is 1.9 percent, but this declines substantially to an annual average of only 1.3 percent per year over the 2001-2010 period.

Most, but not all, of the trends in the Kaya components contribute to this trend of slowing emissions growth in the EIA reference case projection. First, population growth slows from 1.0 percent per year over the 1987-1995 to 0.9 percent per year for 1996-2000 periods and to 0.8 percent per year over 2001-2010.

Second, growth in per capita GDP initially increases but then slows again in the EIA reference case. Over the 1996-2000 period per capita GDP grows at 1.7 percent per year. However, over the 2001-2010 period the growth rate returns to the 1.3 percent per year rate of the 1987-1995 period. Put in perspective, however, this is only about half the growth rate in GDP per capita experienced over the 1960-1973 period.

Third, the energy intensity of economic activity, the energy/GDP ratio, decreases at a much faster rate than in the 1987-1995 period. Over the latter period, the energy/GDP ratio decreased by 0.4 percent per year; over 1996-2000 it is projected by the EIA to decrease by 0.6 percent per year; and over 2001-2010 it is projected to decrease at 0.9 percent per year. The reduction in energy intensity of GDP is not caused by assumed increases in real energy prices. While very modest increases do occur in certain fuel categories, average end-user inflation adjusted energy prices decline modestly over the 1995-2010 period.[12] Rather, the reductions in energy intensity appear to be caused primarily by increases in efficiency in the electricity generation sector, implementation of mandated energy efficiency standards in buildings and motors, plus other energy efficiency improvements in the transportation sector and elsewhere.

However, it is worth noting that the assumed annual decline in the energy/GDP ratio over the 2001-2010 period of 0.9 percent is more than twice the 0.4 percent per year decline over the 1987-1995 period. Unless these rapid reductions in the energy/GDP ratio occur between now and 2010, future emissions will be greater than projected.

One Kaya Identity component that works to increase carbon emissions over the 1996-2010 periods in the EIA reference case relative to the 1987-1995 period is the carbon/energy ratio. The ratio moves from an annual average reduction of 0.4 percent over 1987-1995 to an annual average increase of 0.1 percent over the 2001-2010 period. A major factor contributing to this trend is the anticipated retirement of nuclear power plants at or before they reach the end of their 40-year operating licenses. In EIA's projections, about 52 gigawatts of capacity will be retired by 2020 out of about 101 gigawatts of capacity available in 1996.[13] Twenty-four of these shut-downs are as early as 10 years before licenses expire. This fact is consistent with the view of some industry analysts. For example, a *Wall Street Journal* article cited concerns that perhaps two dozen nuclear power plants, out of 109 plants in the country, could shut down before their licenses expire due to rising costs associated with more strict enforcement of U.S. Nuclear Regulatory Commission regulations.[14]

C. What-If Assessment of Emission Reduction Targets for the U.S.

A significant debate over the ease or difficulty of reducing greenhouse gas emissions in general, and carbon emissions in particular has continued for over a decade. This debate encompasses not only

[12] See Energy Information Administration, *Annual Energy Outlook 1998*, Table A3, page 104.
[13] See Energy Information Administration, *Annual Energy Outlook 1998*, page 5.
[14] Ross Kerber, "Nuclear Plants Face Huge Costs to Fix Problems", *Wall Street Journal*, June 18, 1997, page B1.

the United States but other developed as well as developing countries throughout the world. One of the more recent efforts at addressing the many relevant issues is contained in two of the three volumes of the *Second Assessment Report* by the Intergovernmental Panel on Climate Change. Despite significant effort at resolving the issue, there is still a wide variety of claims regarding the economic impacts of significantly reducing carbon emissions in the U.S. economy, as well as emissions in other countries.

One way the Kaya Identity can be used is for comparing the effort required to meet carbon emission targets and timetables with historical experience, especially the effort required to hold U.S. carbon emissions in 1986 to 1973 levels. This is clearly *not* a modeling effort in the traditional sense. Rather, the Kaya Identity can be used to answer a more narrow question: given government agency assumptions about population and per capita GDP growth and the carbon/energy ratio, how much would the U.S. energy/GDP ratio have to change over the 2001-2010 period to achieve emission targets in 2010, and how does this compare to the changes that occurred over the 1974-1986 period?

For illustration, two alternative targets are evaluated. The first is to limit emissions in 2010 to 1990 levels, and the second is 7 percent below 1990 levels.

The following set of assumptions define these two different cases:

Starting from levels for all Kaya Identity components in 2000;

- Population increases at the annual average rate over the 2001-2010 period in EIA's 1998 reference case;

- GDP/population increases at the annual average rate over the 2001-2010 period in EIA's 1998 reference case;

- Carbon/energy increases at 0.1 percent per year, the average increase over 2001-2010 in EIA's 1998 reference case;

- Carbon emissions in 2010 equal:
  - Case 1: 1990 levels
  - Case 2: Kyoto Target, 7 percent below 1990 levels

These assumptions determine the average annual rate of change required in the energy/GDP ratio over the 2001-2010 period to achieve the assumed carbon emissions target for 2010. This is clearly a *ceteris paribus* approach, for it implicitly assumes that significant alterations in the energy/GDP ratio could be accomplished without imposing costs on the economy and altering GDP from the assumed levels.

At the same time, however, the what-if assessment raises a critical question — namely, if the proposed target requires changes in the energy/GDP ratio equal to or greater than that which occurred during the energy crisis years of 1974-1986, a period in which the per capita GDP growth rate fell by 50 percent and U.S. inflation-adjusted composite fossil fuel prices quadrupled, how could emission targets be met without similar consequences to economic activity?

The results of the what-if assessment are summarized in Table III-2. The energy/GDP ratio would have to decline an average of 3.8 per year over 2001-2010 to reach a target of 1990 level emissions. This is roughly four times the rate of decline in the EIA reference case for 2001-2010. More importantly, the rate of decline is roughly 80 percent greater than that achieved during the energy crisis years of 1974-1986.

More relevant to assessment of the Kyoto Protocol targets, Case 2 addresses the target of limiting U.S. carbon emissions to 7 percent below 1990 levels by 2010. To reach this target under the what-if assessment assumptions, the energy/GDP ratio would have to decline by 4.5 percent per year. This decline rate is roughly 110 percent greater than that achieved during the 1974-1986 period. Additionally,

Table III-2
What-If Assessment of U.S. Emission Reduction Targets for 2010
(average annual percentage changes for 2001-2010)

Case	Carbon	Carbon/ Energy	Energy/ GDP	GDP/ Population	Population
BAU Projection	1.3	0.1	-0.9	1.3	0.8
Case 1: 1990 Target in 2010	-1.7	0.1	-3.8	1.3	0.8
Case 2: 7% Below 1990 in 2010	-2.3	0.1	-4.5	1.3	0.8

this rate of reduction in the energy/GDP ratio is 5 times that in EIA's reference case projection.

D. Conclusions

These examples illustrate how the Kaya Identity can be used for comparing past changes in key components affecting carbon emissions with changes that would be required to achieve carbon emission targets. The most dramatic alteration of U.S. carbon emissions trends in the past 35 years occurred during the 1974-1986 period, sometimes referred to as the energy crisis years. Although U.S. carbon emissions in 1985 and 1986 almost exactly matched emissions in 1973, the 1974-1986 period included a quadrupling of real fossil fuel prices, growing use of nuclear power, numerous government programs to promote energy efficiency, and a 50 percent reduction in the rate of growth of per capita GDP. Over this period, the energy/GDP ratio declined at 2.1 percent per year.

The Kaya Identity approach, using the Energy Information Administration's *Annual Energy Outlook 1998* reference case as a baseline, makes it clear that the changes required to reach carbon emission limitation goals in the Kyoto Protocol would significantly exceed that of the 1974-1986 period in the U.S.

The following chapters extend the analysis. First, more detail is provided on historic trends in OECD countries and the implications of the Kyoto emission targets. Then Chapters V and VI characterize the effort or changes from business-as-usual projections required to reach the Kyoto targets.

IV. OECD Carbon Emissions

A. Historical Trends

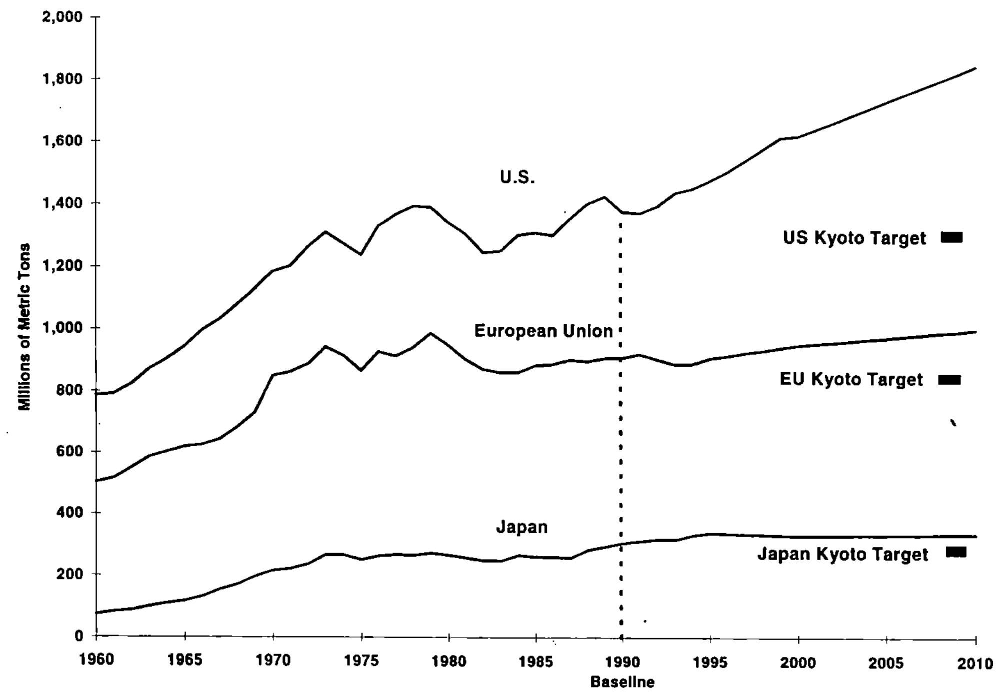
Between 1960 and 1973 carbon emissions in the U.S. increased from nearly 800 million metric tons to 1,300 million metric tons. This represents an average annual increase of about 4 percent. In comparison, growth in the carbon emissions from the 15-member countries of the European Union was even faster, averaging 5 percent annually during this period, and rising from 500 million metric tons to over 900 million metric tons. In Asia, Japan's carbon emissions increased at an average annual rate of more than 10 percent, tripling the amount of carbon emissions from 75 million metric tons in 1960 to 265 million metric tons by 1973.

During the energy price shock years of 1974 through 1986, the rate of growth of carbon emissions fell to zero in the U.S. and turned negative in Europe and Japan, declining slightly by an average of 0.4 percent per year and 0.1 percent per year, respectively. These historical trends are plotted in Figure IV-1 along with "business-as-usual" (BAU) government forecasts of future growth and the targets the EU, the U.S. and Japan committed to in Kyoto.[15]

B. Business-as-Usual Forecasts to 2010

EIA reference case or business-as-usual (BAU) forecasts call for pronounced increases in U.S. carbon emissions in the future compared to the relatively flat EU forecasts for Europe and IEA forecast for Japan. This is due in part to the more rapid growth expected in the U.S. population compared to Europe's and Japan's. (See Chapter V below.) Under a BAU scenario U.S. emissions are expected to increase from nearly 1,400 million metric tons in 1990 to nearly 1,850 million metric tons in 2010.[16] In comparison, the European Union forecasts its carbon emissions to increase from about 900 million metric tons in 1990 to 1,000 million metric tons in 2010. This is about the same level reached in 1979 when the EU's carbon emissions peaked at around 990 million metric tons. Japan's carbon emissions are fore-

Figure IV-1
Carbon Emissions: The Kyoto Target Versus Projected Levels



[15] See Table B-1 for a complete list of sources.
[16] Carbon emissions from fossil fuels are projected to reach 1,803 million metric tons. The estimates in this paper

cast to increase by just 30 million metric tons from the year 1990 to 2010.

C. Promises Made in Kyoto

The U.S. agreed to a 7 percent reduction in greenhouse gas emissions from 1990 levels by 2008 to 2012. Figure IV-1 reveals the distance from the target point in the year 2010 to the forecast trend is substantial, representing a 31 percent decline in emissions compared to the BAU forecast. In comparison, the EU agreed to an 8 percent reduction in carbon emissions, with country specific reductions within the EU "bubble" determined by negotiated EU burden sharing allocation. This results in a 16 percent decline compared to the "business-as-usual" forecast for 2010, or about half the difference required of the U.S. Japan's agreement calls for a 6 percent reduction in carbon emissions. This represents an emissions level which would be 14 percent below Japan's BAU forecast for the year 2010.

D. The EU Bubble

Estimates of country specific reductions within the European Union are based on agreements reached by the EU Council of Ministers in Brussels in March 1997. The commitments of European member states at that time added up to a 10 percent reduction from the 1990 base year level by 2010. The country specific targets associated with this reduction range from a 30 percent reduction for Luxembourg on up to a 40 percent increase for Portugal. These targets are shown in the second column of Table IV-1.

It is assumed that country specific commitments under the Kyoto Protocol will closely follow those agreed to earlier in the year in Brussels. Therefore, in order to match the slightly smaller 8 percent reduction the EU agreed to in Kyoto, the country specific commitments under the Brussels agreement are proportionately scaled back as shown in the third column of Table IV-1. For example, under the March 1997 Brussels commitments, Sweden is allowed to increase its emissions by 5 percent between 1990 and 2010. Under the Kyoto commitments for the EU, Sweden's allowance is assumed to increase slightly to 6.7 percent. Similarly, Austria's early commitment was to a 25 percent reduction in carbon emissions by the year 2010 compared to 1990 levels. The Kyoto Protocol would allow a smaller reduction of 23.8 percent. These and other country estimates are shown in Table IV-1.

E. Kyoto Targets v. Forecasted Growth and Historical Experience

Measurements of the difference between European government forecasts of carbon emissions in the year 2010 and the changes required to meet the commit-

Table IV-1
Calculation of EU Country Changes Required to Reach 8% Reduction Target

Country	Required % Change from 1990 Baseline by 2010: 10% Bubble	Required % Change from 1990 Baseline by 2010: 8% Bubble	% Reduction from 2010 BAU Baseline with 8% Bubble
Austria	-25%	-23.8%	-33.3%
Belgium	-10%	-8.6%	-8.6%
Denmark	-25%	-23.8%	-31.9%
Finland	0%	1.6%	-28.9%
France	0%	1.6%	-4.9%
Germany	-25%	-23.8%	-23.4%
Greece	30%	32.1%	6.8%
Ireland	15%	16.8%	-1.7%
Italy	-7%	-5.5%	-17.6%
Luxembourg	-30%	-28.9%	-13.4%
Netherlands	-10%	-8.6%	-14.9%
Portugal	40%	42.2%	-10.7%
Spain	17%	18.8%	-1.5%
Sweden	5%	6.7%	-44.3%
United Kingdom	-10%	-8.6%	-13.4%
European Union	-10%	-8.0%	-16.3%

Source: Calculated from EU Council of Ministers Environment, "EU Conclusions on Climate Change," Brussels, 3 March 1997.

include 44 million metric tons of emissions from half of a small miscellaneous combustibles category.

ments made in Kyoto are shown in the last column of Table IV-1 and are plotted in Figure IV-2 along with the changes required of other OECD countries. The U.S. is shown to require one of the most pronounced reductions in emissions—31 percent. However, Sweden, Austria, and Denmark, are estimated to require even greater efforts. The large change required of Sweden is somewhat surprising given the fact that it is among only a few European Union countries allowed to increase their emissions. But projections for Sweden are highly dependent on decisions regarding the decommissioning of nuclear power plants. Nonetheless, the difference between the targeted increase and the IEA's projected emissions growth for Sweden is great—more than 44 percent. In the case of Austria and Denmark, the large change required reflects especially ambitious emission reduction targets.

Other measures of the relative change in carbon emissions required of OECD countries are illustrated in Figure IV-3. This figure compares carbon emission levels among major OECD countries in the base year 1990 with forecasted levels for the year 2010 and the Kyoto targets for the same year. The U.S. is shown to account for 1,377 million metric tons of carbon emissions in the year 1990, or nearly half of the OECD's total of 2,815 million metric tons. Much of the forecasted growth to the year 2010 is expected to occur in the U.S. Between 1990 and 2010 government forecasts call for OECD carbon emissions to increase by 656 million metric tons to 3,471 million metric tons in 2010 with the U.S. share reaching 53 percent. The promises made in Kyoto would bring this total down by 847 million metric tons or 24 percent to 2,624 million metric tons, with most of the reduction (67% or 566 million metric tons) required of the U.S.

Figure IV-2:
Change from Projected Levels of Carbon Emissions Required to Meet Kyoto Targets in 2010

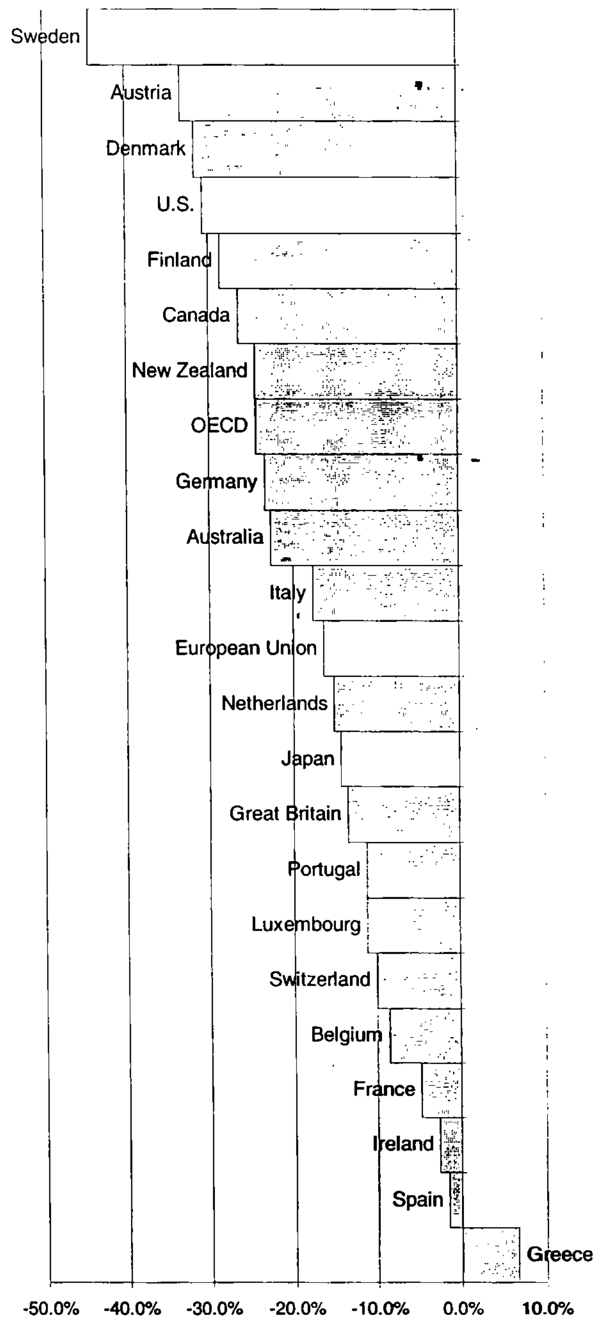
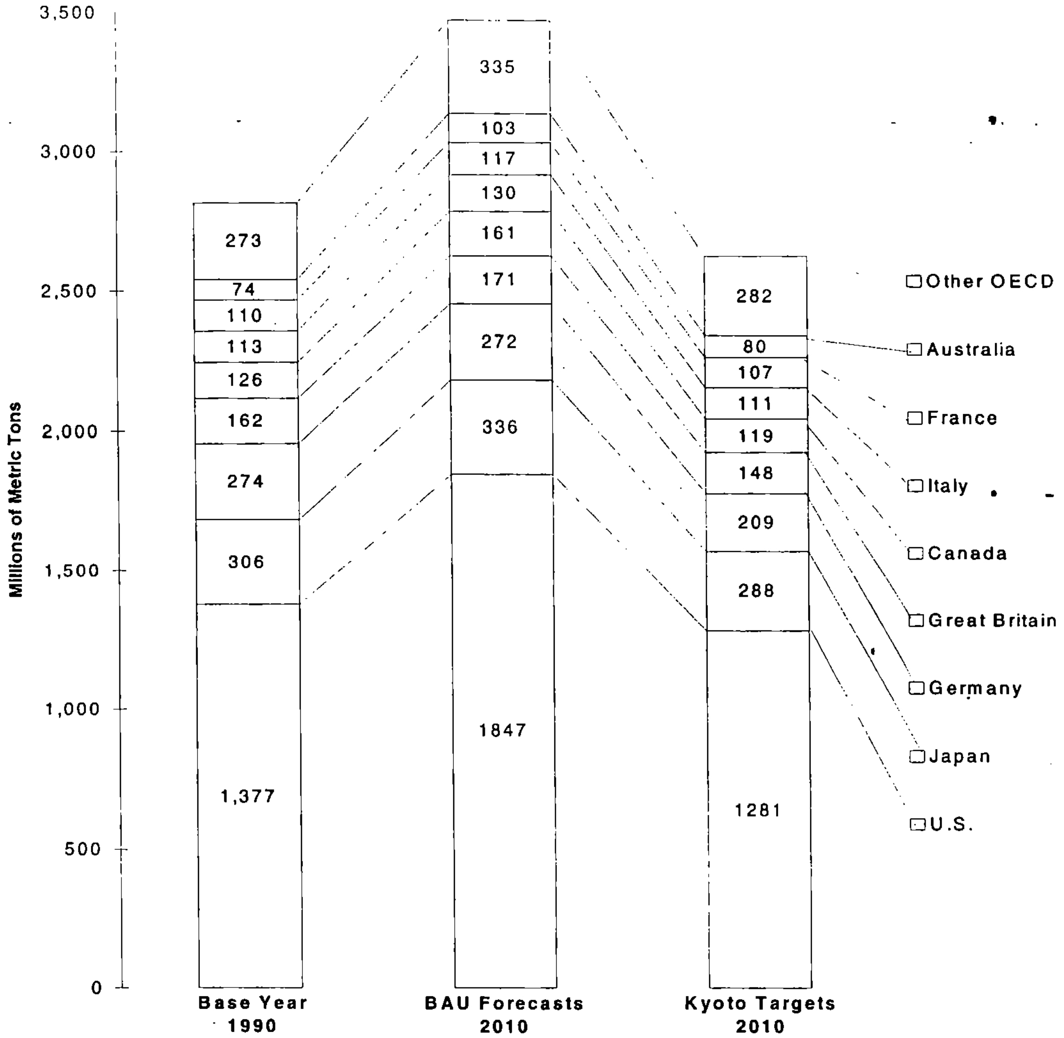


Figure IV-3
OECD Carbon Emissions



U.S. carbon emissions are projected to grow at a faster rate than most of Europe, especially major OECD partners, hence the U.S. carbon emission reduction target is larger and more difficult to meet. This is illustrated in Table IV-2. This table compares the average annual percentage change in carbon emissions required by the Kyoto Protocol during the ten-year period 2001-2010 with changes in carbon emissions over three historical periods (1961-1973, 1974-1986, and 1987-1995) and two forecasted periods (1996-2000 and 2001-2010). For all but a few countries, the reductions required by the Kyoto Protocol, shown in the last column of the table, are not only significantly greater than those for the same "business-as-usual" forecasted period, but are also notably larger than the declines which occurred during the energy crisis years of 1974-1986.

The underlying factors affecting these historical and projected differences in carbon emissions are explored in Chapter V below.

Table IV-2
Average Annual Percent Change in Carbon Emissions

	Historical			Forecasts		Kyoto
Country	1961-1973	1974-1986	1987-1995	1996-2000	2001-2010	2001-2010
United States	4.0%	0.0%	1.4%	1.9%	1.3%	-2.3%
Austria	4.7%	0.3%	0.8%	2.1%	0.3%	-3.7%
Belgium	4.3%	-1.9%	1.2%	-1.0%	-0.3%	-1.2%
Denmark	5.5%	0.7%	0.4%	1.2%	-0.8%	-4.5%
Finland	6.5%	0.6%	0.9%	5.0%	1.0%	-2.3%
France	5.2%	-1.7%	0.3%	1.2%	0.1%	-0.4%
Germany	6.4%	-0.2%	-1.6%	1.5%	0.2%	-2.4%
Greece	13.0%	3.3%	3.5%	1.2%	0.9%	1.6%
Ireland	4.3%	2.3%	1.9%	1.3%	0.6%	0.3%
Italy	9.5%	0.3%	1.7%	1.1%	0.5%	-1.5%
Luxembourg	1.4%	-3.2%	-0.3%	-1.4%	0.0%	-1.2%
Netherlands	6.8%	0.3%	1.5%	-1.1%	0.5%	-1.1%
Portugal	7.1%	4.8%	5.6%	0.7%	2.7%	1.5%
Spain	8.4%	2.3%	3.3%	-2.2%	1.4%	1.3%
Sweden	5.0%	-1.6%	-0.1%	1.3%	5.0%	-1.0%
United Kingdom	1.3%	-1.0%	-0.2%	1.3%	0.2%	-1.2%
European Union	5.0%	-0.4%	0.2%	0.9%	0.5%	-1.3%
Australia	4.4%	2.0%	2.6%	2.7%	1.3%	-1.3%
Canada	5.3%	0.7%	1.8%	0.9%	1.2%	-1.9%
Japan	10.4%	-0.1%	3.0%	-0.5%	0.2%	-1.4%
Switzerland	7.3%	0.0%	0.0%	0.0%	0.5%	-0.5%
New Zealand	NA	NA	2.0%	2.2%	1.7%	-1.1%
OECD*	4.8%	0.1%	1.2%	1.3%	1.0%	-1.8%

* Excludes Iceland and Norway because comparable governmental energy and emissions projections were not available. Also excludes Turkey because it has no emission limitation specified in the Kyoto Protocol.

NA = not available

Sources: Historical data calculated from IEA/OECD *Energy Balances of OECD Countries* using IPCC suggested methodology. U.S. projections derived from the U.S. Energy Information Administration *Annual Energy Outlook 1998*; EU country projections from the EU Directorate General for Energy (DG XVII) *Energy in Europe—European Energy to 2020: Scenario Approach*, and the projections for other OECD countries from *Energy Policies of IEA Countries-1997 Review*, published by the International Energy Agency/OECD.

V. Measures of the OECD Level of Effort Required to Meet Kyoto's Targets

A. Kaya Identity Factors Affecting Carbon Emissions

The commitments made by the U.S. and other nations to meet the carbon emission reduction targets set in Kyoto is unprecedented. The Kaya Identity discussed in Chapter III provides a useful tool for measuring the effort required to meet these targets by demonstrating the implicit tradeoffs between the key factors affecting carbon emissions. These factors include the carbon content of energy (C/E), the energy intensity of economic activity (E/GDP), the per capita gross domestic product (GDP/Population), and the population. Comparing past and forecasted changes in these key factors provides a framework for measuring the level of effort that would be required to achieve the carbon emission reduction targets set in Kyoto.

Table V-1 shows the average annual percentage changes in carbon emissions and the key factors affecting these emissions in the U.S., Japan, and the European Union over different periods of time. The table follows the Kaya Identity formulation. Reading from left to right, the percentage changes in carbon emissions shown in the second column are equal to the sum of the percentage changes in each of the key factors shown in the remaining columns.[17]

1. The Early Years, 1960-1973

The top part of Table V-1 provides data on the early years, 1960-1973. During this time, U.S. carbon emissions increased at an average annual rate of 4 percent, Europe's grew by 5 percent, and Japan's averaged 10 percent. These increases were fueled largely by growth in per capita gross domestic product, and to a lesser extent by population growth

Table V-1
Kaya Identity Factors Affecting Carbon Emissions
(average annual percentage changes)

Period of Years for Country/ Region	Carbon =	Carbon/ Energy +	Energy/ GDP +	GDP/ Capita +	Population
The Early Years: 1960-1973					
United States	4.0	-0.2	0.3	2.7	1.2
European Union	5.0	-0.9	1.1	4.0	0.7
Japan	10.4	-0.6	1.3	8.4	1.2
The Oil Crisis Years: 1974-1986					
United States	0.0	-0.2	-2.1	1.3	1.0
European Union	-0.4	-1.1	-1.4	1.8	0.3
Japan	-0.1	-1.1	-2.3	2.5	0.9
Recent History: 1987-1995					
United States	1.4	-0.4	-0.4	1.3	1.0
European Union	0.2	-0.8	-1.1	1.8	0.4
Japan	3.0	-0.6	0.6	2.6	0.4
Business-as-Usual Forecasts: 2001-2010					
United States	1.3	0.1	-0.9	1.3	0.8
European Union	0.5	-0.2	-1.5	2.1	0.1
Japan	0.2	-1.1	-1.3	2.4	0.2

Sources: See Appendix B, Table B-1 for a complete list of sources and for other OECD country results.

[17] As discussed in Chapter III, the Kaya Identity expresses a multiplicative relationship among the Kaya Identity components. However, unless the change in individual components is large, the average annual change in carbon emissions will be very

and growth in the amount of energy used per dollar of gross domestic product. The modest declines in the carbon content of energy during this time were swamped by the growth in these other factors.

2. The Oil Crisis Years, 1974-1986

The reductions in carbon emissions during the oil crisis years of 1974-1986 are shown in the second section of Table V-1. Europe's emissions declined at an average annual rate of 0.4 percent. Japan's fell by 0.1 percent annually and in the U.S. carbon emissions remained flat over the period.

Comparing the oil crisis years with the earlier years shows reductions in the rate of growth of per capita gross domestic product to be the single most important factor affecting the decline in carbon emissions between the two periods. In the U.S. and Europe, growth in the GDP per capita was cut in half. In Japan it was two-thirds less than it had been. Since population growth declined slightly between these two periods, the sharp decline in the GDP/capita was due to declining growth in gross domestic product.

The second most important contributing factor to the declines in carbon emissions during the oil crisis years was the changes in the amount of energy used per dollar of GDP. In Japan, the E/GDP ratio changed from an average annual growth rate of 1.3 percent during the early years of 1960-1973 to a 2.3 percent annual decline during 1974-1986. Similarly, in Europe the E/GDP ratio changed from +1.1 percent per year to -1.4 percent. For the U.S., the ratio fell from +0.3 percent to -2.1 percent.

3. Recent History, 1987-1995

In recent years, 1987-1995, growth in carbon emissions has averaged 1.4 percent per year in the U.S., 0.2 percent in Europe, and 3.0 percent in Japan. These rates are significantly higher than those experienced during the oil crisis years, but far below those recorded during the early years before the crisis. The recent growth in carbon emissions has been partly a function of the growth in gross domestic product. For the U.S., the growth in population also has made a significant difference, with the U.S. population growth rate two and a half times that of the EU and Japan. For Japan, growth in the amount of energy used per dollar of GDP is a major contributing factor. Growth in per capita GDP has been the same in recent years for the U.S. and Europe as it was during the oil crisis years, and has been nearly the same for Japan, but substantially below the early years for all three. While the amount of energy used per dollar of GDP continues to decline in the U.S. and Europe, it is declining at a slower pace than during the oil crisis years.

4. Business-as-Usual Forecasts, 2001-2010

As noted above, the EIA forecasts carbon emissions in the U.S. will increase at an average annual rate of 1.3 percent during the years 2001-2010. This increase is fueled by forecasts of population growth of 0.8 percent annually and GDP growth of 1.3 percent annually. The carbon to energy ratio also increases, but by just 0.1 percent annually. This is due primarily to the retirement of nuclear plants. The amount of energy used per dollar of GDP is forecast to fall at the rate of 0.9 percent yearly. In some respects, this appears optimistic because the reduction is twice that which occurred over 1987-1995.

The European Union forecasts[18] its emissions will increase by 0.5 percent annually with GDP/capita growing at the rate of 2.1 percent annually and population increasing by just 0.1 percent yearly. Interestingly, the EU forecasts declines in its E/GDP ratio of 1.5 percent. This is slightly greater than the 1.4 percent average annual decline experienced during the oil crisis years when energy prices skyrocketed. In contrast, forecasts for the U.S. and Japan show their E/GDP ratios declining about half as rapidly as during the oil crisis years.

In the IEA BAU forecast, Japan's carbon emissions will increase by just 0.2 percent annually. Unlike Europe and the U.S., Japan's carbon to energy ratio is expected to decline at the comparatively rapid pace of 1.1 percent annually. This is due to Japan's expectation of rapid expansion of nuclear power. This forecasted rapid decline in its C/E ratio, combined with expected declines in its energy to GDP ratio, offset increases in Japan's per capita gross domestic product which is expected to grow at an average annual rate of 2.4 percent, or nearly twice as fast as the U.S.

closely approximated by the sum of the average annual change of the Kaya Identity components.

[18] See Appendix A for a discussion of alternative forecasts.

B. Changing the Kaya Identity Factors Affecting Carbon Emissions

Given that negotiations on the Kyoto Protocol were completed in December 1997, that it may be several years or more before the protocol becomes legally binding, if ever ratified, and that new policies would require actions by national legislatures, this analysis assumes that carbon emissions will essentially follow projections until the year 2000. Hence, the Kyoto Protocol would require significant reductions in carbon emissions over the period from 2001-2010.

The U.S. would be required to reduce emissions at the rate of 2.3 percent annually, compared to the "business-as-usual" forecasted growth of 1.3 percent. Europe would need to reduce its emissions 1.3 percent yearly, instead of growing at the forecasted rate of 0.5 percent. Japan would be required to lower its emissions by 1.4 percent annually, in contrast to the 0.2 percent annual rate forecasted. The only way to reach these targeted levels is for one or more of the key factors affecting carbon emissions, identified by the Kaya Identity, to be changed so that significant reductions can occur. Numerous combinations are possible, but by holding all of the factors constant, except one, the magnitude of the effort required is put into perspective.

The changes from projected levels in each of the key factors affecting future carbon emissions are shown in Table V-2. The second column in each of the four sections of this table shows the carbon emission reduction growth rates required of the U.S., Europe, and Japan in order to meet the Kyoto emission reduction targets over the period 2001-2010.

1. Changes in the Carbon Content of Energy Only

In the first section of Table V-2, the average annual change in energy used per dollar of GDP, per capita GDP and population growth rates are held constant at their business-as-usual-forecasted rates. Under this first scenario, the only way to meet the emissions reduction targets is for the carbon content of energy to decline at dramatic and unprecedented rates. The U.S. would be required to reduce its C/E ratio at an average annual rate of 3.5 percent. Europe would need to reduce its by 2.0 annually, and Japan's annual rate of decline would need to be 2.6 percent. (A glance back at the carbon/energy ratios recorded in Table V-1 shows the rates of decline needed to meet Kyoto's targets are far beyond historical experience or forecasted expectations.)

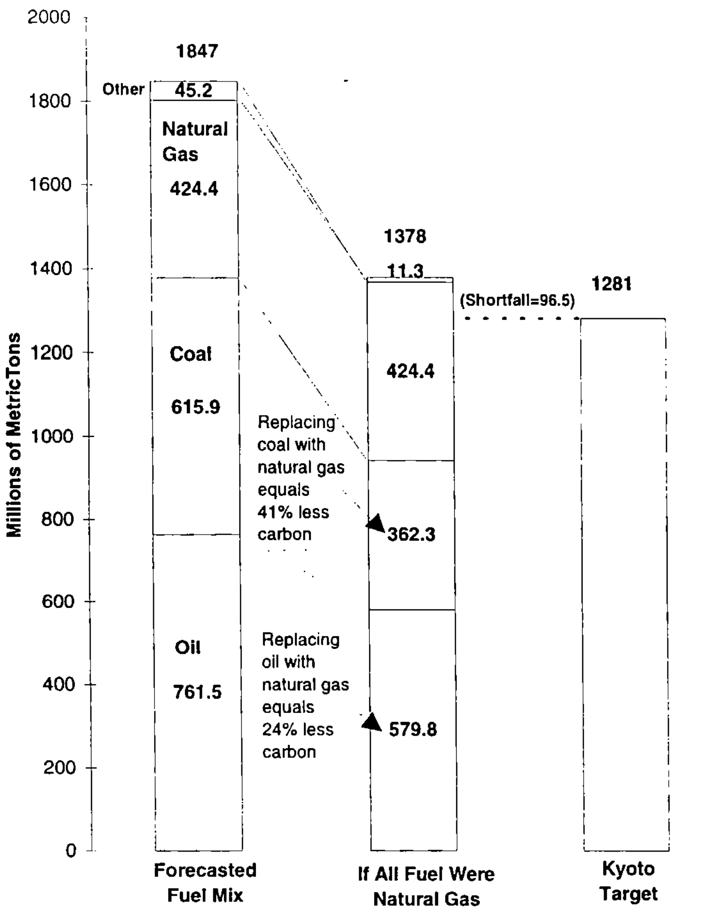
It is difficult to fully appreciate the degree of change in the fuel mix which would be required to bring about such declines in the C/E ratios. Figure V-1 gives some idea of the magnitude of the effort for the U.S. The left bar shows the source of carbon

Table V-2
Changes in Kaya Identity Factors Affecting Carbon Emissions Over the Period 2001-2010
(average annual percentage changes)

Changes in One Factor Only by Country/ Region	Carbon =	Carbon/ Energy +	Energy/ GDP +	GDP/ Capita	Population
Changes in Carbon/Energy Only					
United States	-2.3	-3.5	-0.9	1.3	0.8
European Union	-1.3	-2.0	-1.5	2.1	0.1
Japan	-1.4	-2.6	-1.3	2.4	0.2
Changes in Energy/GDP Only					
United States	-2.3	0.1	-4.5	1.3	0.8
European Union	-1.3	-0.2	-3.3	2.1	0.1
Japan	-1.4	-1.1	-2.8	2.4	0.2
Changes in GDP/Capita Only					
United States	-2.3	0.1	-0.9	-2.4	0.8
European Union	-1.3	-0.2	-1.5	0.4	0.1
Japan	-1.4	-1.1	-1.3	0.8	0.2
Changes in the Population Only					
United States	-2.3	0.1	-0.9	1.3	-2.8
European Union	-1.3	-0.2	-1.5	2.1	-1.7
Japan	-1.4	-1.1	-1.3	2.4	-1.4

Sources: See Appendix B, Table B-1 for a complete list of sources and for other OECD country results.

Figure V-1
Meeting the U.S. Carbon Emissions Kyoto Target: Theoretical Impact of Substituting Natural Gas for All Forecasted Coal, Oil, and Combustible Energy Use by 2010



emissions by fuel type under the Energy Information Administration's "business-as-usual" (reference case) forecast. Carbon emissions from coal, for example, are projected to amount to 615.9 million metric tons in the year 2010. Coal contains approximately 70 percent more carbon per unit of energy than natural gas. If the U.S. substituted natural gas for all forecasted coal use then the amount of carbon emitted would be reduced to 362.3 million metric tons. (This is shown in the middle bar of Figure V-1.) Similarly, oil contains approximately 31 percent more carbon per unit of energy than natural gas. If natural gas replaced all projected oil use shown in the first bar of Figure V-1 (761.5 million metric tons), then emissions would fall to 579.8 million metric tons.

These are unrealistic assumptions to say the least. Even so, the cumulative impact of these substitutions falls short of the Kyoto emissions target of 1,281 million metric tons. More specifically, the middle bar shows that if we could theoretically switch away from *all* of the forecasted use of higher carbon content coal, oil and other combustibles and substitute these fuels with the lower carbon content natural gas by the year 2010, emissions would reach 1,378 million metric tons by the year 2010, or 96 million metric tons more than the Kyoto target shown in the right bar.

Moreover, this comparison does not address the practical question, where would all the natural gas come from? In reality and in all probability, the carbon to energy ratio for a nation can be changed only slowly and at substantial expense.

2. Changes in the Amount of Energy Used Per Dollar of Gross Domestic Product Only

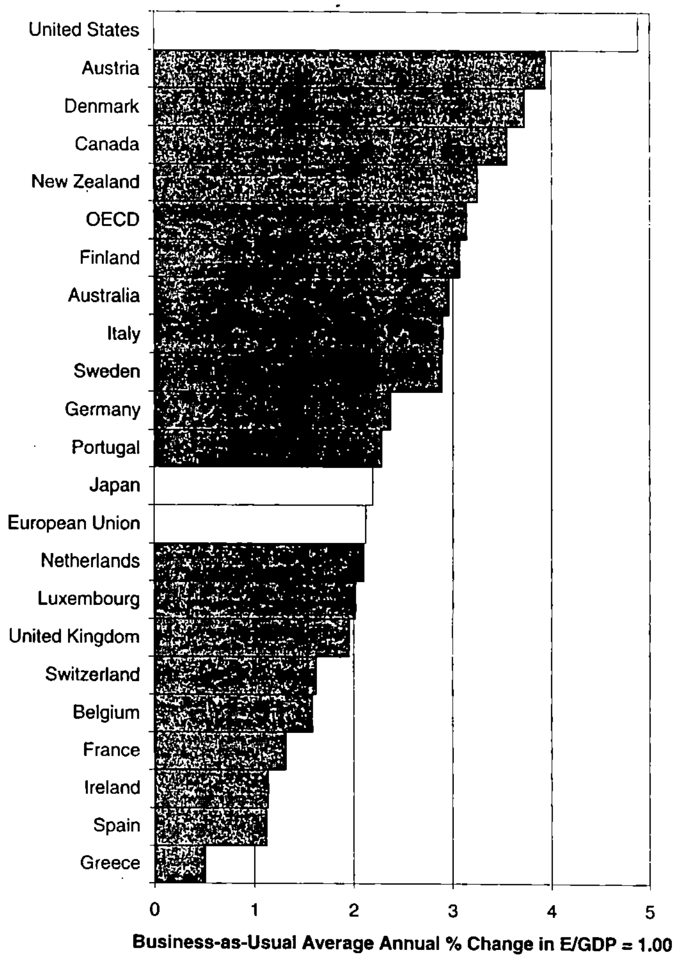
Technological breakthroughs and efficiency improvements can help reduce the amount of energy used per dollar of gross domestic product in the future. This analysis uses the Kaya Identity to measure just how much the E/GDP ratio would have to change to meet the Kyoto targets, without sacrificing economic or population growth and assuming changes in the C/E ratio would not deviate from government forecasts.

The results are highlighted in the second section of Table V-2. The rate of decline in the U.S. necessary to achieve the Kyoto emission reduction target is 4.5 percent annually. This is five times greater than the rate of decline forecast by EIA, and more than twice as great as the decline which occurred during the oil crisis years. Europe's E/GDP ratio would need to decline at an average annual rate of 3.3 percent. This represents a rate twice as great as forecasted or experienced during the oil crisis years. For Japan, the effort is similar to Europe's. Japan would need to reduce its E/GDP ratio by 2.8 percent annually to meet its target.

The reductions in energy per dollar of GDP required of the U.S., Japan, Europe and other OECD countries to meet their Kyoto targets are illustrated in Figure V-2. The changes required of each country are indexed to their "business-as-usual" forecasts. So, for example, the U.S., with a rate of decline in its E/GDP ratio five times greater than the EIA's fore-

Figure V-2
Relative Change in E/GDP Required to Meet Kyoto Targets*

$$\left[\frac{\text{Change in E / GDP Required to Meet Kyoto Targets}}{\text{Baseline Forecast Changes in E / GDP}}\right]$$



* This index is calculated by dividing the average annual percent growth in the energy to gross domestic product ratio that would be required of each country or region in order for them to meet their Kyoto targets by the average annual percent business-as-usual growth forecasted by governments. See Appendix B for individual country growth rates.

cast, leads the group of countries illustrated in terms of the level of effort required. Greece is at the opposite end, requiring half as much more effort as in its BAU forecast. Under the EU bubble arrangement, Greece's carbon emission are allowed to grow in the future, and at a comparatively rapid pace. See Table IV-1 above.

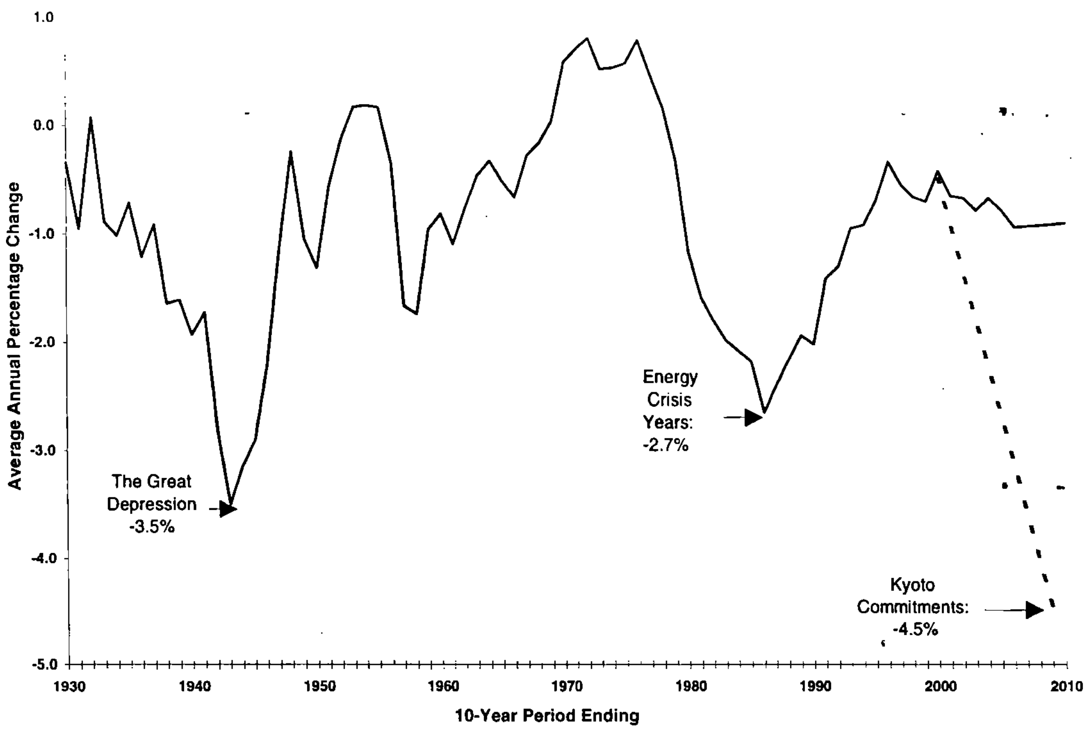
Another way to put these changes into perspective is to view them over the long term. For example, its useful to ask if the U.S. ever achieved such a reduction in its E/GDP ratio. Throughout this century, the closest America came to such declines was during the Great Depression. This is illustrated in Figure V-3. This chart plots the average annual percentage change in the U.S. E/GDP ratio over ten-year periods from 1920 through 2010. It shows that over the ten-year period ending in 1943, the E/GDP ratio declined at a rate of 3.5 percent annually. The next really sharp decline did not occur again until the energy crisis years. Over the ten-year period ending in 1986, the E/GDP ratio fell 2.7 percent annually. The EIA forecasts a decline in the E/GDP ratio of 0.9 percent annually over the period from 2001-2010, a rate of reduction that already is more than twice as fast as actually occurred over 1987-1995. The distance from this forecast to the annual 4.5 percent decline required to reach the targeted emission reduction by 2010 is much greater than anything previously experienced.

3. Changes in the Per Capita Gross Domestic Product Only

If reductions in energy intensity are no greater than governments forecast, and the mix of fuels and population growth does not differ from expectations, then the economy must pay the full costs of emission reductions in order to achieve the Kyoto targets. The third section of Table V-2 shows the consequences on the economy of holding the other Kaya Identity variables constant. The largest change is for the U.S. Per capita GDP would need to decline at an average annual rate of 2.4 percent over the period 2001-2010 in order for the U.S. to meet the emission reduction target set in Kyoto. This is in sharp contrast to the forecast BAU growth of 1.3 percent annually during this period. The results for Europe show its growth in GDP per capita would be required to slow to 0.4 percent annually from a forecast growth rate of 2.1 percent. In Japan the per capita GDP growth rate would fall from 2.4 percent to 0.8 percent annually.

Such changes in growth rates would result in profound reductions in gross domestic product compared to "business-as-usual" forecasts. The forecast $8.4 trillion (1990 $) U.S. economy in 2010 would be reduced by 31 percent to $5.8 trillion. Europe's GDP would fall from $10.4 trillion to $8.7 trillion, or by

Figure V-3
U.S. Energy Use per Dollar of Gross Domestic Product
(measured in 10-year average annual percentage changes)



about 16 percent, and Japan's would fall by 14 percent to $4.1 trillion.

These stunning reductions are difficult to comprehend. What would a 31 percent loss of GDP represent? One way to illustrate the loss for the U.S., for example, is in terms of consumer expenditures. Americans spend about 31 percent of their income on housing, another 14 percent goes to food and 17 percent is spent on transportation. Having 31 percent less GDP is like eliminating all housing, or all food and transportation. While this example is clearly hypothetical, it does serve to underscore the fact that clearly if economic activity was reduced the full amount necessary to reach the Kyoto targets, with all other Kaya variables fixed at their forecasted levels, then the consequences for consumers would be profoundly adverse.

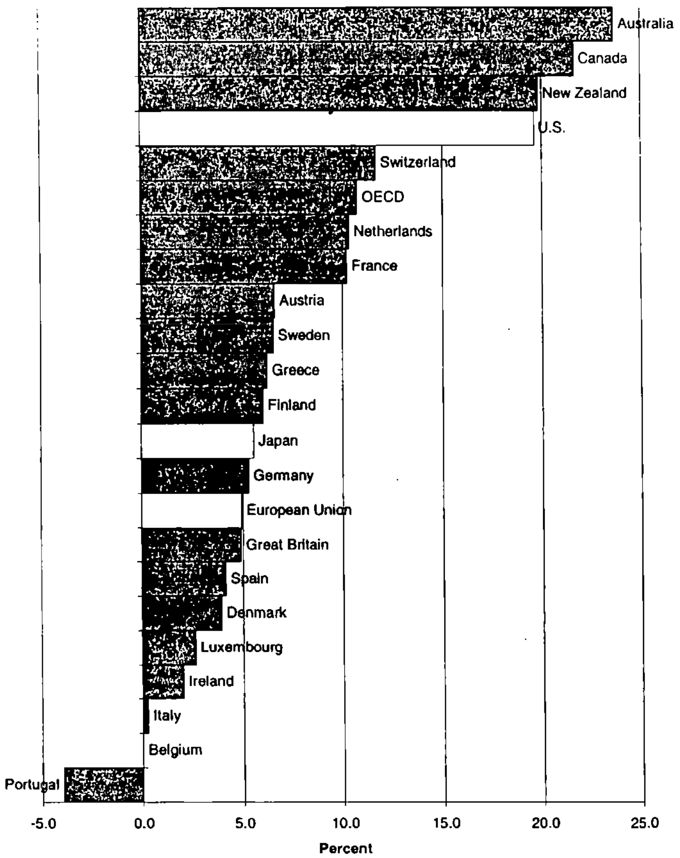
4. Changing the Population Only

Barring an enormous catastrophe, it is unrealistic to assume the burden of meeting carbon emission reduction targets could be borne *entirely* by reducing the population. In reality, short of draconian new policies to limit immigration and lower birth rates, it is unrealistic to assume *any* of the effort required to reach the Kyoto target would come through reduced population growth.

Nonetheless, its instructive to measure what would be involved in meeting the Kyoto targets if government forecasts of other Kaya Identity variables are held constant. The reductions in population needed are highlighted at the bottom of Table V-2. Instead of growing at an average annual rate of 0.8 percent during the period 2001-2010, the population of the U.S. would be forced to decline by 2.8 percent a year. Similarly, Europe's population would be required to decline by 1.7 percent annually compared to forecasted annual growth of 0.1 percent. Japan's population would need to fall by 1.4 percent yearly instead of the 0.2 percent growth forecasted. For the U.S., these rates of decline would result in a population 30 percent smaller than forecasted for the year 2010. Europe's would be 15 percent less and Japan's 13 percent smaller.

These results are an extreme example. Under the Kaya Identity formulation, the population variable is the least likely to change from forecasted expectations. However, the results are useful only in as much as they provide one more measure of the enormous challenge presented by the Kyoto targets.

Figure V-4
Projected Percentage Change in Populations Between 1990 and 2010



This is especially true for the U.S., whose population is expected to grow at a rapid rate compared with Europe and Japan and most of its other OECD partners. Between 1990 and 2010, the U.S. population is forecasted to increase by 20 percent from 250 million to 299 million, or by about 49 million people. According to the U.S. Census Bureau, if children of recent immigrants are included, then immigration accounts for about half of the forecasted growth.[19] Over the same period, the population of Europe is expected to grow from 365 million to 383 million, or by nearly 5 percent. Figure V-4 provides a comparison of the percentage changes in population forecasted for the U.S. and other OECD countries over the period from 1990 through 2010. Three countries—Australia, Canada, and New Zealand—forecast increases slightly above the U.S.'s. All the others are notably smaller.

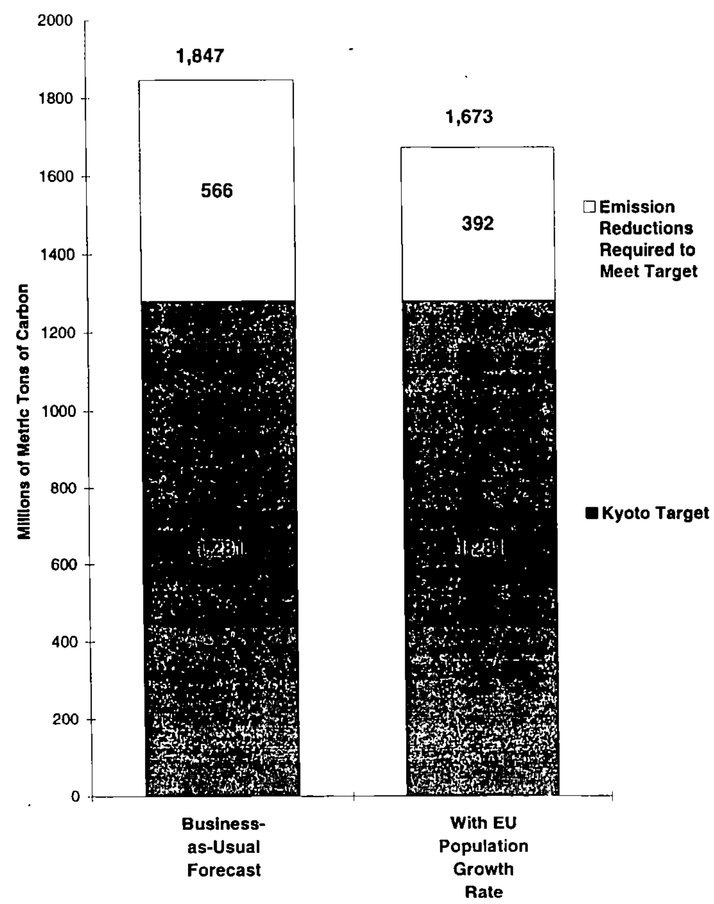
These changes are important because they fuel much of the forecasted growth in carbon emissions. This can be readily demonstrated with the Kaya Identity formulation. Table V-3 illustrates the impact of population growth rates on forecasts of carbon emissions by showing what would happen to U.S. emissions if our population growth rates were the same as Europe's. Instead of increasing at an average annual rate of 1.3 percent as forecasted for the period 2001-2010, U.S. emissions would be expected to grow at the same rate as Europe's—0.5 percent annually.

Figure V-5 illustrates how this affects the carbon emission reductions required of the U.S. Under a business-as-usual forecast, U.S. emissions are expected to reach 1,847 million metric tons by 2010. Under this forecast, emissions must fall 566 million metric tons in order to meet the Kyoto target level of 1,281 million metric tons. If U.S. population were to grow at the same pace as Europe's—0.1 percent annually, instead of at the business-as-usual forecasted rate of 0.8 percent, then U.S. emissions would reach 1,673 million metric tons by the year 2010 and the reduction required to meet the Kyoto target would fall by nearly one-third to 392 million metric tons.

Hence, if the U.S. had a slower pace of population growth, its emissions targets would be much easier to meet. However, with few exceptions, U.S. rates of population growth are significantly higher than other OECD countries. And this population growth fuels much of the expected carbon emissions growth in the future.

[19] William Branigin, "Immigration Policy Dispute Rocks Sierra Club, *Washington Post*, March 7, 1998.

Figure V-5
U.S. Carbon Emissions in 2010:
The Impact of Population Growth Rates



In sum, numerous combinations of changes in the Kaya Identity factors are possible and probable in the future. The foregoing examined each factor in turn, while the next chapter addresses simultaneous changes in each Kaya Identity component.

Table V-3
The Impact of Population on the Growth of U.S. Carbon Emissions
(average annual percentage changes)

Scenarios	Carbon =	Carbon/ Energy +	Energy/ GDP	+	GDP/Capital	+	Population
Business-as-Usual	1.3	0.1	-0.9		1.3		0.8
With EU's Population Growth Rate	0.5	0.1	-0.9		1.3		0.1

VI. The Kyoto Target versus the Maximum Historic Efforts

A. Overview

One of the difficulties in evaluating public policy is reflected in the dictum: *you never do only one thing.* With respect to the just completed Kaya Identity analysis, one may ask, how realistic is it to address a change in the energy/GDP ratio without a change in the carbon/energy ratio and/or the GDP/population ratio? And from a broader public policy perspective, it is difficult to envision a policy that reduces carbon emissions by causing the premature abandonment of existing capital equipment that also does not slow future economic growth, since such capital stock no longer generates a flow of income for future capital investment.

A strength of the Kaya Identity approach, however, is that it can be used to evaluate what emissions would be under specific assumptions about the various Kaya components. For example, the Kaya Identity can answer the question, what would emissions be in 2010 if the maximum past changes in each Kaya Identity component which resulted in limiting carbon emissions were somehow to reoccur *simultaneously* for the next decade? This provides another measure of the level of effort required if a country is to reach its Kyoto target through domestic emissions limitations.

It must be emphasized that the Kaya Identity does not address what policies would be necessary to force or induce the behavioral changes necessary to repeat past maximum efforts during the 2001-2010 period. While these policy questions are not addressed, it remains true that unless the Kaya components are altered as indicated below, or in an equivalent fashion, the calculated reductions in carbon emissions *will not occur.*

B. Assumptions

The following "maximum historic what-if assessment" assumes that the annual average change in each Kaya component over the 2001-2010 period, except population, is equal to the maximum carbon emission limiting change that occurred in any of the time periods during the 1960-1995 period. More specifically, the maximum historic case makes the following assumptions which are summarized in Table VI-1:

1. Carbon/Energy Ratio

Reductions in this ratio lead to lower carbon emissions. The greatest reduction in this ratio for the U.S. occurred during the 1987-1995 period while the greatest annual reduction for the EU and Japan occurred in the energy crisis years of 1974-1986. The primary contributors to these reductions were growth in nuclear power generation, reduction in petroleum's share of total energy due to then current or past high prices, and increased use of natural gas (especially in the U.S.). Except for planned large scale expansion of nuclear power in Japan, none of these events appear repeatable without major increases in energy prices. Nevertheless, this case assumes that the carbon energy ratio is reduced at its maximum historic annual rates.

2. Energy/GDP Ratio

As with the carbon/energy ratio, reductions in the energy/GDP ratio lead to reductions in carbon emissions. For the U.S., Japan and the EU, the maximum historic reductions in energy/GDP ratios occurred in the energy crisis years. It was during this period that U.S. composite, inflation adjusted, fossil fuel prices quadrupled before declining somewhat toward the end of the period. This quadrupling, plus a host of government programs aimed at improving energy efficiency, provided substantial pressure for reductions in the energy intensity of economic activity. For the U.S. and Japan, these maximum historic rates are far different than what occurred over the 1987-1995 period. Interestingly, the projected decline in EU's energy/GDP ratio is slightly greater than the maximum historic reduction. Historically, however, rapid reductions in this ratio have only occurred with sharply higher energy prices.

3. GDP/Population Ratio

Increases in this ratio increase carbon emissions, but also reflect improvements in the economic standard of living. Compared to levels over the 1960-1973 period, the projected rates of increase in per capita GDP are quite low. However, during the period of low growth in carbon emissions during the energy crisis years, the annual average increase in GDP/population in the U.S. declined by 50 percent compared to the 1960-1973 period. Large reductions also occurred in the EU and Japan. As a measure of maximum historic effort, this what-if scenario assumes that the annual change in the GDP/population ratio over 2001-2010 is 50 percent lower than the projected level for each region. For example, for the U.S. the rate of change falls from 1.3 percent per year in the baseline projection to 0.6 percent per year.

5. Population

Reductions in the rate of growth of population also lead to reductions in the rate of growth of carbon emissions. As noted earlier, the relatively high U.S. population growth rate is a major contributor to the relatively high U.S. growth rate in carbon emissions compared. While lowering immigration would lower the rate of population growth, it may be unrealistic to assume that immigration would become a part of climate policy. This assessment assumes no alteration in population growth rates between now and 2010 for the U.S., the EU or Japan.

6. Results

Table VI-1 summarizes the results of this maximum historic effort what-if scenario. The first line in each section repeats the business-as-usual projection while the second line gives the what-if assumptions as well as the resulting annual change in carbon emissions. The short third line gives the annual change in carbon emissions required to reach the Kyoto target.

The U.S. falls far short of the Kyoto target even under the maximum historic effort scenario which yields an emissions reduction of 1.0 percent/year compared to a 2.3 percent/year reduction required to reach the Kyoto target. The EU just falls short of meeting its Kyoto target under this scenario, even though growth in GDP per capita is cut in half, as in the U.S. Japan's emissions fall more rapidly than required to meet the Kyoto target under the maximum historic scenario. However, without a drastic reduction in the rate of growth in per capita GDP, Japan also would miss the Kyoto target.

Figure VI-1 gives the U.S. carbon emissions under the maximum historic effort case, as well as emissions under the business-as-usual projection and the Kyoto target case. Carbon emissions in 2010 under these three cases are:

- Business as Usual Projection
  1,847 million metric tons
- Maximum Historic Effort Case
  1,448 million metric tons
- Kyoto Target
  1,281 million metric tons.

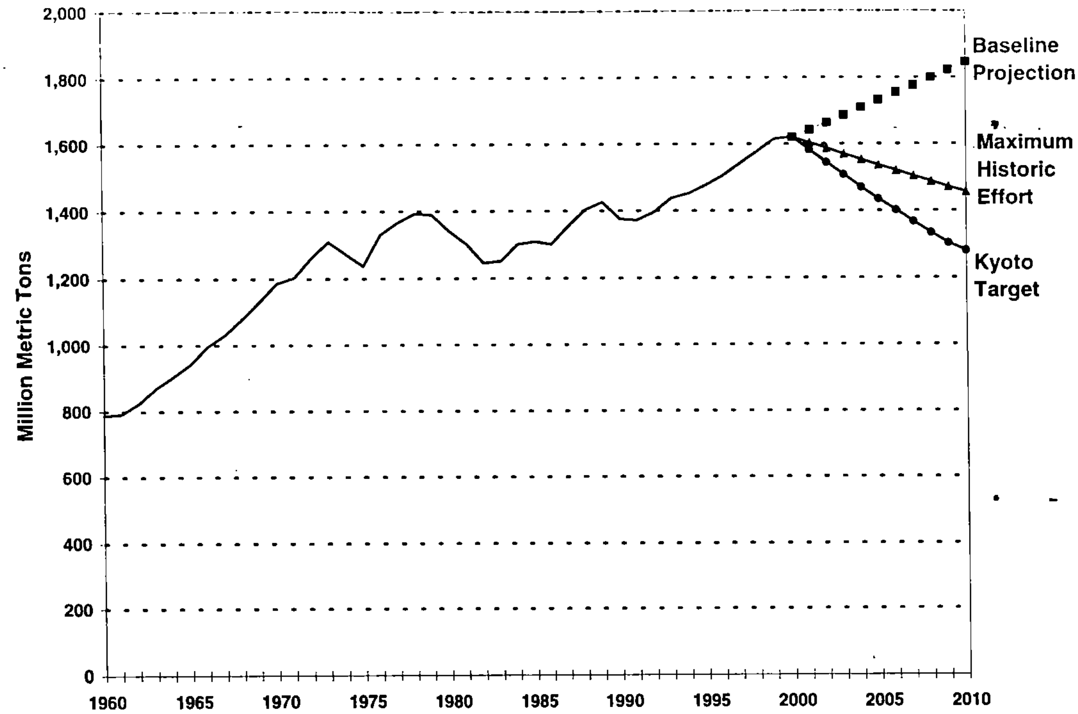
Under the maximum historic effort case, carbon emissions are limited only to 1,448 million metric tons, far short of the Kyoto target of 1,281 million metric tons. Hence, even if the maximum historic efforts that occurred over any extended period since 1960 somehow reoccurred simultaneously during the 2001-2010 period, U.S. carbon would exceed the

Table VI-1
Maximum Historic Effort Case for 2001-2010
(average annual percentage changes)

Case	Carbon	Carbon/ Energy	Energy/ GDP	GDP/ Population	Population
United States					
BAU Projection	1.3	0.1	-0.9	1.3	0.8
Max. Effort Case	-1.0	-0.4	-2.1	0.6	0.8
Kyoto Target	-2.3				
European Union					
BAU Projection	0.5	-0.2	-1.5	2.1	0.1
Max. Effort Case	-1.2	-1.1	-1.4	1.1	0.1
Kyoto Target	-1.3				
Japan					
BAU Projection	0.2	-1.1	-1.3	2.4	0.2
Max. Effort Case	-2.0	-1.1	-2.3	1.2	0.2
Kyoto Target	-1.4				

Source: Appendix B, Table B-1 for sources and for other OECD country results.

Figure VI-1
U.S. Carbon Emissions:
Projected (Business-as-Usual), Maximum Historic Effort, and the Kyoto Target



Kyoto target by 13 percent.

Clearly, reproducing the maximum historic efforts at limiting emissions is not enough to meet the Kyoto target domestically. But it also should be remembered that maximum historic efforts occurred with the economy and the energy system under severe strain. For example, in the U.S.:

- Reducing the carbon/energy ratio by 2010 as assumed would require a major alteration in what fuels are used in the U.S. And with the nuclear sector shrinking instead of expanding and the natural gas sector already deregulated and capturing a larger fuel share, the task would be even harder.

- The last time the assumed maximum historic effort reduction in the energy/GDP ratio occurred (in 1974-1986), U.S. fossil fuel energy prices quadrupled. Without a similar price increase, it would take breathtaking advances in technology plus extremely rapid diffusion into the market place to even approach the reduction in the energy/GDP ratio assumed in this case.

- The 50 percent reduction in improvements in the GDP/population ratio, that is, in GDP per capita, has only occurred once before in the last 35 years, in the 1974-1986 period. Contributing to that slowing were three recessions. In all three of these recessions, U.S. GDP per capita declined on a year to year basis. The notion of slowing economic growth to achieve climate change policy objectives has been widely rejected.

C. Conclusions

This analysis raises serious questions about the claims that the Kyoto target is "realistic." In the past, achieving the assumed maximum historic efforts required rapidly rising energy prices, an expanding nuclear power sector, deregulation of the energy sector, significant advances in technology, and a host of government efficiency programs. Even if the maximum historic effort were repeated, the U.S. would not achieve the Kyoto target. Neither would the EU, nor would Japan succeed without drastic cuts in its GDP growth. This indicates that the level of effort required to reach the Kyoto targets would be quite large.

As noted in Chapter II, the Kyoto Protocol is really the third set of national commitments to limit carbon emissions. Compared to current projections, neither the commitments made prior to 1991 nor the commitments made in 1992-1995 are likely to be met.

VII. Conclusions

The proposed Kyoto Protocol establishes limits on greenhouse gas emissions in developed countries for the 2008-2010 period, with an emphasis on carbon emissions, that are well below current projections of emissions for that period. Although the Kyoto Protocol is intended to establish legally binding limits on emissions, it may be years before the proposed protocol is ratified as an international treaty, if in fact it ever is ratified.

In this regard, it is useful to note that past aims or commitments to limit emissions have essentially not been met. First, seven of the nine mainly European countries who made early commitments in the 1987-1990 period to significantly limit carbon emissions in the 2000-2005 period appear likely to exceed their own targets by between 8 and 80 percent. The other countries—the smallest one and the one with the least aggressive target—may succeed in meeting these early emission limitation commitments.

Second, in the years surrounding the negotiation, signing and ratification of the Framework Convention on Climate Change (1992-1995), many countries made national commitments to limit their emissions to 1990 levels by 2000. The few countries that appear likely to meet their commitments each have unique explanations for that achievement, generally unrelated to climate change policy. Germany probably will meet its year 2000 aim because former East Germany was integrated into West Germany after 1990 and old energy inefficient factories and businesses were shut down. If Great Britain meets its commitment, it will be because it made a one-time change in laws to promote the use of natural gas in electric generation, thereby reducing the roles of coal, and mining unions, in the British economy. Based on recent government projections, 13 of 21 countries for which data are available, including the United States, are expected to exceed the year 2000 target by 8 percent to 30 percent. Only three or perhaps four countries, including some of the smallest countries (Luxembourg and Switzerland) might make the year 2000 target.

The proposed Kyoto Protocol establishes aggressive emissions targets and timetables that would be legally binding on countries that ratify the agreement. For the 2008-2012 period, some developed nations, like Australia and Iceland, would be allowed emissions 8 percent to 10 percent above 1990 levels. Canada and Japan have targets that are 6 percent below 1990 levels, and the U.S. target is 7 percent below 1990 levels. And while the European Union has a target that is 8 percent below 1990 levels, the EU nations operate within a "bubble" in which some countries will be allowed to increase emissions while others must have greater emission reductions.

The Kyoto Protocol includes other actions that might theoretically allow the limits on carbon emissions to be less than the targets indicated above. Theoretically is the operative word because these additional mechanisms might also lead to a greater requirement to reduce carbon emissions if a country is to meet its target. For example, the greenhouse gas emissions target covers the aggregate emissions of six gases. If some of the other gases are hard to control, or it is difficult to document their control, reductions in carbon emissions might have to be increased.

Other Kyoto Protocol mechanisms, including emissions trading among developed nations, carbon sinks, joint implementation and the Clean Development Mechanism, are as yet not defined. Hence, it is difficult to assess whether they will allow smaller reductions in domestic carbon emissions than indicated above. At this time, a conclusion that these alternative mechanisms will substantially reduce obligations to limit carbon emissions is based more on faith or hope than on hard facts.

Existing government projections of carbon emissions, based on the assumption of no new policies (alternatively called business-as-usual, baseline, or reference case projections), indicate that the OECD countries would have carbon emissions in 2010 of about 3,470 million metric tonnes carbon. This would exceed the Kyoto targets in 2010 by roughly 850 million metric tonnes carbon. Roughly two-thirds of the required emissions reductions would have to occur in the United States.

Most countries would require reductions in carbon emissions that are equivalent to about 10 percent to 20 percent of business-as-usual projected emissions in 2010. A few nations have emission reduction requirements in 2010 that are closer to that in the U.S., about 30 percent from projected levels.

For over a decade, there has been a significant debate over the ease or difficulty of reducing greenhouse gas emissions in general, and carbon emissions in particular. The Kaya Identity provides a yardstick to evaluate the level of effort required to meet the Kyoto targets. Comparing past and forecasted changes in the factors that determine carbon emissions in the U.S. and among other OECD countries with the changes needed to meet the targets set in Kyoto provides a useful framework for measuring the level of effort needed.

While the Kaya Identity clearly identifies the extent of the effort required to meet an emissions target, it does not evaluate the policies necessary to alter the Kaya Identity components. However, if the Kaya Identity components are not altered from their business-as-usual projected levels, then the Kyoto Protocol targets would not be met.

The results show the level of effort required of the U.S. and many other nations to meet the carbon emission reduction targets set in Kyoto is by any measure unprecedented. For the United States, the level of effort to meet the Kyoto targets is, in fact, dramatic. For example, during the 1974-1986 energy crisis years when U.S. inflation adjusted composite fossil fuel prices quadrupled, the U.S. reduced its energy/GDP ratio by an average of 2.1 percent per year. If the effort to achieve the Kyoto target focused *only* on the energy/GDP component of the Kaya Identity—the component that reflects improvements in energy efficiency—then the energy/GDP ratio would have to decline at 4.5 percent per year over 2001-2010. This is more than twice the rate of change of the energy crisis years, and about 5 times the rate of change in the business-as-usual projection, indicating massive required changes in how energy is used in the U.S.

If, instead, the effort to achieve the Kyoto target focused *solely* on changing the carbon content of energy, then the U.S. would be required to reduce its carbon/energy ratio at an average annual rate of 3.5 percent over 2001-2010, a rate far beyond historical experience or forecasted expectations. The degree of change in the fuel mix which would be required to bring about such declines in the carbon/energy ratio is incomprehensible. For example, even if the U.S. could theoretically substitute lower carbon content natural gas for all of the higher carbon content coal, oil and other combustibles forecasted for the year 2010, the U.S. would still fall short of its Kyoto target.

If reductions in energy intensity are no greater than governments forecast, and the mix of fuels and population growth does not differ from expectations, then under the Kaya Identity formulation, reductions in economic growth would be required to meet the Kyoto targets. For the U.S. per capita GDP would need to decline at an average annual rate of 2.4 percent over the period 2001-2010 in order to meet the target. Such growth rates would result in profound reductions in gross domestic product compared to government forecasts. For example, the forecast $8.4 trillion (1990$) U.S. economy in 2010 would be reduced by 31 percent to $5.8 trillion.

If economic growth is not to be sacrificed and the mix of fuels and energy efficiency improvements are the same as governments forecast, then under the Kaya Identity formulation, all of the effort to reduce emissions would fall on populations. Under this circumstance, what would it take to effect the changes needed to meet the Kyoto targets? For the U.S. it would mean that the population would need to be about 30 percent smaller than expected for the year 2010.

This extreme example is useful only in as much as it provides one more measure of the enormous extent of the effort required to meet Kyoto's targets. Short of draconian new policies to limit immigration and lower birth rates, it is unrealistic to assume any of the effort required to reach the Kyoto targets would come through reduced population growth. It is this population growth, however, which fuels much of the future growth in carbon emissions. Between 1990 and 2010 the U.S. population is forecasted to increase by 20 percent whereas Europe's is expected to grow only about 5 percent. This makes U.S. emission reduction targets that much more difficult to meet.

Finally, even if the maximum past efforts at limiting carbon emissions in each Kaya Identity component were somehow to reoccur simultaneously for the next decade, the U.S. would still fall far short of its Kyoto target. This scenario yields an emissions reduction of 1.0 percent per year compared to a 2.3 percent annual reduction required to reach the Kyoto target. And the EU would just fall short of achieving its target, while Japan would not succeed without drastic cuts in its GDP.

Clearly, the U.S. is not alone in terms of the level of effort required to meet the commitments made in Kyoto. Other countries, including many countries in the European Union and Asia, could have major difficulties meeting the Kyoto targets and timetables. This raises serious questions about how realistic the targets are.

Meeting the Kyoto Protocol targets clearly would require major changes in how countries use energy, and perhaps what energy is used and how fast economic growth occurs. Based on the Kaya Identity analysis, it appears highly unlikely that the Kyoto targets could be met without major new policies to limit energy use and carbon emissions, and highly likely that these policies would have significant adverse impacts on the rate of growth in per capita GDP.

Appendix A: Data Sources and Comparison of Projections

This analysis draws on original sources for historic energy, GDP and population data. Carbon emissions are calculated using IPCC suggested methodology and checked against published sources with comparable data.

The energy data for 1960 - 1995 are from the OECD's *Energy Balances of OECD Countries.* This source reports total primary energy and includes coal, crude oil and petroleum products (non-energy use is identified and excluded from this analysis), natural gas, nuclear, hydro-power, geothermal, solar, wind & other, combustible renewables and waste, and other non-specified combustion (for electricity generation or heat).

Carbon emissions from the fossil fuels for 1960 - 1995 are calculated following procedures suggested by the Intergovernmental Panel on Climate Change. For example, see Part 1 of Volume 3 of the *Greenhouse Gas Inventory Reference Manual– IPCC Draft Guidelines for National Greenhouse Gas Inventories,* 1994. To allow for the possibility that some of the carbon in the "combustible renewables and waste" category is being "recycled," that is drawn from the atmosphere and then emitted during combustion, the carbon content of these fuels is counted as only half that suggested by the IPCC. While this adjustment has no material impact on the analysis because combustible renewables are such a small part of energy supplies, it does cause calculated emissions to not be identical to some other published sources.

Historic GDP data are drawn from the OECD *National Income Accounts – Main Aggregates* as well as from the U.S. *Economic Report of the President.* Population data are drawn from the OECD *Labour Force Statistics* and the U.S. *Economic Report of the President.*

Projections for the 1996 - 2010 period are drawn from a variety of sources, each one of which contained carbon, energy, GDP and population projections. For the U.S., this analysis relied upon the U.S. Energy Information Administration's *Annual Energy Outlook 1998* reference case. For European Union countries, projections from the EU Directorate General for Energy (DG XVII) *Energy in Europe - European Energy to 2020: Scenario Approach,* were used. The projections for other OECD countries are from *Energy Policies of IEA Countries - 1997 Review,* published by the International Energy Agency/OECD. To ensure consistency across the historic data as well as the projections used in this analysis, growth rates from the projections covering the 1995-2010 period were applied to historic 1995 data.

Iceland, Norway, and Turkey are not included in the analysis because comparable governmental energy and emissions projections were not available. It should be noted that Turkey has requested that it be removed from the Annex I obligations under the Framework Convention on Climate Change and is not listed in Annex B of the Kyoto Protocol.

As noted in Chapter 2, Table II-2, of this report, there are alternative sources of projections for 2000 and 2010. For example, Appendix Table A-1 compares carbon emission projections for EU countries that are covered in both the EU's Directorate General for Energy study *Energy in Europe - European Energy to 2020: Scenario Approach,* as well as in IEA's *Energy Policies of IEA Countries – 1997 Review.* In some instances, the somewhat more recent projections from the IEA are substantially higher (see Finland, Greece and Ireland). However, Germany's emissions are lower in the IEA projection. For Great Britain, IEA emission projections are somewhat lower in 2000 but somewhat higher in 2010. However, for total emissions for countries covered for all years in both sets or projections, there is little difference across the two sets of projections.

Table A-1
Comparison of EU and IEA Carbon Emission Projections
(in million metric tons of CO_2)

	EU Projections			IEA Projections		
	1990	2000	2010	1990	2000	2010
Austria	56	62	64	59.4	61.4	66.1
Belgium	111	114	111	109.3	114.2	122.5
Denmark	52	63	58	53.3	53.4	45.2
Finland	52	67	74	53.7	80.4	99.0
France	368	391	393	378.0	415.9	404.6
Germany	978	954	972	982.3	908.6	893.6
Greece	72	81	89	72.5	90.3	136.4
Ireland	30	34	36	33.2	38.4	45.2
Italy	402	439	461	409.3	448.3	NA
Luxembourg	12	8	8	10.9	7.9	7.8
Netherlands	157	161	169	161.5	159.3	165.4
Portugal	40	49	64	41.6	54.0	66.2
Spain	208	218	251	215.9	269.0	NA
Sweden	50	59	96	52.8	55.0	NA
United Kingdom	579	599	611	584.1	562.9	623.5
EU Total	3,166	3,298	3,457	3,217.8	3,319.0	NA
Comparable Country Total			2,649			2,675.5

Sources: EU projections are from Directorate General for Energy (DG XVII) *Energy in Europe - European Energy to 2020: Scenario Approach.* IEA projections are from *Energy Policies of IEA Countries - 1997 Review*, published by the International Energy Agency/OECD.

Appendix B: Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

Table B-1 shows the average annual percent changes in carbon emissions and the Kaya Identity factors affecting these emissions for each of the OECD countries (excluding Iceland, Norway, and Turkey), and the average for the 15-member nations of the European Union and the 21-member average for the OECD countries. The percent changes in carbon emissions shown in the bottom row are equal to the sum of the percent changes in each of the Kaya Identity factors shown in the rows above the last one.[20] Table B-1 compares the past annual average changes in carbon emissions and the Kaya Identity factors affecting these emissions over the 1960-1995 period with government business-as-usual (BAU) forecasts of changes in these factors, as well as measures of the degree of change required if the Kyoto targets are to be met by 2010.

The historic time periods shown in the first few columns of the Table B-1 were selected to highlight the "energy crisis" years of 1974-1986. This period was identified in part by very large increases in energy prices. For example, Austria's carbon to energy ratio declined at an average annual rate of 0.6 percent during 1974-1986. Its energy to GDP ratio fell at an annual rate of 1.2 percent. Per capita GDP grew by 2.2 percent annually, or just half the rate of growth of the previous period, 1961-1973. Population growth also fell slightly from 0.6 percent in the earlier period to a flat average annual rate during the energy crisis years.

Government business-as-usual forecasts for the period 2001-2010 are shown in the sixth column of Table B-1. Austria projects its carbon to energy ratio will decline at an average annual rate of 0.5 percent and that the amount of energy used per dollar of GDP will decline by 1.3 percent annually. Its per capita GDP is projected to increase by 2.0 percent annually, while population expands at the rate of 0.1 percent yearly. Taken together these government forecasts result in carbon emissions *growing* at an average annual rate of 0.3 percent. However, in order for Austria to meet its EU bubble target of 24 percent below 1990 level carbon emissions by the year 2010, emissions must *decline* at an average annual rate of 3.7 percent over the 2001-2010 period.

The only way for Austria to meet its target with domestic actions is for one or more of the Kaya Identity factors affecting carbon emissions to be changed in a way that significant reductions can occur. While numerous combinations are possible, the magnitude of the change required is put into perspective by holding all of the factors constant, except one. The results are shown in the 7th, 8th, 9th and 10th columns of Table B-1. Compared to historical and projected business-as-usual forecasts, the changes needed to reach the targets are clearly very large for all of the countries shown in Table B-1.

The last two columns of the table summarize how emissions would grow if the maximum past efforts at limiting carbon emissions in each Kaya Identity component were somehow to reoccur *simultaneously* over the next decade. This assessment assumes that the annual average change in each Kaya component over the 2001-2010 period, except population, is equal to the maximum carbon emissions limiting change that occurred in any of the time periods over 1960-1995. For example, the fastest decline in Austria's carbon to energy ratio occurred during the 1961-1973 and 1974-1986 periods, when it fell at the rate of 0.6 percent annually. Similarly, the most rapid decline in energy use per dollar of GDP occurred in the 1987-1995 period, when it fell in Austria by 1.5 percent yearly. This assessment assumes that the annual change in the GDP/population ratio over 2001-2010 is 50 percent lower than the business-as-usual-projected level for each country. For example, for Austria the rate of change falls from 2.0 percent per year in the BAU forecast (shown in the 6th column) to 1.0 percent per year (shown in the second to last column). Finally, this assessment assumes no alteration in BAU projected population growth rates between now and 2010.

[20] As discussed in Chapter III, the Kaya Identity expresses a multiplicative relationship among the Kaya Identity components. However, unless the change in individual components is large, the average annual change in carbon emissions will be very closely approximated by the sum of the average annual change of the Kaya Identity components.

The results show that even under this maximum effort, Austria falls far short of meeting its Kyoto target. Emissions are shown to decrease at an average annual rate of 1 percent, whereas the average annual decline needed to meet its target is 3.7 percent.

Some countries can meet their target under this maximum changes scenario. However, taken together, the 15-member nations of the European Union fail to reach their Kyoto target, as does the U.S., and as a result the OECD fails, too.

Table B-1
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

AUSTRIA

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.6%	-0.6%	-0.3%	0.1%	-0.5%	-4.4%	-0.5%	-0.5%	-0.5%	-0.6%	
Energy / GDP	0.5%	-1.2%	-1.5%	-1.0%	-1.3%	-1.3%	-5.3%	-1.3%	-1.3%	-1.5%	
GDP / Population	4.3%	2.2%	2.0%	2.8%	2.0%	2.0%	2.0%	-2.0%	2.0%	1.0%	
Population	0.6%	0.0%	0.7%	0.2%	0.1%	0.1%	0.1%	0.1%	-3.8%	0.1%	
Carbon (Million MT)	**4.7%**	**0.3%**	**0.8%**	**2.1%**	**0.3%**	**-3.7%**	**-3.7%**	**-3.7%**	**-3.7%**	-1.0%	NO

AUSTRALIA

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.3%	-0.2%	0.0%	0.0%	0.0%	-2.6%	0.0%	0.0%	0.0%	-0.3%	
Energy / GDP	-0.4%	-0.6%	-0.5%	-0.5%	-1.3%	-1.3%	-3.8%	-1.3%	-1.3%	-0.6%	
GDP / Population	3.2%	1.5%	1.8%	2.3%	1.5%	1.5%	1.5%	-1.0%	1.5%	0.8%	
Population	1.9%	1.3%	1.3%	0.9%	1.1%	1.1%	1.1%	1.1%	-1.5%	1.1%	
Carbon (Million MT)	**4.4%**	**2.0%**	**2.6%**	**2.7%**	**1.3%**	**-1.3%**	**-1.3%**	**-1.3%**	**-1.3%**	**1.0%**	NO

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

BELGIUM

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-1.1%	-2.0%	-0.2%	-1.5%	-0.6%	-1.5%	-0.6%	-0.6%	-0.6%	-2.0%	
Energy / GDP	0.5%	-1.7%	-0.8%	-2.1%	-1.5%	-1.5%	-2.4%	-1.5%	-1.5%	-1.7%	
GDP / Population	4.4%	1.7%	1.9%	3.1%	1.9%	1.9%	1.9%	1.0%	1.9%	0.9%	
Population	0.5%	0.1%	0.3%	-0.3%	0.0%	0.0%	0.0%	0.0%	-0.9%	0.0%	
Carbon (Million MT)	**4.3%**	**-1.9%**	**1.2%**	**-1.0%**	**-0.3%**	**-1.2%**	**-1.2%**	**-1.2%**	**-1.2%**	**-2.7%**	YES

CANADA

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.5%	-0.9%	-0.2%	-0.7%	0.2%	-2.8%	0.2%	0.2%	0.2%	-0.9%	
Energy / GDP	0.4%	-1.7%	-0.1%	-0.6%	-1.2%	-1.2%	-4.2%	-1.2%	-1.2%	-1.7%	
GDP / Population	3.6%	2.3%	0.7%	1.3%	1.3%	1.3%	1.3%	-1.8%	1.3%	0.6%	
Population	1.8%	1.2%	1.4%	0.9%	0.9%	0.9%	0.9%	0.9%	-2.2%	0.9%	
Carbon (Million MT)	**5.3%**	**0.7%**	**1.8%**	**0.9%**	**1.2%**	**-1.9%**	**-1.9%**	**-1.9%**	**-1.9%**	**-1.1%**	NO

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

DENMARK

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.8%	0.5%	-0.4%	-0.5%	-1.4%	-5.1%	-1.4%	-1.4%	-1.4%	-0.8%	
Energy / GDP	1.9%	-2.0%	-0.8%	-1.4%	-1.4%	-1.4%	-5.0%	-1.4%	-1.4%	-2.0%	
GDP / Population	3.6%	2.0%	1.3%	3.1%	1.8%	1.8%	1.8%	-2.0%	1.8%	0.9%	
Population	0.7%	0.2%	0.2%	0.0%	0.2%	0.2%	0.2%	0.2%	-3.6%	0.2%	
Carbon (Million MT)	**5.5%**	**0.7%**	**0.4%**	**1.2%**	**-0.8%**	**-4.5%**	**-4.5%**	**-4.5%**	**-4.5%**	**-1.7%**	**NO**

EUROPEAN UNION

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.9%	-1.1%	-0.8%	-0.2%	-0.2%	-2.0%	-0.2%	-0.2%	-0.2%	-1.1%	
Energy / GDP	1.1%	-1.4%	-1.1%	-1.7%	-1.5%	-1.5%	-3.3%	-1.5%	-1.5%	-1.4%	
GDP / Population	4.0%	1.8%	1.8%	2.6%	2.1%	2.1%	2.1%	0.4%	2.1%	1.1%	
Population	0.7%	0.3%	0.4%	0.3%	0.1%	0.1%	0.1%	0.1%	-1.6%	0.1%	
Carbon (Million MT)	**5.0%**	**-0.4%**	**0.2%**	**0.9%**	**0.5%**	**-1.3%**	**-1.3%**	**-1.3%**	**-1.3%**	**-1.2%**	**NO**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

FINLAND

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	0.4%	-1.4%	0.0%	1.2%	0.0%	-3.3%	0.0%	0.0%	0.0%	-1.4%	
Energy / GDP	1.1%	-0.7%	-0.4%	0.6%	-1.6%	-1.6%	-4.8%	-1.6%	-1.6%	-0.7%	
GDP / Population	4.6%	2.3%	0.9%	2.9%	2.4%	2.4%	2.4%	-1.0%	2.4%	1.2%	
Population	0.4%	0.4%	0.4%	0.2%	0.2%	0.2%	0.2%	0.2%	-3.1%	0.2%	
Carbon (Million MT)	**6.5%**	**0.6%**	**0.9%**	**5.0%**	**1.0%**	**-2.3%**	**-2.3%**	**-2.3%**	**-2.3%**	**-0.7%**	**NO**

FRANCE

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-1.0%	-3.1%	-1.6%	-0.1%	-0.8%	-1.3%	-0.8%	-0.8%	-0.8%	-3.1%	
Energy / GDP	0.8%	-0.7%	-0.1%	-1.4%	-1.5%	-1.5%	-2.0%	-1.5%	-1.5%	-0.7%	
GDP / Population	4.4%	1.5%	1.5%	2.0%	2.1%	2.1%	2.1%	1.6%	2.1%	1.0%	
Population	1.0%	0.5%	0.5%	0.7%	0.4%	0.4%	0.4%	0.4%	-0.1%	0.4%	
Carbon (Million MT)	**5.2%**	**-1.7%**	**0.3%**	**1.2%**	**0.1%**	**-0.4%**	**-0.4%**	**-0.4%**	**-0.4%**	**-2.3%**	**YES**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

GERMANY

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.9%	-0.8%	-0.9%	0.5%	-0.2%	-2.8%	-0.2%	-0.2%	-0.2%	-0.9%	
Energy / GDP	2.8%	-1.4%	-2.9%	-2.8%	-1.9%	-1.9%	-4.4%	-1.9%	-1.9%	-2.9%	
GDP / Population	3.7%	2.1%	1.7%	3.5%	2.3%	2.3%	2.3%	-0.4%	2.3%	1.1%	
Population	0.6%	-0.1%	0.6%	0.4%	0.0%	0.0%	0.0%	0.0%	-2.6%	0.0%	
Carbon (Million MT)	**6.4%**	**-0.2%**	**-1.6%**	**1.5%**	**0.2%**	**-2.4%**	**-2.4%**	**-2.4%**	**-2.4%**	**-2.6%**	**YES**

GREECE

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	0.0%	0.4%	0.0%	-0.3%	-0.4%	0.3%	-0.4%	-0.4%	-0.4%	0.0%	
Energy / GDP	5.1%	0.4%	1.7%	-0.6%	-1.3%	-1.3%	-0.7%	-1.3%	-1.3%	0.4%	
GDP / Population	7.1%	1.6%	1.2%	1.8%	2.5%	2.5%	2.5%	3.2%	2.5%	1.3%	
Population	0.5%	0.9%	0.5%	0.3%	0.2%	0.2%	0.2%	0.2%	0.8%	0.2%	
Carbon (Million MT)	**13.0%**	**3.3%**	**3.5%**	**1.2%**	**0.9%**	**1.6%**	**1.6%**	**1.6%**	**1.6%**	**1.8%**	**NO**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

IRELAND

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.8%	0.0%	-0.4%	0.9%	-0.6%	-0.9%	-0.6%	-0.6%	-0.6%	-0.8%	
Energy / GDP	0.8%	-1.0%	-3.4%	-2.1%	-1.9%	-1.9%	-2.1%	-1.9%	-1.9%	-3.4%	
GDP / Population	3.7%	2.4%	5.8%	2.7%	3.1%	3.1%	3.1%	2.8%	3.1%	1.6%	
Population	0.6%	1.1%	0.1%	-0.1%	0.0%	0.0%	0.0%	0.0%	-0.3%	0.0%	
Carbon (Million MT)	**4.3%**	**2.3%**	**1.9%**	**1.3%**	**0.6%**	**0.3%**	**0.3%**	**0.3%**	**0.3%**	**-2.7%**	**YES**

ITALY

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	0.6%	-0.3%	-0.1%	-0.5%	-0.5%	-2.4%	-0.5%	-0.5%	-0.5%	-0.3%	
Energy / GDP	3.4%	-2.1%	-0.2%	-0.9%	-1.0%	-1.0%	-2.9%	-1.0%	-1.0%	-2.1%	
GDP / Population	4.6%	2.4%	1.8%	2.6%	2.0%	2.0%	2.0%	0.1%	2.0%	1.0%	
Population	0.7%	0.3%	0.1%	0.0%	-0.1%	-0.1%	-0.1%	-0.1%	-2.0%	-0.1%	
Carbon (Million MT)	**9.5%**	**0.3%**	**1.7%**	**1.1%**	**0.5%**	**-1.5%**	**-1.5%**	**-1.5%**	-1.5%	-1.5%	**YES**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

JAPAN

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.6%	-1.1%	-0.6%	-0.4%	-1.1%	-2.6%	-1.1%	-1.1%	-1.1%	-1.1%	
Energy / GDP	1.3%	-2.3%	0.6%	-3.0%	-1.3%	-1.3%	-2.8%	-1.3%	-1.3%	-2.3%	
GDP / Population	8.4%	2.5%	2.6%	2.7%	2.4%	2.4%	2.4%	0.8%	2.4%	1.2%	
Population	1.2%	0.9%	0.4%	0.3%	0.2%	0.2%	0.2%	0.2%	-1.3%	0.2%	
Carbon (Million MT)	**10.4%**	**-0.1%**	**3.0%**	**-0.5%**	**0.2%**	**-1.4%**	**-1.4%**	**-1.4%**	**-1.4%**	**-2.0%**	**YES**

LUXEMBOURG

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-1.1%	-0.8%	-1.5%	-1.4%	-0.6%	-1.8%	-0.6%	-0.6%	-0.6%	-1.5%	
Energy / GDP	-1.6%	-4.8%	-4.4%	0.7%	-1.1%	-1.1%	-2.3%	-1.1%	-1.1%	-4.8%	
GDP / Population	3.2%	1.9%	4.5%	-0.2%	2.1%	2.1%	2.1%	0.9%	2.1%	1.0%	
Population	0.9%	0.4%	1.2%	-0.4%	-0.3%	-0.3%	-0.3%	-0.3%	-1.4%	-0.3%	
Carbon (Million MT)	**1.4%**	**-3.2%**	**-0.3%**	**-1.4%**	**0.0%**	**-1.2%**	**-1.2%**	**-1.2%**	**-1.2%**	**-5.5%**	**YES**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

NETHERLANDS

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-1.8%	-0.1%	0.1%	-0.8%	-0.2%	-1.8%	-0.2%	-0.2%	-0.2%	-1.8%	
Energy / GDP	3.7%	-1.7%	-1.1%	-2.3%	-1.5%	-1.5%	-3.0%	-1.5%	-1.5%	-1.7%	
GDP / Population	3.6%	1.4%	1.9%	1.3%	1.9%	1.9%	1.9%	0.2%	1.9%	0.9%	
Population	1.2%	0.6%	0.7%	0.7%	0.3%	0.3%	0.3%	0.3%	-1.3%	0.3%	
Carbon (Million MT)	**6.8%**	**0.3%**	**1.5%**	**-1.1%**	**0.5%**	**-1.1%**	**-1.1%**	**-1.1%**	**-1.1%**	**-2.2%**	**YES**

NEW ZEALAND

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	N.A.	N.A.	-0.5%	-0.4%	0.0%	-2.8%	0.0%	0.0%	0.0%	N.A.	
Energy / GDP	N.A.	N.A.	0.9%	-0.3%	-1.2%	-1.2%	-3.9%	-1.2%	-1.2%	N.A.	
GDP / Population	2.3%	1.0%	0.6%	2.3%	2.1%	2.1%	2.1%	-0.7%	2.1%	1.1%	
Population	1.7%	0.8%	1.0%	0.7%	0.9%	0.9%	0.9%	0.9%	-1.9%	0.9%	
Carbon (Million MT)	**N.A.**	**N.A.**	**2.0%**	**2.2%**	**1.7%**	**-1.1%**	**-1.1%**	**-1.1%**	**-1.1%**	**N.A.**	**N.A.**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

OECD

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.5%	-0.7%	-0.5%	-0.1%	-0.1%	-2.8%	-0.1%	-0.1%	-0.1%	-0.7%	
Energy / GDP	0.3%	-1.8%	-0.6%	-1.3%	-1.2%	-1.2%	-3.9%	-1.2%	-1.2%	-1.8%	
GDP / Population	4.0%	1.8%	1.7%	2.3%	1.8%	1.8%	1.8%	-0.9%	1.8%	0.9%	
Population	1.0%	0.6%	0.6%	0.5%	0.4%	0.4%	0.4%	0.4%	-2.2%	0.4%	
Carbon (Million MT)	**4.8%**	**-0.1%**	**1.2%**	**1.3%**	**1.0%**	**-1.8%**	**-1.8%**	**-1.8%**	**-1.8%**	**-1.1%**	**NO**

PORTUGAL

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	0.0%	0.3%	0.7%	-0.1%	0.5%	-0.7%	0.5%	0.5%	0.5%	0.0%	
Energy / GDP	0.2%	2.1%	1.7%	-1.7%	-0.9%	-0.9%	-2.1%	-0.9%	-0.9%	0.2%	
GDP / Population	6.9%	1.2%	3.2%	3.6%	3.1%	3.1%	3.1%	1.9%	3.1%	1.6%	
Population	0.0%	1.2%	-0.1%	-0.9%	0.0%	0.0%	0.0%	0.0%	-1.1%	0.0%	
Carbon (Million MT)	**7.1%**	**4.8%**	**5.6%**	**0.7%**	**2.7%**	**1.5%**	**1.5%**	**1.5%**	**1.5%**	**1.8%**	**NO**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

SPAIN

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.8%	-0.5%	-0.5%	-1.2%	0.0%	-0.1%	0.0%	0.0%	0.0%	-0.8%	
Energy / GDP	1.9%	0.8%	0.9%	-3.8%	-1.3%	-1.3%	-1.4%	-1.3%	-1.3%	0.8%	
GDP / Population	6.2%	1.2%	2.7%	2.6%	2.5%	2.5%	2.5%	2.3%	2.5%	1.3%	
Population	1.0%	0.8%	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%	0.0%	0.2%	
Carbon (Million MT)	**8.4%**	**2.3%**	**3.3%**	**-2.2%**	**1.4%**	**1.3%**	**1.3%**	**1.3%**	**1.3%**	**1.4%**	**NO**

SWEDEN

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.3%	-3.6%	-0.4%	0.5%	5.8%	-0.3%	5.8%	5.8%	5.8%	-3.6%	
Energy / GDP	1.1%	0.2%	-0.9%	-0.7%	-2.9%	-2.9%	-8.5%	-2.9%	-2.9%	-0.9%	
GDP / Population	3.5%	1.6%	0.6%	1.3%	2.1%	2.1%	2.1%	-3.7%	2.1%	1.0%	
Population	0.6%	0.2%	0.6%	0.3%	0.2%	0.2%	0.2%	0.2%	-5.5%	0.2%	
Carbon (Million MT)	**5.0%**	**-1.6%**	**-0.1%**	**1.3%**	**5.0%**	**-1.0%**	**-1.0%**	**-1.0%**	**-1.0%**	**-3.3%**	**YES**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

SWITZERLAND

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.4%	-1.7%	-0.7%	0.2%	0.0%	-1.1%	0.0%	0.0%	0.0%	-1.7%	
Energy / GDP	3.1%	0.8%	-0.6%	-2.0%	-1.6%	-1.6%	-2.7%	-1.6%	-1.6%	-0.6%	
GDP / Population	3.0%	0.8%	0.4%	1.0%	1.9%	1.9%	1.9%	0.8%	1.9%	1.0%	
Population	1.4%	0.2%	0.8%	0.8%	0.3%	0.3%	0.3%	0.3%	-0.8%	0.3%	
Carbon (Million MT)	**7.3%**	**0.0%**	**0.0%**	**0.0%**	**0.5%**	**-0.5%**	**-0.5%**	**-0.5%**	**-0.5%**	**-1.1%**	**YES**

UNITED KINGDOM

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-1.1%	-0.6%	-1.0%	-0.6%	-0.4%	-1.9%	-0.4%	-0.4%	-0.4%	-1.1%	
Energy / GDP	-0.6%	-2.1%	-1.2%	-0.6%	-1.5%	-1.5%	-2.9%	-1.5%	-1.5%	-2.1%	
GDP / Population	2.6%	1.6%	1.7%	2.4%	1.9%	1.9%	1.9%	0.5%	1.9%	1.0%	
Population	0.5%	0.1%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	-1.2%	0.2%	
Carbon (Million MT)	**1.3%**	**-1.0%**	**-0.2%**	**1.3%**	**0.2%**	**-1.2%**	**-1.2%**	**-1.2%**	**-1.2%**	**-2.1%**	**YES**

Table B-1 (continued)
Average Annual Percent Changes in Kaya Identity Factors Affecting Carbon Emissions

UNITED STATES

Kaya Identity Factors	1961-1973	1974-1986	1987-1995	1996-2000	Business as Usual Forecasts 2001-2010	Meeting the Kyoto Target Over 2001-2010 by Changing Only One Kaya Factor and Setting Other Factors Equal to BAU Forecasts: Carbon/Energy	Energy/GDP	GDP/Population	Population	Historical and/or BAU Projected Maximum Changes	Can Maximum Changes Meet Target?
Carbon / Energy	-0.2%	-0.2%	-0.4%	0.0%	0.1%	-3.5%	0.1%	0.1%	0.1%	-0.4%	
Energy / GDP	0.3%	-2.1%	-0.4%	-0.6%	-0.9%	-0.9%	-4.5%	-0.9%	-0.9%	-2.1%	
GDP / Population	2.7%	1.3%	1.3%	1.7%	1.3%	1.3%	1.3%	-2.4%	1.3%	0.6%	
Population	1.2%	1.0%	1.0%	0.9%	0.8%	0.8%	0.8%	0.8%	-2.8%	0.8%	
Carbon (Million MT)	**4.0%**	**0.0%**	**1.4%**	**1.9%**	**1.3%**	**-2.3%**	**-2.3%**	**-2.3%**	**-2.3%**	**-1.0%**	**NO**

N.A. = not available or not applicable.

Sources: The average annual changes in the Kaya Identity factors were calculated from the following sources: Energy data for 1960 - 1995 are available in diskette form from the OECD's *Energy Balances of OECD Countries.* The data used here are for total primary energy and include: coal, crude oil and petroleum products (excluding non-energy use), natural gas, nuclear, hydro-power, geothermal, solar, wind & other, combustible renewables and waste, and other non-specified combustion (for electricity generation or heat). The carbon content of these fuels is calculated following procedures suggested by the Intergovernmental Panel on Climate Change. Carbon emissions include the above fossil fuels plus 50 percent of the carbon content of combustible renewables to allow for some "recycling" of carbon. Historic GDP data are drawn from the OECD *National Income Accounts - Main Aggregates* as well as from the U.S. *Economic Report of the President.* Population data are drawn from the OECD *Labour Force Statistics* and the U.S. *Economic Report of the President.* All projections are "business-as-usual," "reference case" or "basecase" projections. The EU country projections are from the EU Directorate General for Energy (DG XVII) *Energy in Europe - European Energy to 2020: Scenario Approach.* The U.S. projection is from the U.S. Energy Information Administration *Annual Energy Outlook 1998,* and the projections for other OECD countries are from *Energy Policies of IEA Countries - 1997 Review,* by the International Energy Agency/OECD. IEA projections have emissions in some countries substantially higher (Finland, Greece and Ireland) than the EU projections. Germany's emissions are somewhat lower and emissions for the United Kingdom are lower in 2000, but about the same in 2010. In calculating the average annual change in carbon emissions needed to reach the Kyoto Protocol targets for 2008-2012, or the midpoint of that period 2010, adjustments have been made to EU country targets because of the "EU-bubble." Under the bubble, some countries will be allowed to increase their emissions while others must have offsetting reductions that allow the EU to meet its overall target. The assumption here is that the EU bubble proposal reached by the EU Council of Ministers Environmental ("EU Conclusions on Climate Change," reached in Brussels, 3 March 1997) will be adjusted proportionately for each county so that the EU Kyoto target of a 8 percent below 1990 levels is reached, rather than the roughly 10 percent reduction from 1990 levels in the "EU Conclusions."

References

Australian Bureau of Agricultural and Resource Economics, *The Economic Impact of International Climate Change Policy*, Research Report 97.4, Canberra, Australia, 1997.

Branigin, William, "Immigration Policy Dispute Rocks Sierra Club," *Washington Post*, March 7, 1998.

Dougher, Rayola and Jones, Russell. "OECD Country Carbon Emissions: A Kaya Identity Perspective on Historic Emissions and Proposed Emission Reduction Targets and Timetables," *Proceedings of the 21st IAEE Annual International Conference*, Quebec City, May 13-17, 1998.

European Commission Directorate General for Energy (DG XVII), *Energy in Europe, European Energy to 2020*, Brussels, Luxembourg: Office for Official Publications of the European Communities, 1996.

European Union Council of Ministers Environment, "EU Conclusions on Climate Change," Brussels, Luxembourg, March 3, 1997.

Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reporting Instructions*, Volume 1, (97-95-05-1) ISBN 92-64-14378-5, Paris, France: OECD Publications, June 1995.

International Energy Agency, *Climate Change Policy Initiatives*, (61 92 14 1) ISBN 92-64 13754-8, No 46243, Paris, France: OECD Publications, 1992.

_____, *Climate Change Policy Initiatives, 1994 Update* (61 94 14 1) ISBN 92-64 14142-1, No 47287, Paris, France: OECD Publications, 1994.

_____, *Energy Balances of OECD Countries, 1994-1995*, Paris, France: OECD Publications, 1997.

_____, *Energy Policies of IEA Countries, 1997 Review*, (61 97 25 1) ISBN 92-64-15610-0, No. 49724, Paris, France: OECD Publications, 1997.

_____, *Indicators of Energy Use and Efficiency*, (61 97 07 1) ISBN 92-64 14919-8, No 48935, Paris, France: OECD Publications, 1997.

_____, *Key World Energy Statistics from the IEA*, Paris, France: IEA.

Jones, Russell and Tierney, Barbara. "Carbon Emissions—A Kaya Identity Perspective on Historic Emissions and Proposed Emission Reduction Targets and Timetables," *International Energy Markets, Competition and Policy*, Conference Proceedings of the 18th Annual North American Conference of the U.S. Association for Energy Economics, and the International Association for Energy Economics, San Francisco, September 1997.

Kaya, Y. "Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios," paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris, France, 1990.

Kerber, Ross. "Nuclear Plants Face Huge Costs to Fix Problems," *Wall Street Journal*, June 18, 1997, page B1.

Organization for Economic Co-operation and Development, Statistics Directorate Direction Des Statistiques, *Historical Statistics 1960-1994*, (30-96-09-3) ISBN 92-04850-2, Paris, France: OECD Publications, July 1996.

_____, Statistics Directorate Direction Des Statistiques, *Main Economic Indicators*, Paris, France: OECD Publications, June 1996.

_____, Statistics Directorate Direction Des Statistiques, *National Accounts, Main Aggregates, 1960-1995*, Volume 1, Paris, France: OECD Publications.

_____, Statistics Directorate Direction Des Statistiques, *Quarterly Labour Force Statistics*, Paris, France: OECD Publications, various issues.

Sutherland, Ronald J., "Climate Change Policy Commitments: A Reality Check," American Petroleum Institute Discussion Paper #089, Washington, D.C., December 1997.

United Nations, "Kyoto Protocol to the United Nations Framework Convention on Climate Change," Conference of the Parties, Third Session, Agenda Item 5, Kyoto, Japan, 1-10 December 1997.

U.S. Climate Action Report, *1997 Submission of the United States Under the United States Framework Convention on Climate Change*, U.S. Department of State, July 1997.

U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1998 With Projections Through 2020*, DOE/EIA-0383(98), Washington, D.C., December 1997.

_____, *Annual Energy Review, 1995*, DOE/EIA-0384(95), Washington, D.C., July 1996.

_____, *International Energy Outlook 1996*, DOE/EIA-0484(96), Washington, D.C., May 1996.

United States *Economic Report of the President*, Transmitted to the Congress, Washington, D.C., February 1997.

Weise, Arthur M., "Impacts of Market-Based Greenhouse Gas Emission Reduction Policies on U.S. Manufacturing Competitiveness," American Petroleum Institute Research Study #090, Washington, D.C., January 1998.

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1. No Trade → this doesn't all have to happen here

2. Never tried to reduce C/E ratio historically [inter-coal substitution/fuel]

3. No restructuring (Elect)

4. Haven't looked at 5 yr max – only max in these specific 5 yr. periods

~~5.~~

QF JF

Talking Points on the Economic Impact of the Kyoto Protocol
June 9, 1998

1. ***The model used to derive these numbers is flawed. It omits all the flexibility mechanisms included in the Kyoto Protocol and the Administration's policies.***

- **The WEFA analysis omits international emissions trading.** This study assumes that no countries undertake emissions trading, even though the right to trade is explicitly stated in the Kyoto agreement. International trading among industrialized countries could reduce costs of emissions by half.

- **The WEFA study does not include developing country participation in emissions reduction.** This study assumes developing countries do nothing to reduce greenhouse gas emissions. However, the Kyoto Protocol establishes the Clean Development Mechanism, and even if developing nations only participate in this mechanism the costs to the United States could be 20 to 25% lower. If key developing countries participate more fully, for example by taking on emissions targets and undertake emissions trading, the costs to the United States could be reduced even more.

- **The WEFA study does not account for six categories of greenhouse gases.** This study assumes that emissions reductions would occur only through carbon dioxide reductions, even though all six major greenhouse gases are covered by the Protocol. Since the Kyoto agreement requires countries to reduce emissions to specific targets, on average across all kinds of greenhouse gases, the flexibility is available to reduce emissions of some gases more than others if it is cost-effective. Allowing for trading across gases could lower costs by about 10%.

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- **The WEFA analysis omits carbon sinks.** This study assumes that no carbon sink opportunities for absorbing greenhouse gas emissions are available, even though the Kyoto agreement explicitly includes forestry activities. Low-cost carbon sink options provide another opportunity to achieve emissions targets at a modest cost.

By ignoring these flexibility mechanisms, this analysis fails to assess accurately the Kyoto Protocol as well as the Administration's efforts to reduce greenhouse gas emissions. The Administration has always said that reducing emissions can be done smart or dumb. By failing to account for these flexibility mechanisms, the WEFA analysis illustrates the costs of doing it dumb. The Administration believes that by including market mechanisms it can be done smart.

The costs of meeting the challenge of climate change will be modest. The Administration is working to ensure that greenhouse gas emissions that contribute to global warming are reduced in common sense, cost-effective ways. The Administration believes that with effective market mechanisms -- international emissions permit trading, the Clean Development Mechanism joint implementation, timing flexibility during the commitment period, opportunities to trade across greenhouse gases, and carbon sinks -- as well as with meaningful developing country participation and flexible timetables, the economic cost to the United States of meeting the Kyoto targets will be modest.

2. ***The potential costs of waiting too long to address the threat of climate change exceed the costs of acting now.*** The threats climate change presents are widespread and range from potential increases in asthma and infectious diseases to increasingly frequent and severe storms. Despite the challenge of putting a price tag on the risks of inaction, economists have nonetheless developed troubling cost estimates of the risks of global climate change -- ranging in the tens of billions of dollars per year for the United States.

- ***Human health.*** Warmer temperatures are projected to increase fatalities attributable to heat waves in the U.S. of the kind that killed 400 in Chicago in 1995. The incidence of asthma and other respiratory illnesses, particularly among children and the elderly, is expected to increase from the additional smog caused by warmer temperatures. In a warmer, wetter world, the geographic ranges for infectious diseases could significantly expand. The incidence of malaria, for example, could increase by 50 million or more cases a year by 2100.

- ***Extreme weather.*** Warmer, wetter weather is projected to increase the frequency and intensity of extreme events such as floods and drought. The 1993 Mississippi River flood alone caused damages of $10-20 billion, while the Pacific Northwest floods in 1996-97, and the 1997 Ohio River and Red River floods resulted in substantial costs to business and homeowners. Global warming may also mean increased drought in the U.S., particularly in the Great Plains and other arid areas.

- ***Sea level rise.*** Scientists project that sea level will rise by an additional 6-38 inches by 2100. A 20 inch-rise could inundate 7,000 square miles of the U.S. coastline, with Florida and the Gulf Coast at greatest risk. Changes in rain and snowfall could affect water supplies and water quality, posing threats to irrigation, fisheries, and drinking supplies

- ***Agricultural impacts.*** Changes in growing seasons, water availability, soil moisture and precipitation could cause significant regional shifts in food productivity, with decreases in food production.

3. ***The President's plan protects the environment and grows the economy.*** In October 1997, President Clinton put forward a responsible, balanced approach to begin meeting the challenge of global warming, while protecting our economy and maintaining our international competitiveness. This plan emphasizes win-win initiatives designed to cut emissions by increasing energy efficiency; developing new, cleaner energy technologies; working with industry and others to promote sensible solutions; and relying on market-based mechanisms to ensure cost-effective reductions.

- The plan includes a $6.3 billion package of tax incentives and R&D aimed at cutting greenhouse gas emissions and building partnerships with industry to remove barriers to the development and widespread use of energy efficient technologies and practices.

4. ***Enabling environmental protection and economic growth to go hand-in-hand.*** For the past 25 years, efforts to protect the environment, whether by cleaning our air and water, eliminating acid rain or closing the ozone hole, have been repeatedly assailed as a threat to our economy. Yet today we have the cleanest environment in a generation and the strongest economy in a generation. President Clinton's balanced approach to the challenge of climate

change will allow us to grow the economy and protect the environment at the same time.

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FIRST COMPREHENSIVE POST-KYOTO STUDY SHOWS TREATY WILL COST FAMILIES $2,700 A YEAR

inconsistent w/table

WASHINGTON, D.C. – The climate treaty negotiated in Kyoto, Japan, last December will cost the typical American family of four $2,700 a year in higher costs for such things as energy, manufactured goods, and food, according to a study released today by the Global Climate Coalition.

The study, conducted by the independent economic forecasting firm WEFA, Inc., projects that the treaty jeopardizes 2.4 million jobs in the mining, energy, manufacturing, agriculture, and service industries.

WEFA is the first independent organization to calculate, both nationally and on a state-by-state basis, the full economic consequences of the treaty negotiated in Kyoto. In addition, it looks at impacts in 20 representative cities, counties, and metropolitan areas across the nation.

"While scientists debate the extent of human impact on the global climate, there is no question that the Kyoto treaty will have a dramatic effect on what American families pay for gasoline, electricity, and food," said Mary Novak, WEFA Senior Vice President and lead author of the study.

The WEFA study's cost projections are based on several key assumptions: that the U.S. will cut greenhouse gas emissions to a point seven percent below 1990 levels by the years 2008 to 2012, as required by the treaty; that there will be no international system for emissions trading with developing nations; and that there will be no Clean Development Mechanism enabling U.S. companies to build efficient new facilities in developing nations and take credit for emissions reductions.

- More -

"These assumptions reflect the way things are today," Novak said. "None of the devices included in the treaty to ease the economic burden of cutting U.S. energy consumption by 35 percent or more exists. And there is no reason to believe they will be available in time to make a difference. The sad truth is, we need to be looking at this kind of worst case scenario because that's the reality Americans face."

GCC President Gail McDonald said the WEFA study confirms the worst fears the U.S. Senate expressed last year when it voted 95-0 to oppose any treaty that would harm the American economy. "This treaty is a threat to our new prosperity," she said. "The WEFA study proves conclusively that the Kyoto Protocol is impractical and it won't work."

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The Global Climate Coalition is an organization of trade associations and private companies established in 1989 to coordinate participation in the scientific and policy debate on global climate change.

Economic Impacts of the Kyoto Protocol On Selected Cities and Counties

(WEFA, Inc., June 1998)

City, County	Jobs Lost
Boston, Massachusetts	42,000
Billings, Montana	26,000
Chicago, Illinois	94,000
Charlotte, North Carolina	25,000
Clark County, Nevada	14,000
Cleveland, Ohio	25,000
Fairfax, Virginia	9,500
Fort Wayne, Indiana	8,000
Fulton County, Georgia	26,000
Harris County, Texas	45,000
Hennepin County, Minnesota	14,000
Howard County, Maryland	1,500
Jefferson County, Kentucky	11,000
Madison County, Alabama	3,600
New Orleans, Louisiana	20,000
Oklahoma City, Oklahoma	9,400
Philadelphia, Pennsylvania	43,000
Phoenix, Arizona	68,000
San Jose, California	27,000
Seattle, Washington	24,000

Economic Impacts of the Kyoto Protocol On States

(WEFA, Inc., June 1998)

State	Jobs Lost	Cost per family of four ($)
Alabama	67,500	948
Alaska	4,300	1,603
Arizona	102,300	1,572
Arkansas	20,600	932
California	278,800	1,312
Colorado	47,400	1,144
Connecticut	28,100	1,264
Delaware	4,500	1,240
Florida	142,000	1,816
Georgia	80,000	1,708
Hawaii	9,700	1,020
Idaho	11,600	764
Illinois	190,700	1,516
Indiana	99,700	1,228
Iowa	21,600	772
Kansas	18,400	968
Kentucky	56,500	1,436
Louisiana	64,500	1,232
Maine	7,000	1,772
Maryland	33,300	1,012
Massachusetts	45,600	1,736
Michigan	96,500	1,156
Minnesota	46,900	1,376
Mississippi	28,600	924
Missouri	48,700	1,084
Montana	41,500	2,740
Nebraska	19,000	1,136
Nevada	27,300	1,356
New Hampshire	12,400	1,628
New Jersey	120,500	800
New Mexico	13,500	724
New York	140,000	976
North Carolina	107,200	1,272
North Dakota	3,600	992
Ohio	119,800	1,188
Oklahoma	26,600	732
Oregon	22,900	820
Pennsylvania	108,000	748
Rhode Island	3,400	1,592
South Carolina	32,500	976
South Dakota	7,200	1,168
Tennessee	39,500	892
Texas	124,600	828
Utah	12,700	976
Vermont	2,300	1,512
Virginia	34,600	756
Washington	47,700	1,120
West Virginia	19,400	948
Wisconsin	69,800	1,348
Wyoming	7,600	928

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Global Warming: The High Cost of the Kyoto Protocol

WEFA

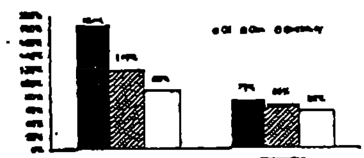
National and State Impacts – Executive Summary

Implementing the Kyoto Protocol Would Reduce Economic Prosperity and Cost US Jobs

- ➢ Loss of 2.4 Million Jobs
- ➢ Loss of $300 billion in US GDP annually, an average loss of $2700 per household
- ➢ Loss of competitiveness to developing-countries which refuse to commit to emission targets

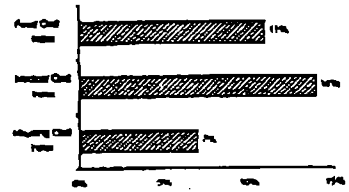
Energy Prices Would Double for Businesses

(Percent Increase from Baseline)



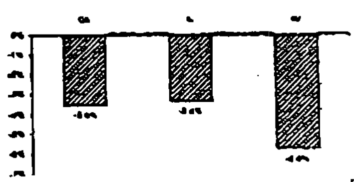
The Cost of Basic Necessities Would Rise

(Percent Increase from Baseline)



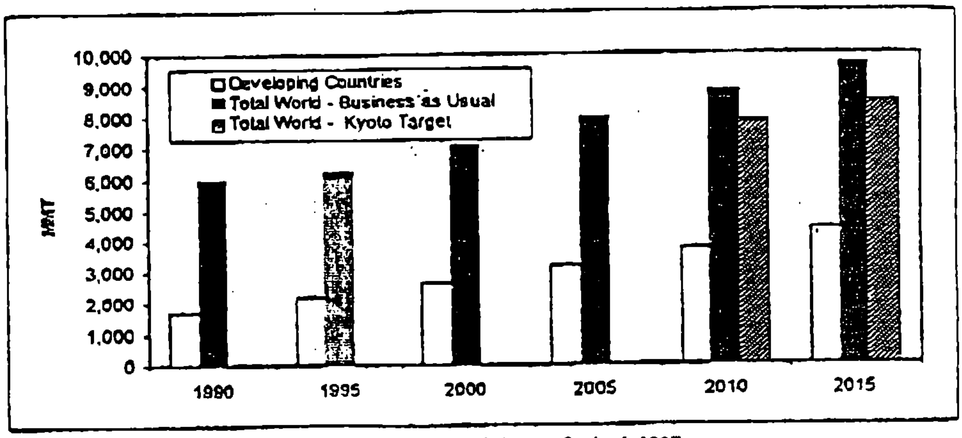
Every State Would Suffer Large Manufacturing Job Losses, Even Non-Energy-Intensive States

(Percent Decrease from Baseline)



The Kyoto Protocol is an international treaty that would commit the U.S. and other industrialized countries to reduce greenhouse gas emissions by late next decade. Developing countries would not commit to reduce their greenhouse gas emissions. Without the participation of the developing countries, the impact on global greenhouse gas emissions from implementing the Kyoto Protocol would be small.

The Kyoto Protocol Would Have Little Impact on Global Carbon Emissions from Man-Made Sources



Source: Energy Information Administration, *International Energy Outlook 1997*

The US faces a daunting task: reducing greenhouse gas emissions to 93% of the 1990 level. Today, carbon emissions exceed the target by 16%; by 2010 -- 37% or more.

The Kyoto Protocol's Call for Near-Term Action Costs US Jobs

Economists at academic institutions and independent firms, including WEFA, have helped define climate policy options and their likely costs for more than a decade. All of their studies estimated high costs at both the national and individual state levels – without carbon limits, the economy and energy–use are expected to grow steadily. Reducing energy-use to achieve carbon emission reductions to or below 1990 levels within 10-12 years requires sending very powerful price signals through the economy. However, these powerful price signals, implemented by adding permit fees or taxes to energy prices, result in: premature retirement of capital stock, a decline in GDP, a rise in unemployment, less capital for business investments, and less disposable household income. The result is a picture of a less prosperous America.

A Better Strategy: Promote Technological Progress and Global Participation

WEFA believes the better climate strategy would be to match policy actions to an evolving understanding of climate science, as global warming is likely to be gradual and limited to only a small change in average global temperature. Measures consistent with this approach would be:

- increase investments in technology and gradually replace existing capital stock ✓
- encourage voluntary actions to reduce greenhouse gas emissions ✓
- insist that developing countries meaningfully participate ✓

Sounds like actual Clinton Admin plan

Unemployment Rate in 2010:

State	Base	Kyoto
Alaska	7.20	8.61
Alabama	3.63	6.33
Arkansas	4.72	6.13
Arizona	3.03	5.73
California	6.10	7.73
Colorado	3.75	5.32
Connecticut	5.48	6.97
Delaware	4.71	5.64
Florida	4.97	6.66
Georgia	3.92	6.48
Hawaii	6.55	8.15
Iowa	5.07	6.29
Idaho	3.92	5.28
Illinois	3.38	6.06
Indiana	3.65	6.15
Kansas	4.21	5.39
Kentucky	4.60	7.10
Louisiana	6.35	8.85
Massachusetts	4.32	5.50
Maryland	4.71	5.92
Maine	5.31	6.37
Michigan	3.80	5.64
Minnesota	3.45	4.93
Missouri	4.04	5.65
Mississippi	6.86	7.94
Montana	6.04	9.94
North Carolina	3.95	6.14
North Dakota	2.78	3.66
Nebraska	3.09	4.82
New Hampshire	4.39	6.12
New Jersey	5.15	7.84
New Mexico	7.26	8.68
Nevada	4.64	6.48
New York	6.24	7.76
Ohio	3.92	5.74
Oklahoma	3.83	6.41
Oregon	5.47	6.63
Pennsylvania	4.65	6.37
Rhode Island	4.57	5.27
South Carolina	5.48	6.99
South Dakota	3.23	4.81
Tennessee	5.41	6.61
Texas	5.21	6.32
Utah	3.09	3.89
Virginia	4.23	6.06
Vermont	4.12	4.79
Washington	5.35	6.76
Wisconsin	2.59	4.71
West Virginia	4.87	7.09
Wyoming	5.45	8.29
U.S.	5.43	6.95

Overview

In Washington, DC and throughout the nation, elected officials and key leaders are debating whether the Kyoto Protocol, an international treaty negotiated by the Clinton Administration that would legally bind developed countries to reduce their greenhouse gas emissions, should be signed and ultimately ratified by the US Senate. By the terms of the Protocol, the US would have to reduce its emissions 7% below 1990 levels by late next decade. And, unless developing countries agree to binding emissions targets, a competitive imbalance would be created between industrial and developing nations.

Meeting the goal of the Kyoto Protocol would be a daunting task. In 1997, carbon emissions from the energy sector, the majority of greenhouse gas emissions, exceed the goal established at Kyoto by 16%. By late next decade, WEFA projects that carbon emissions would exceed the goal by at least 37%. Due to population increases, on a per capita basis, the required reduction would exceed 50%.

WEFA has analyzed the economic consequences to the U.S. of achieving the Kyoto target through domestic actions. These consequences would be severe, a result that others analyzing even less onerous targets also have reported. These include the U.S. Department of Energy, leading academic institutions, and other independent consulting firms. Meeting the Kyoto target would:

- **Nearly double energy and electricity** prices, and raise gasoline prices an additional 65 cents per gallon.
- **Cost 2.4 million US jobs and reduce US total output $300 billion (1992$) <u>annually</u>,** 3.2% below baseline GDP projections, an amount greater than the total expenditure on primary and secondary education.
- **Harm U.S. competitiveness,** as developing countries will not need to raise energy prices (or product prices) to meet mandatory greenhouse gas targets.
- **Reduce the average annual household income nearly $2700,** at a time when the cost of all goods, particularly food and basic necessities, would rise sharply.
- **State tax revenues would be reduced by $93.1 billion** due to job and output loses attributable to lost US competitiveness in the global market and higher energy costs.

The sharp rise in energy prices would reduce economic growth opportunities. Compounding this effect is the loss of competitiveness the industrialized countries would suffer, as developing countries would not raise energy prices to meet greenhouse gas reduction targets. Although developing countries argue that full responsibility for mitigating the risk of global warming rests with industrialized countries, developing countries exempted themselves from emission limits because they recognize the role energy plays in their economic development.

The Administration has argued that new technology can drastically reduce the costs of implementing the Kyoto Protocol, and that international permit trading, sinks and other market-based mechanisms mentioned in the Protocol also will lower costs. WEFA has carefully assessed the ability of technology to reduce costs over the time period in question. Without very powerful price incentives, such rapid technology improvement is extremely unlikely. Hence, technology implementation does not invalidate the estimates determined through this analysis. As for permit-trading and other international market mechanisms, the Kyoto Protocol leaves all such instruments undefined, to be worked out in the future among the parties. Further, according to the Protocol, they are to be supplemental to indigenous efforts, not primary mechanisms to reach country targets. And finally, there is great hostility on the part of many countries to their use. For these reasons, WEFA does not ascribe significant savings to them.

The high cost estimates reported would only be justified if catastrophic climate change were imminent.

As global warming may be gradual and largely due to natural causes, measures that more closely link economic cost to the still-potential threat of very long-term global warming may be more appropriate.

The high cost estimates reported would only be justified if catastrophic climate change were imminent. As global warming may be gradual and largely due to natural causes, measures that more closely link economic cost to the still-potential threat of very long-term global warming may be more appropriate. Such measures include encouraging voluntary actions, supporting academic research and educational programs on climate, and investing in the development and deployment new energy technologies.

Key results of this study of meeting the Kyoto target through intra-country tradable permits are:

Energy prices would double

The estimated costs of achieving the Kyoto target are high at both the national and state level because, without carbon limits, the economy, population and energy use are expected to grow steadily. Reducing energy use to 1990 levels within 10 years or more requires sending very powerful price signals through the economy. WEFA's analysis has determined that a $265 per metric ton of carbon (1992$) would be required. When added to energy prices, consumers would see an increase of 65 cents per gallon of gasoline and nearly a doubling of natural gas and electricity prices for businesses.

Consumers would see price increases in excess of 55% for electricity and 70% for home heating oil by 2010.

Commercial establishments, including hospitals and schools, as well as industrial facilities, would see electricity price increases of 60% by 2010.

Truckers and railroads would see their fuel costs rise by nearly 70 cents per gallon by 2010.

Energy Price Impact
of Limiting Carbon Emissions to 93% of 1990 Levels by 2008-2012
(Percent Difference from Baseline)

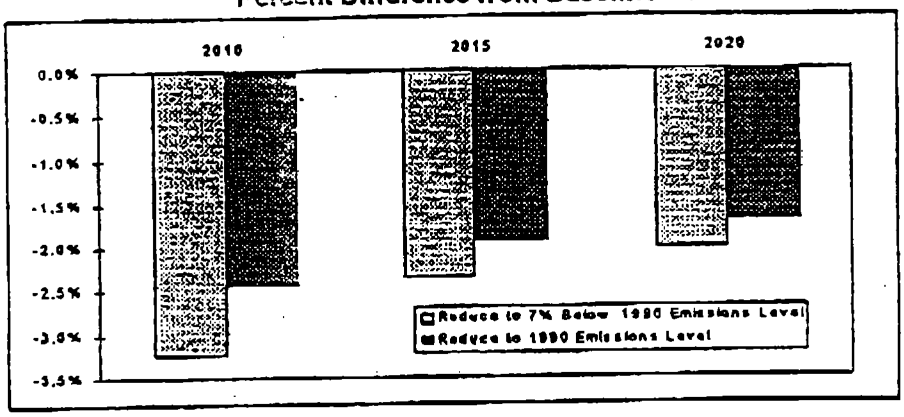
	2010	2015	2020
Carbon Permit Fee ($96/metric ton)	$265	$310	$360
Consumer Impacts			
Home Heating Oil	73.2	83.7	95.4
Natural Gas	65.7	78.3	94.3
Electricity	55.7	65.7	72.9
Motor Gasoline	47.5	53.6	60.2
Difference, Cents Per Gallon (96$)	59.1	68.1	78.2
Business Impacts			
Commercial Establishments			
Distillate Fuel Oil	98.3	112.0	127.3
Natural Gas	76.3	89.9	107.5
Electricity	60.2	71.3	79.4
Industrial Facilities			
Residual Fuel Oil	184.5	210.9	240.1
Natural Gas	118.6	135.5	156.4
Electricity	87.7	98.3	105.1
Trucking and Rail			
Diesel	56.2	64.4	73.6
Difference, Cents Per Gallon (96$)	68.3	78.8	90.7

Economic consequences would be severe: The U.S. would lose $300 billion in real GDP

The results paint a picture of a less prosperous 21st century America.

These powerful price signals result in premature retirement of capital stock, less capital for business investments, and less disposable household income as prices climb for electricity, gasoline, heating oil and air conditioning. As a result, the growth in GDP would be substantially slower, there would be a sharp rise in unemployment, salaries and wages would be lower, and prices for basic necessities such as food, medical care and housing would be significantly higher.

Percent Difference from Baseline GDP



Job losses would exceed 2.4 million; wages would be lower

Some workers would lose their jobs through a weaker economic environment.

All workers would face a slowing in their real wage growth as more workers compete for fewer jobs.

Implementing the Kyoto Protocol would have a devastating impact on workers. Some workers lose their jobs through a weaker economic environment while other workers lose relatively high paying manufacturing jobs and find only lower wage service jobs. All workers face a slowing in their real wage growth as more workers compete for fewer jobs. Hence, though the government compensates workers — through a refund of the fees collected to consume carbon-based energy resources — for their increased energy expenditures, total real disposable income falls due to reduced employment.

Families would suffer as the loss in aggregate income per household exceeds $2700

On a per household basis, the cost of signing the Kyoto Protocol results in an average real GDP loss in 2010 of $2,728 per household.

Real GDP Loss per Household	
2010	$2,728
2015	$2,083
2020	$1,876

Low and moderate income families would be hardest hit.

Low and moderate income families would be squeezed: higher costs, lower wages, fewer jobs.

Low and moderate income families would be hurt

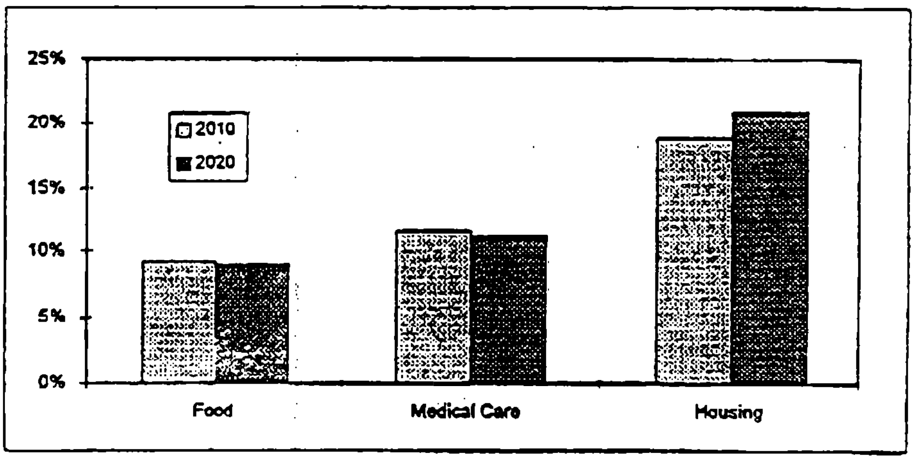
Low and moderate income families would be the ultimate losers under a carbon limits regime. Energy use is pervasive: all commercial activities require the use of energy, and energy is a necessity for households. Low and moderate income families spend a significant share of their income on basic necessities including energy. Raising energy prices would present an enormous hardship to these families. In combination with a weaker economy where workers are competing for less-well-paying jobs, families are projected to see a large rise in costs and a reduction in income.

Commodities such as food, medical care, and housing would be nearly 10% more expensive by 2020.

The cost of all necessities would rise substantially

Throughout the forecast period, food, medical care, and housing continue to become more expensive under the carbon stabilization case. By 2020, food is nearly 9% more expensive, medical care is roughly 11% higher, and housing is nearly 21% higher than the base case.

Inflation in the Prices of Food, Medical Care, and Housing: Percent Difference 7% Carbon Limitation Case and Base Case



The most severely impacted industries would be energy producing industries, industries that produce energy-intensive products, and industries that depend on export sales or face strong import competition.

As the imposition of carbon limits is not borne equally by all countries, U.S. exports would be relatively more expensive on world markets.

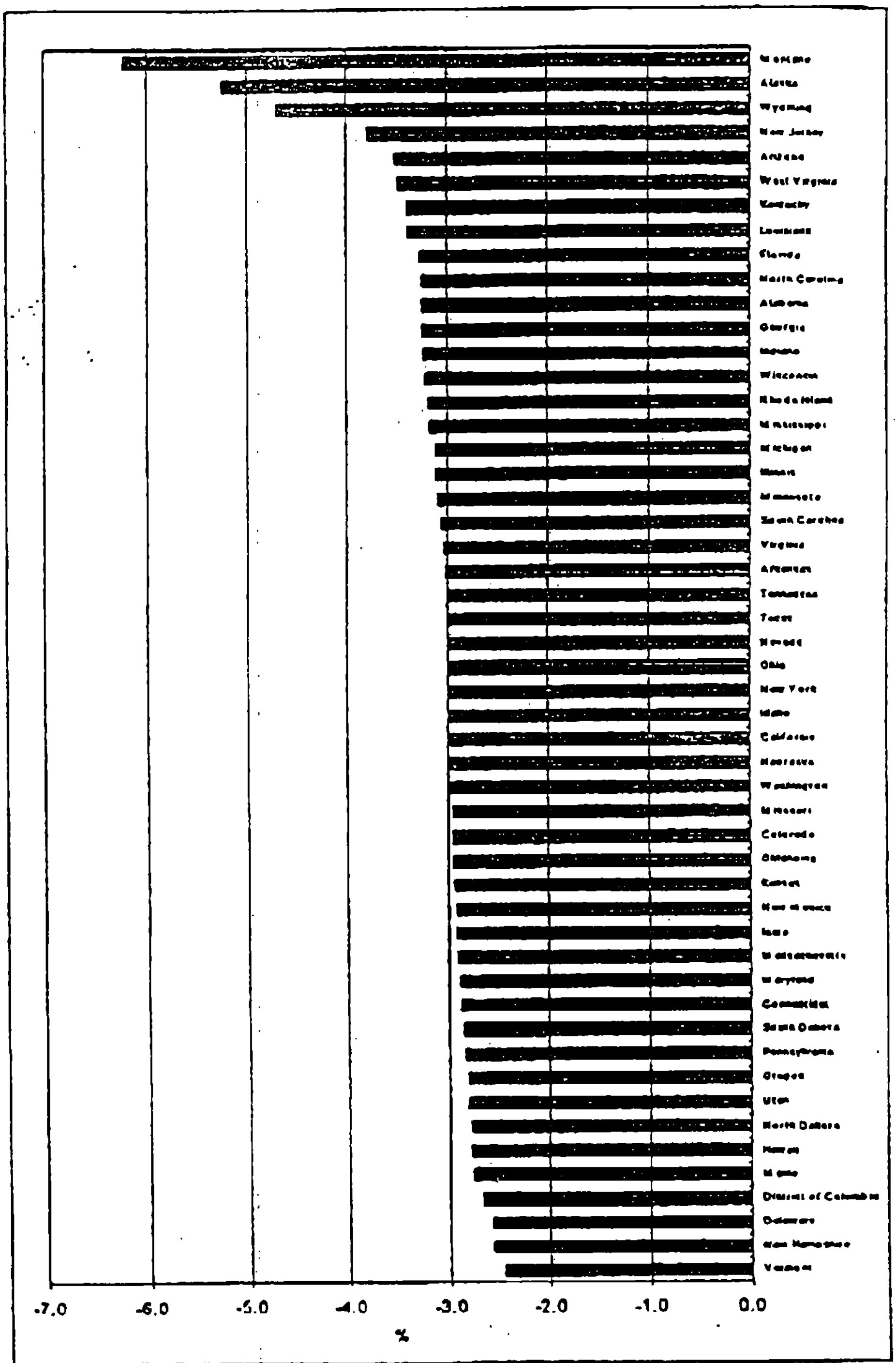
Every state would suffer output and job losses

The most severely affected industries would be energy producing industries, industries that produce energy-intensive products, and industries that depend on export sales or face strong import competition. Because the imposition of the carbon target and permit system is not borne equally by all countries (the developed economies of the OECD face comparable energy price increases, but the developing countries do not) U.S. exports are relatively more expensive on the world market. As a consequence, real exports are lowered dramatically, while imports are increased substantially, affecting:

- the chemicals and paper industries, which are both energy-intensive and already subject to stiff price competition from new producers in developing countries,
- the textile and apparel industries, which have difficulty competing on price due to higher U.S. labor rates, and
- the computer and electronic products industries, particularly from imports. (It is worth noting that the trade deficit in this area would escalate dramatically under the carbon emission limitation case.)

As a result, all states would suffer output and job losses that would persist as long as developing nations exempt themselves from the similar constraints on carbon emissions.

Real Gross State Product: Percent Difference from Baseline in 2010



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Trading, Sinks And Other Mechanisms

Measures not included in WEFA's analysis are international emission trading, sinks, the inclusion of an additional three gases, and mechanisms for promoting technology transfer.

While the Kyoto Protocol includes provisions that have been touted by its proponents as a means for alleviating the cost of complying with the Protocol's goals, these measures have not been tested and have been heavily discounted in WEFA's analysis. These provisions are currently only conceptual or have very uncertain implications for meeting the target. Measures not included in WEFA's analysis are international emission trading, sinks, the inclusion of an additional three gases, and mechanisms for promoting technology transfer (Joint Implementation and the Clean Development Fund).

However, these "market based" mechanisms are undefined in the Protocol and hence have to be negotiated by a large number of UN nations, many of whom have expressed open hostility toward such ideas. Further, the Protocol itself indicates these may only be supplemental to a country's internal programs. And finally, most are limited in scope--emissions trading, for example, won't involve the developing nations--, have no history in international relations, will be costly and difficult to administer, and may conflict with existing GATT or other agreements. For these reasons, it is premature at best to assume costs can be significantly reduced by these measures.

The Kyoto Protocol Is Not the Only Option

WEFA believes that a better climate strategy would be to match policy actions to an evolving understanding of climate science.

As the present study and the work of others make clear, the Kyoto Protocol forces policymakers to decide whether they are willing to risk the economic well being of their nation. From both economic and risk-assessment viewpoints, WEFA believes that there is a better climate strategy; namely to match policy actions to an evolving understanding of climate science; to increase investments in technology (should it prove necessary to substantially reduce fossil fuel use); and to gradually retire existing capital stock.

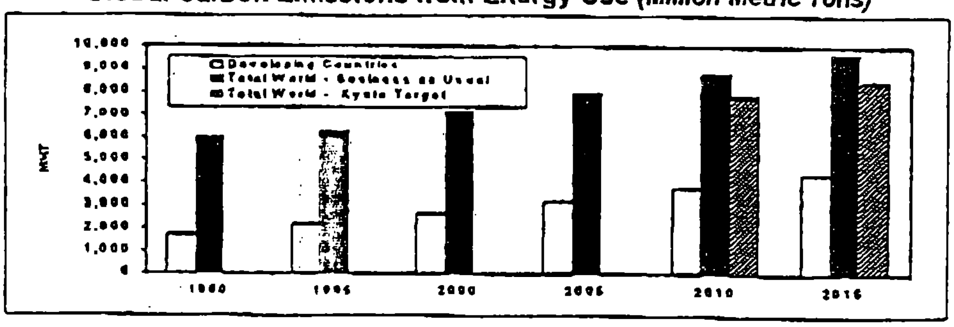
The developing economies of the world will not meaningfully participate in a greenhouse gas emission reduction or limitation program *until* technological alternatives exist that provide an equal or better opportunity for economic growth than is offered by fossil fuels.

Further support for investing in a technologically based solution is evident from the chart below. It is the developing countries that are the principal contributors to annual global emission increases. Driven by their expanding economies and their rising populations, the less developed economies of the world will emit more emissions than the industrialized economies by 2015. The reduction in carbon emissions that would result from the developed economies fully meeting their targets under the Kyoto Protocol would not significantly affect the annual global emissions. The developing economies of the world will not meaningfully participate in a greenhouse gas emission reduction or limitation program *until* there are technological alternatives that provide equal or better opportunities for economic growth than is offered by fossil fuels today.

The principal contributors to GHG emission growth are the emerging economies.

Reducing carbon emissions from participating industrialized countries by 5% would not substantially impact global emissions.

Global Carbon Emissions from Energy Use *(Million Metric Tons)*



Source: Energy Information Administration, *International Energy Outlook 1997*

(The study itself)

WEFA

A PRIMARK Company

Global Warming:
The High Cost of the Kyoto Protocol
National and State Impacts

1998

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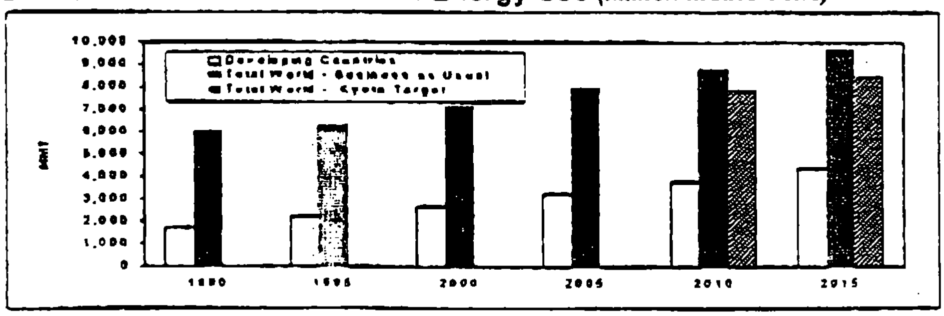
Global Carbon Emissions from Energy Use ***(Million Metric Tons)***



Source: Energy Information Administration, *International Energy Outlook 1997*

White House Climate Change Task Force

73+ Jackson Place, N.W. • Washington, DC 20503

FAX

To: ROB STAVINS

Organization/Title:

Fax: 617/495-1635 Phone:

Pages (including cover): 3 Date:

From: MARTHA WOFFORD

Phone: 202/395-2345 or 343-1074

Message:

ROB,

I'M STILL TRYING TO TRACK DOWN THE WEFA STUDY. IN THE MEANWHILE, I'VE ATTACHED SOME TALKING POINTS. NPR MAY NOT DO A STORY, APPARENTLY BECAUSE THEY'VE JUST LEARNED THAT THE STUDY WAS FUNDED BY THE GLOBAL CLIMATE COALITION. I'LL LET YOU KNOW IF ANYONE ELSE IS INTERESTED.

THANKS,

MARTHA

EXECUTIVE OFFICE OF THE PRESIDENT

COUNCIL OF ECONOMIC ADVISERS

Date: 6/9/98

Please deliver to: Rob Stavins

FAX number of addressee: 617-495-1635

Telephone number of addressee: ____________

From: JEFFREY A. FRANKEL, MEMBER
Lisa D. Branch, Exec. Asst.

FAX number of sender: 202-395-6958

Telephone number of sender: 202-395-5046

Number of pages, including cover sheet: 18

Message:

09/01/98 TUE 09:18 FAX
08/29/98 SAT 18:13 FAX

TALKING POINTS ON EIA STUDY OF THE KYOTO PROTOCOL

draft 8/30/98

- EIA is the premier statistical agency for energy matters. Their ability to collect and present data is second to none. However, a study of the economic effects of the Kyoto Protocol requires analytical skills that are not a main focus of EIA's activities. Therefore, it is not surprising that the analysis has some severe shortcomings.

① Gases; Sinks

- The Administration's economic analysis of the Kyoto Protocol incorporated directly all the key features of the Protocol -- the inclusion of 6 different greenhouse gases, the ability to average emissions over the 2008-2012 period to meet the target, the existence of flexibility mechanisms such as international emissions trading and the Clean Development Mechanism that will help reduce costs, and the fact that countries around the world will be looking for the most cost-effective ways to reduce greenhouse gas emissions. None of these features are incorporated into the Congressionally sponsored (Sensebrenner?) EIA analysis.

- The Administration's analysis of the Kyoto Protocol estimates that the United States will be able to meet its emissions reduction commitment under the Protocol using the international emissions trading system included in the Protocol at a permit price of $14-23 dollars per ton of carbon equivalent. Under this analysis, this permit price is the global cost of emissions permits -- all countries can buy permits at $14-23 per ton, and there are enough available permits for all countries to meet their Protocol commitments. (Other metrics could be used here -- gasoline prices, change in GDP, etc. I used permit prices as a shorthand metric.)

CEA: 83% Foreign
17% Dom
Equiv 80

② Does not include trading - takes as exogenous.

- Under the Congressionally-sponsored EIA analysis, the United States is assumed to meet its Protocol obligations completely alone, without the benefits of a worldwide emissions trading system. Effectively, what the EIA analysis does is compute the cost curve for emissions abatement in the United States alone, and ignores low-cost emissions abatement opportunities available in other countries. The Administration is aware that the United States may have a relatively high cost of reducing emissions domestically, which is why the Administration insisted that flexibility mechanisms such as international emissions trading were included in the Protocol.

- The Congressionally-sponsored EIA analysis is based on a short-term macroeconomic forecasting model (the DRI) model, that is inappropriate for making forecasts going out a decade or more. A more sensible approach (and one that the Administration used) is to base estimates on a general equilibrium-type model, which incorporates the dynamism and flexibility that is the hallmark of the American economy, especially when viewed over periods of a decade or more. (For example, the American economy has adopted the Internet in the past decade, leading to industries and services that could not be dreamed of a decade ago. The class of models used by EIA does not adequately capture the inherent flexibility in the U.S. economy.)

Compliance with the Kyoto Protocol

Macroeconomics of emissions trading joint implementation,

and the clean development mechanism

Johannes Bollen, Arjen Gielen, and Hans Timmer[1]

Abstract

We analyse the economic impacts of regional CO_2- emission constraints under the assumption that on the medium term the Annex-1 region (OECD regions and Economies in Transition) will make abatement efforts to comply with the Kyoto Protocol. The paper focuses on the role of flexible instruments. Next to the polar cases with no or full Annex-I emission trade, we first analyse emission trade within two separated markets in Annex-1 (the first block contains Europe, including Central European countries, and all other Annex-1 countries as the second block). The second case concerns a restriction on the reductions to be achieved abroad. Third, we analyse the case in which Annex-1 countries may jointly implement investments non Annex-1 countries. The applied general equilibrium model WorldScan is used to analyse macro-economic impacts for several different regimes and cases.

Keywords: International Agreements, CO_2- emissions, Climate change, tradeable permits, joint implementation, clean development mechanism, cost-effectiveness

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1 Introduction

The Kyoto Protocol was adopted during the third Conference of Parties to the Framework Convention on Climate Change (FCCC) in December 1997. The Protocol defines commitments for developed country (Annex-1) parties to reduce their overall greenhouse gas emissions by an average of at least 5.2 % below their 1990 levels in the five years after 2008 (the first budget period). The average reduction commitments differ among the Annex-1 parties. The EU committed to 8%, the USA to 7% and Japan to 6%, while Australia, New Zealand, Norway and Iceland committed to levels above 1990 emissions. Of the Central European Countries listed in Annex-1, most share the EU reduction target, except for Poland (6%), Hungary (6%) and Croatia (5%). Russia and the Ukraine have only committed to a stabilisation at 1990 levels. The parties to the FCCC have introduced three new instruments under the Protocol, allowing parties (or firms) with emission limits to achieve emission reductions outside their national borders. There are three mechanisms for transferring the emissions under the protocol:

- *Joint Implementation* (concerning project-level 'credits', as defined in Article 6, transferrable among Annex 1 parties - credits can be earned only in the first budget period and be used during that same period of five years),
- *Clean Development Mechanism* (concerning 'certified reductions', defined in Article 12, transferrable from non Annex 1 parties to Annex 1 parties - certified reductions can be earned in projects from 2000 onwards, and be used to enlarge the quotas in the first 'budget period', running from 2008 till 2012), and
- *Emission Trading* (defined as 'permits', in Article 17, transferrable among Annex 1 parties - permits are the quotas that are applicable in the budget period - that is, they are equal to the quotas agreed in Kyoto, corrected for CDM certified reductions).

The main reasons for introducing these instruments have been to reduce the costs of emission reductions, as these are generally lower outside OECD countries. The CDM was also introduced to enhance the effectiveness of emission control by promoting early emission control in non-Annex-1 countries[2]. The impacts of using these instruments are not yet clear. For one, the impacts depends crucially on the effective workings of the 'market' for permits, reductions, and credits. Also, the principles and rules for using the instruments have not yet been clearly defined and will be the subject of further negotiations during the fourth meeting of the Conference of Parties in Buenos Aires, Argentina, in November 1998.

Regarding intra-Annex-1 flexibility, there are some explicit voluntary limitations to the use of the instruments. The Protocol states that the contribution of ET and JIshould be "supplemental" to national measures. During the Kyoto negotiations the EU argued for setting a limit on the contribution of ET to meeting the commitments under the protocol. Another type of limitation is reflected by the possible emergence of 'clubs' or 'coalitions' within the Annex 1 group, or when markets are separated for other reasons. As for flexibility across the Annex-1 borders to non Annex-1 countries, the impacts are not clear. As for the Annex-1 internal flexibility, ET and JI are closely related, and we will take them as parts of the same system. Potentially, the CDM could make a major contribution as there are, generally perceivable, many cheap options for emission reductions in developing (non Annex-1) countries as part of sustainable development projects. Moreover, the Protocol allows for gaining greenhouse gas emission reduction credits from such projects from 2000 onwards, while ET and JI between Annex-1 parties are confined to the first budget period (i.e. from 2008 to 2012). However, dealing with countries that do not have emission reduction targets will make the certification of the reductions a central issue.

[2]At http://www.unfccc.de/fccc/docs/cop.htm the protocol text is published.

In this paper, we will shed light on three issues on the agenda in Buenos Aires:

- [1] limitations to ET to deal with additionality,
- [2] possible impacts of separated markets, and
- [2] the effects of the CDM.

We make use of WorldScan to analyse the quantitative effects of the different cases, taking an Annex 1 perspective and focussing on regional differences within this group.

The rest of this paper is organised as follows. Section 2 analyses the three issues. Section 3 provides information on how to we used WorldScan to analyse these. Section 4 presents the results of the model simulations. Section 5 draws the main conclusions of the outcomes.

2 Analysis of limiting ET, separated markets, and CDM

Generally, geographical flexibility is analysed under the assumption that uniform marginal abatement costs across countries imply the least-cost - or 'efficient' - solution to distributing emission reductions (see IPCC, 1996, for an overview on flexible instruments). The allocation of emission reductions can be agreed upon based on other considerations than efficiency. In theory, the efficiency and equity can be separated. Thus, the efficient allocation can be combined with an equitable distribution of the burden. For such an equitable burden sharing, international side payments are necessary.

Two emission trading clubs

As opposed to a fully competitive ET system among all parties - where a unique price goes for all emissions[3] - a non-competitive system and/or a system in which not all parties join may have many prices. For our purposes, we assume that there will be two clubs. This is a limit to competition: not all permits may be traded by all Annex 1 countries. However, we assume a competitive market within both clubs, so that there is no price discrimination within the clubs[4]. This leads to two carbon prices - one price for each club. The existence of two prices implies an efficiency loss compared to trade among all parties. There will be a club with high marginal costs - the high price club - and one with lower marginal costs - a low-price club. The effects on the members of the clubs are determined by the terms of trade. In the high-price club, the net exporters of permits will have a gain compared to a full trade case because their permit exports are now more valuable. They will, on the other hand, export less permits, so that the net effect depends on the combination of these two effects. Conversely, the net importers in the high-price club suffer a loss compared to full trade, because their imports become more expensive. Assuming that there is no price discrimination within the club therefore implies that the net exporters may gain, while the net importers may suffer a terms of trade loss. Also, the loss to the importers is that they will now have to abate more domestically and at higher cost. Given the same assumptions, the reverse story goes for the low-price club. In that club, the net importers may gain, because the price for their imported

[3] See IPCC (1996) for a concise overview of the basic analysis of ET, and the relevenat literature.

[4] The competitive price need not be the outcome in a club: a club is a non-competitive outcome, so why should distribution within the club be competitive? The competitive prices do deliver information on the negotiation space of the clubs. The competitive price is the lowest price at which the net exporter in the club would be willing to trade in the club. The no trade price of the net importer in the club is the maximum price at which this country would be willing to trade. In case of more countries, the price would lie between the highest no-trade price of net exporters, and the lowest no-trade price of the net importers.

permits is now lower than in a full trade case, while net exporters in that club may lose. Clearly, as compared to a no trade case, the clubs may prove to be a step forward. The step delivers gains, because there is trade in both clubs. Given that bilateral deals may be easier to strike on a shorter term, clubs could be a first step. However, it is unlikley to deliver gains on the long run, because there will be losers. Given that the protocol is a volunatry agreement, this is likely to lead to problems with the compliance and enforcement of the agreement.

Limits to emission trading

The condition that ET should be supplemental to domestic action has led to discussions on limits to ET. Assume we allow for a maximum of 50% of the reduction targets to be reached outside the national borders. Assume for clarity that all OECD countries are rationed in their demand for emission permits when a restriction percentage of 50% is agreed. The rest of the Annex 1 countries will then be net exporters of permits. Given that OECD regions are rationed in their demand for permits, they will face a higher price domestically than the price in case of full trade. So, apart from the restriction that more should be done domestically, this amount of emission reductions also has a higher unit cost. Also, the domestic marginal costs will again differ across region. This points at an inefficient solution. In this way in it a step back from the full ET case towards a no-trade case. The competitive import price of permits can lie below the domestic price of the importing regions. When supply is competitive, a unique price will emerge which is determined by the region with the lowest marginal abatement costs. Therefore, the part of demand for permits that can be imported can for many countries be traded at a lower price than domestic marginal costs. The price for traded permits can become very low when supply is fully competitive. Now assume that not all regions are rationed. When a region is not rationed by the restriction on permit imports, its marginal costs will not lie above the full trade case. Indeed, when the 50% target lies above its full-trade demand, the domestic marginal costs may now be the same as in case of full trade. At the same time, given that other regions are rationed, the demand for the traded permits must be lower than in the full trade case. Thus, with competitive permit supply, the price for traded permits will be lower as well. This also benefits the region that is not rationed - its imports become cheaper and it will import more. Therefore, although the quotas have been agreed in Kyoto, the burden sharing is still highly dependent upon the rules and guidelines for ET as well as on the possible emergence of clubs. The principle of additionality could lead to different percentages for different regions. This could be used to force rationing on all countries involved and in so doing reduce the bias in favour of the non-rationed regions, and perhaps to aim at equalising the marginal abatement costs for domestic actions[5].

In case of both types of restrictions, the impacts on international trade are important aspects of the debate. When restrictions imply marginal abatement costs diverging across regions, the pressure from industry on the negotiations will become more severe: because the competitive position of industry in the rationed region will be negatively affected compared to the non-rationed region. This relates to one of the major benefits of ET. The equality of marginal abatement costs across regions will lead to an efficient emission reduction. Also, given that some regions have already implemented carbon taxes, equalising the marginal abatement costs allows for some of these distorting prices to be removed. The ET approach leads to a more levelled playing field for international trade and environment issues.

[5] Another restriction could be on the exports of permits in ET systems. These restrictions are suggested in order to deal with the 'hot air' problem. Hor air refers to emission permits which a country can obtain without implementing any abatement - simply because its baseline lies below the targets as set in Kyoto. Such hot air problems are a special case of 'giving too much permits'. Restricting exports leads to higher prices for the potential importers thus leading to a welfare loss. At the same time, given that the targets are guaranteed - which we assume throughout this paper - hot air does not pose any problems, because quotas are already defined.

The Clean Development Mechanism

In case of CDM projects, the host country has no targets, and the investor can add all certified reductions to its targets in the first budget period. To a large extent, CDM investments are based on the same incentives as ET. They will only be profitable when they concern projects of which the abatement costs are substantially lower than those in another location - e.g. the investor country itself. Also, for this reason, the economic rationale as well as impacts on marginal abatement costs and allocation of emission reductions can be compared using the same macroeconomic model. CDM differs in a fundamental respect from ET: in the former case there are no quotas for the host country. For this reason, CDM may have some undesirable aspects, which do not emerge with ET among countries that do have quotas. First - as with JI projects - a technology may be subsidized that would be applied even without subsidy, because it is difficult to assess a business as usual world without subsidies. In this case the subsidy will be a mere income transfer, instead of a tool to reduce emissions. With JI, there will be a feedback on the national level, because the host country will have to reach its quota. With CDM, this causes a second problem. Due to the subsidy, unit production costs of energy intensive production could decrease, so that host country output of energy-intensive industries can be expanded at the cost of investor country market share. This could imply at least some loss of market share by investor country industries, which will reduce the profitability from the investor's point of view (the effect is akin to the industry relocation effect, but in this case it is even stimulated by the investor countries). It can also imply that lower energy intensity the host country goes hand in hand with higher total energy use. This is a perverse type of carbon leakage: effectively the investment has not led to emission reduction, but it has yielded emission credits. The perverse effect can be that global emissions grow due to such projects. To avoid, or at least limit, the carbon leakage effects of CDM projects, the projects should probably be focussed mostly on the *replacement of existing capacity* by cleaner production technologies that can produce the same amount of products[6]. E.g. the replacement of a power station using coal by a power station which produces the same amount of electricity, but uses oil or other cleaner energy sources. Such a replacement does not change total capacity in the receiving country and it does not change the costs of new capacity. Therefore, the probability of serious leakage is low. Also the business as usual scenario is rather straightforward, at least as long as the existing capacity was not about to be scrapped because of economic or technical reasons.

We therefore analyse CDM projects only on existing capital. Such investments are assumed not to affect the overall production capacity, but to alter the input of factors of production[7]. For the*investor*, the incentives for such CDM investments are derived from the marginal abatement costs in alternative locations, and its marginal investment costs. As long as the marginal cost of CDM investment is lower than the marginal cost in alternative locations, it will be profitable for the investor to continue expanding its CDM activities in the host country. The investor earns credits which it can add to its current quotas[8]. The incentives for the *host* country are determined by the revenues of the project. Will the project be paid

[6] In such cases, the business-as-usual scenario is rather certain and the tendencies for leakage are only limited, because expansion of output is impossible. When there are pure - i.e. costless - technology spill-overs due to such investments, there is still some danger of leakage, but pure spill-overs are difficult to imagine in these cases.

[7]Note that with ET also the existing capital will be adjusted. But, because there are national quotas, ET can also safely be used to address emission reductions on new investment: there will be a macroeconomic feedback which ensures that the national quota will be reached. The main difference with CDM/JI is that the later is defined *solely* on existing capacity. See the technical appendix for a description of the model of JI/CDM in WorldScan.

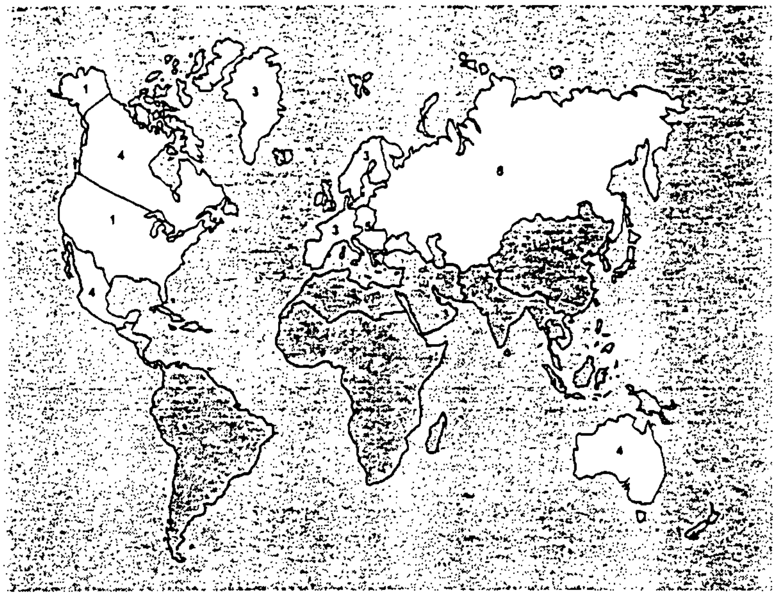
[8]We assume for simplicity, that investors have a one-year horizon for such investments. As with all recursive dynamic models with an explicit distinction between existing and new capacity, the emission reductions during a certain period will have effects after the end of the relevant period. Thus, when we analyse ET in Kyoto's first budget period we should be aware of the effects that such ET has on the capital stock. Even after the end of the budget period, emissions will be lower than in the baseline because the capital stock has become less energy-intensive. By making the same assumption for CDM/JI projects, the policy cases are comparable.

in full by the investor, there will be no costs for the host. There are, however, secondary effects, which provide incentives for the host. Most importantly, the adjustments have made the existing capital stock less energy-intensive, so that production costs are decreased. Although carbon leakage is reduced by focusing on existing capital, it cannot be excluded. For example, the replacement could increase future capacity if the *life expectancy* of the new factor is longer than of the old one. Also, when Part of the Annex 1 target may be reached outside the Annex 1 area, this implies that non-Annex 1 energy demand is reduced, while Annex 1 energy demand is increased. The energy demand reduction in non-Annex 1 countries affects the regional energy markets. If energy markets are not entirely globalised (due to transportation costs, e.g. for coal) the lower domestic energy demand leads to lower domestic energy prices. These will lead to leakage (from existing to new capital) witin the non-Annex 1 region. Although energy-saving investments are focused on the old capital stock, the lower energy price affects the new capital stock. Therefore, expansions of the capital stock will become more energy intensive than without CDM projects.

3 Model, baseline, and policy assumptions

In this section, we discuss some features of the world economic model WorldScan and the assumptions on the baseline and the policy cases.

Figure 1 *World regions and Annex 1 regions in WorldScan*



1: United States, 2: Japan, 3: Western Europe, 4: Rest OECD, 5: Central Europe, 6: FSU, 7: Middle-East and Northern Africa, 8: Rest of Africa, 9: Latin America, 10: China, 11: Dynamic Asian Economies, 12: Rest Asia. The Kyoto agreement contains emission reduction targets for the regions 1 to 6 (the "Annex 1 countries"; in white).

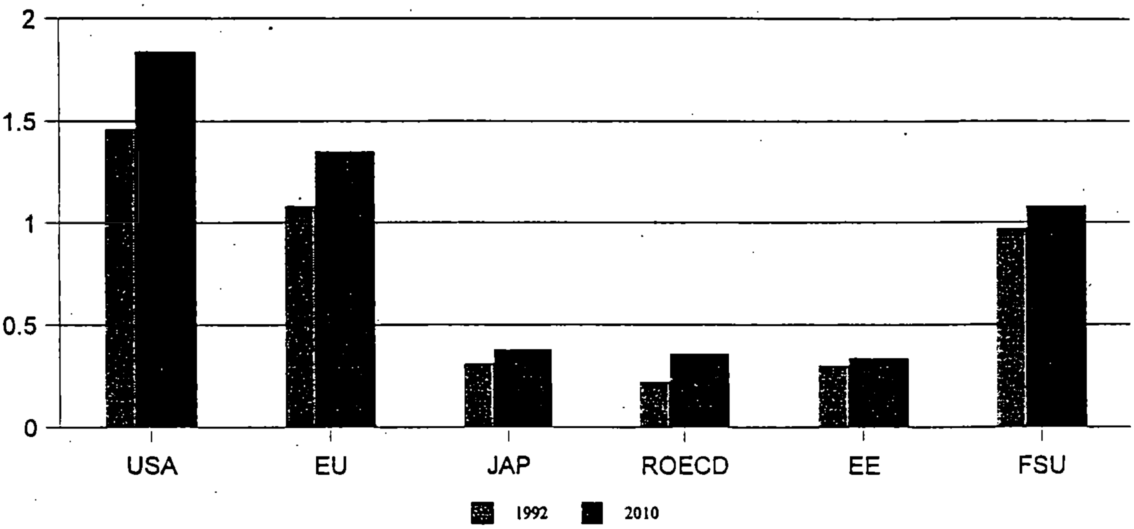
3.1 Model specification

WorldScan is a numerical scenario and policy simulation model. It is based on general equilibrium theory. This implies that economic sectors - and the agents in those sectors - interact in the macro economy. The macroeconomic feedbacks through prices affect production, employment, and value added in all sectors of the economy. In WorldScan, these macroeconomic feedbacks also cover international trade in commodities, financial capital, and emission permits. It has a recursively dynamic structure in which investment in physical capital stock is made every year with a one-year planning horizon. Trade is modelled assuming that sectoral commodities are differentiated according to the region of origin. This implies that there is international bilateral trade in the commodities of each sector. Furthermore, the model distinguishes between newly installed capital - to be used in the next and following periods - and the existing capital stock. The latter can be changed to a limited extent in order to reduce input costs - modelled as retrofit investments - while the former is more easily malleable. We refer to Geurts, Gielen, Nahuis, Tang and Timmer (1997) for an extended discussion of WorldScan. The appendix provides more detailed information on the model. There are six different Annex 1 regions and six non Annex 1 regions. These do not perfectly match the Annex groups, but make a fair approximation. Figure 1 shows the world map with the WorldScan regions.

3.2 Baseline projections

As reduction targets were set with 1990 as a reference year, the regional impacts in 2010 depend on growth in a no-policy or '*baseline*' projection, shown in figure 2. The Annex 1 target of a 5% cut compared to 1990 levels amounts to a 22% cut compared to emissions in 2010. All OECD regions have to reduce their emissions by more than this average.

Figure 2 *Baseline emissions in 1992 and 2010 in GtC per annum*



3.3 Policy cases

Clearly, there is a strong difference between the two reference years. On the one hand, most reductions appear to become more severe for the OECD regions, due to strong economic and emissions growth in the baseline. On the other hand, the rather low growth in emissions in EE and FSU implies that reduction targets are not very severe. For FSU, the zero growth target could even imply some - very modest - growth compared to the baseline. The policy instruments to achieve these targets are presented in table 1.

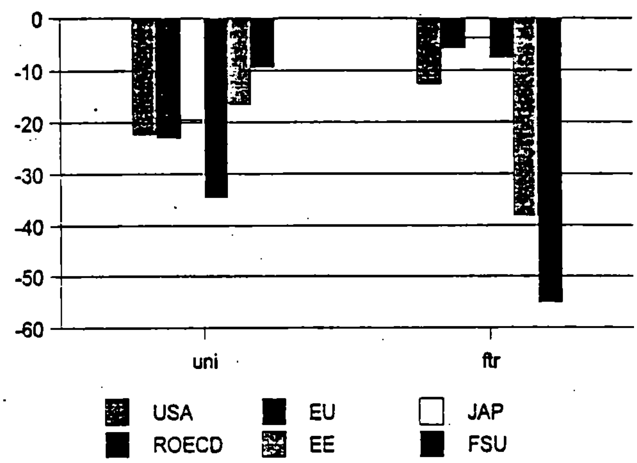
Table 1 Policy cases

Case	*Abbreviation*	*Description*
No trade	*UNI*	Kyoto targets, to be reached within Annex 1 by each model region separately.
Full trade	*FTR*	Kyoto targets, to be reached within Annex 1 with one emissions price and transfers based on Kyoto quotas.
Clubs	*CLUB*	Kyoto targets, to be reached within Annex 1 with two trading clubs (EU/CE and the rest of Annex 1), with transfers within clubs but not between clubs.
Restricted trade	*RTR90*	Kyoto targets, to be reached within Annex 1 with trade up to 10% of the quota in all Annex 1 regions, and transfers based on this 10% (at maximum).
Restricted trade	*RTR85*	Kyoto targets, to be reached within Annex 1 with trade up to 15% of the quota in all Annex 1 regions, and transfers based on this 15% (at maximum).
Clean Development Mechanism	*CDM90*	90% of the Kyoto targets to be reached within Annex 1, without trade among Annex 1 and with investment subsidies from Annex 1 to non Annex 1 equal to investment needed to reduce emissions.

4 Simulation results

This section presents main results of the five cases simulated with WorldScan. We discuss the impact on realised emissions and the real marginal cost of carbon abatement[9]. Figures 3 and 4 present emissions in Gigaton Carbon per annum (GtC) in 2010 compared to the level in the baseline for all cases. Figure 5 presents the marginal abatement cost in real dollars of 1992 per ton of Carbon ($/tC) in 2010. The comparison of UNI with FTR shows that an efficient distribution of emission reduction differs strongly from the agreed targets given our baseline assumptions. OECD reductions - especially those in the ROECD region - should be less from an efficiency point of view. Clearly, with emission trading in FTR, this can be achieved, where burden sharing is restored through the side payments concerned with permit trade. See Gielen and Koopmans (1998) for a discussion of the economic impacts of these two cases.

Figure 3 Emission reduction compared to baseline in 2010, UNI and FTR



Now turn to the other three cases - restrictions to imports of 10% of the quotas (RTR90), two trading clubs (CLUB), and allowing limited use of the Clean Development Mechanism up to 10% of the Annex-1 quotas (CDM90). Figure 4 shows the emission reductions in these cases. Figure 5 shows the real carbon prices in 2010 in 1992 dollars.

4.1 Permit trade clubs - 'CLUB'

Looking at figure 4, the EU and EE appear to be in a high-price club. In that club, the net importer - i.a.c the EU - suffers a loss compared to the FTR case, because the permit price is higher, thus increasing the domestic marginal abatement costs. At the same time, the EE countries gain from the higher carbon price, and because demand is higher - as can be seen from figure 5, they will now reduce more. Thus, they obtain net gains. Clearly, the other club - the low-price club - also has winners and losers compared to a FTR case. The net importers gain because the price at which they can import permits is lower than in FTR, also implying a lower domestic marginal cost and thus lower total costs.

Figure 4 Carbon prices in all cases, in real $/tC in 2010

[9]We do not include results on macroeconomic and sectoral changes, but instead focus on distribution of emissions and the level of carbon prices in order to focus on the big picture. In a follow-up to this paper, we also focus on the macroeocnomic and sectoral impacts.

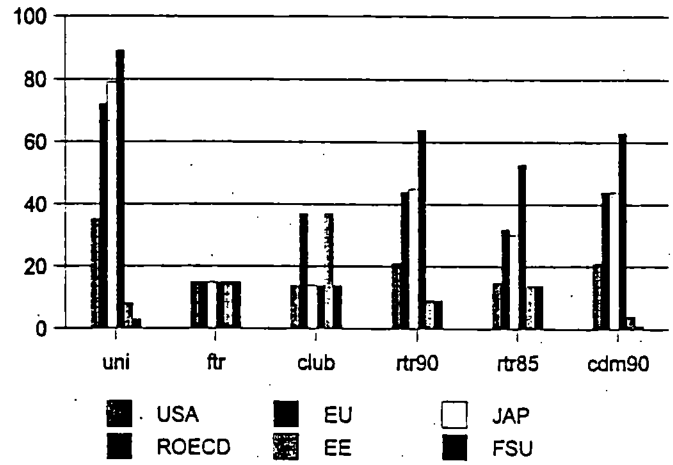
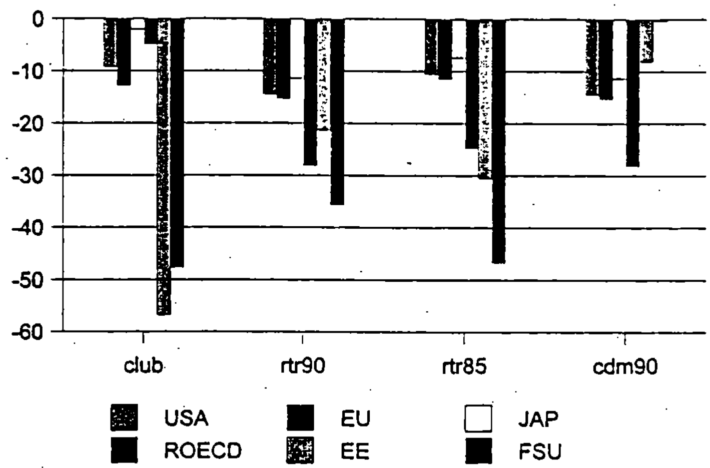


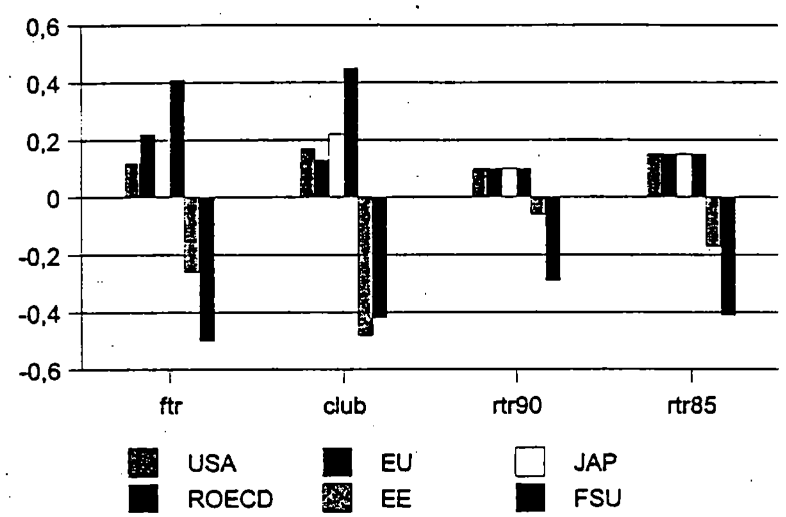
Figure 5 *Emission reduction compared to baseline in 2010, CLUB, RTR90, and CDM90*



4.2 Limited permit trade - 'RTR90 / RTR85'

The demand for traded emission permits has decreased in the RTR cases, so that the price for traded permits has decreased, as is shown in figure 4. Figure 5 shows that all 4 OECD regions reduce more domestically than in the FTR case - this is the target of the policy, and at a 10% restriction it also works this way. Figure 6 shows the percentage of emission quota that is imported from abroad. Clearly, in he RTR90 case, this is at most 10% for all Annex-1 regions.

Figure 6 Permit imports as share of quota in 2010

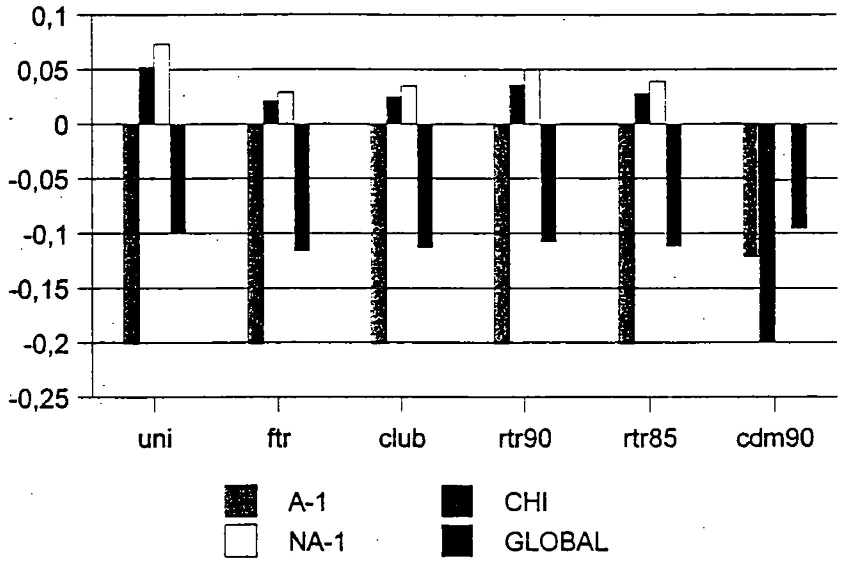


The cut-off points at which import demand is rationed are equal to the import shares in the FTR case. Clearly, ROECD wants to import most and will be hurt most by a binding restriction, even when it is as high as 40%. For the EU and Japan, these shares are around 20%, while the USA's cut-off point lies at 12%. Thus, when the restriction percentage is between 12 and around 20%, the USA will not suffer any loss from the restriction, while the other OECD regions will be rationed. This holds for the RTR85 case. The decrease in the carbon price due to lower demand will imply a gain for the USA: they can import more permits, and at a lower price, so that domestic marginal (and thus total) costs will decrease.

4.3 Limited Clean Development Mechanism - 'CDM90'

We analyse the CDM assuming that there is no ET within the Annex 1. Looking at figure 5, we see that the CDM projects offer opportunities to earn certified reductions that increase the domestic emission allowances. Because the marginal abatement costs are lower outside the Annex-1, this implies that even EE and FSU now import permits. Carbon prices in the UNI case are higher than in the CDM case. This is due to the realisation of targets through CDM investments outside the Annex-1. The prices decline for all regions, because of the less stringent domestic targets.

Figure 7 Emission reductions in 2010 compared to baseline - selected regions



The most important result coming out of this last figure is that global emission reduction is less when CDM is implemented without additional requirements on non Annex-1 countries. We see that global emission reduction without CDM is somewhat higher than that wih CDM - compare the UNI with the CDM case. The perverse leakage is therefore only limited, but it is present at the global level.

5 Conclusions

Given the projections for emissions in the baseline, the Kyoto targets do not reflect an efficient distribution of emission reductions. Marginal abatement costs differ strongly across regions affecting the competitive position of the regions, and leading to high abatement costs. Emission trade based on the Kyoto targets can reduce the costs for the Annex 1 group as a whole, and can also make all separate regions better off. In a fully competitive market, regions with either relatively high or relatively low cost of abatement will gain the most.

The requirement that 10% of the agreed emission quota may be imported from abroad is restrictive for all OECD regions compared to the full trade case, but in the 15% case the USA is not restricted in contrast to the EU. Limiting trade will lead to diverging marginal costs across regions and the total Annex-1 abatement costs will be higher than in a fully competitive trade case. Also, an increasing percentage of allowable emission permit imports will have asymmetric impacts on the different Annex-1 regions. As soon as the restriction is not binding for one of the Annex-1 regions, this region can be gaining compared to a full emission trade case. When compared to full emission trade, two separate clubs of emission trading will be costly to the Annex 1 as a whole: again, the marginal abatement costs will diverge. Compared with a case without emission trade, however, clubs could provide a profitable step in the right direction. From a macroeconomic point of view, the most important difference between Annex 1 flexibility through Joint Implementation and emission trading on the one hand, and global flexibility through the CDM on the other, is the absence of national targets in the case of CDM[10]. This absence leads to a danger of CDM leading to carbon leakage. This leakage can be enlarged when technological spill-overs take place via CDM projects. This is closely related to so-called rebound effects of energy-saving. CDM-related carbon leakage can be minimised by focussing the CDM primarily on replacement investments, and on sectors which are sheltered from international competition. The non-OECD regions in the Annex 1 stand to lose from CDM without emission trade, as compared to Annex 1 ET. This is because they become net importers of permits. This is worse than being a net exporter of permits to the Annex 1 in case of competitive Annex 1 emission trading. The majority of CDM projects will take place in China. A very limited amount of carbon leakage takes place when CDM is implemented.

[10]The model used has limitations which limit the scope of the conclusions. One of the major reasons to have JI and the CDM is that international ET requires institutional development as well as political will. We explicitly view both JI and CDM as precursors to emission trade. This should be the long run focus for the climate change policy approach. Another limitation placed by the model is that is assumes flexible adjustments. On the medium term, this implies that the overall level of macroeconomic costs will be higher than presented here.

Technical appendix: Emission Trading in WorldScan

The discussion on ET, JI and CDM in section 2 leads to two distinct approaches in the model. For ET and JI in the first budget period, we take the Kyoto targets for emission levels as the emission permits allocated to each region. In the model, we take energy price increases as the policy instrument in these cases. This will reduce energy demand and in so doing lead to lower CO_2-emissions. In order for the emission target to be achieved, we use of a standard procedure to calculate the corresponding shadow price. This shadow price can be interpreted as tradeable emission permits or tradeable JI credits. Especially at the inter-regional level in the model, this price will then be uniform across a set of regions. Such a uniform price will lead to another distribution of the total emissions over regions than the targets. Thus, when we project that Central Europe will reduce not 8% as compared to 1990 but 18%, it will export 10% of 1990 levels as permits to other regions. The income obtained from this export of permits is equal to the volume (in tC) multiplied with the uniform shadow price (in \$/tC). The box below shows the equations in the model to calculated the shadow price and the payments.

Box 1: Modelling ET in WorldScan

The WS model calculates the equilibrium carbon shadow price P^* using an iterative process, in which the value of P^* is calculated from that in the previous step - P - increased by the difference between the targeted emission TAR and the resulting emission EM. As long as the emissions are not equal to their target level, P^* will not be equal to P. The equilibrium value of $P^*=P$ is obtained when EM=TAR. Thus,

$$CTAX^* = CTAX + (EM - TAR) / TAR$$

with the following identities

EM	=	$\sum_r (EM_r)$	r= countries in the abatement coalition (from 1 to 12)
TAR	=	$\sum_r (TAR_r)$	r= countries in the abatement coalition (from 1 to 12)
EM_r	=	$\sum_f (EM_{fr})$	f= coal, oil/gas
EM_f	=	$EQN_f * \sum_s (Q_{f,s})$	s= energy demand sectors
PD_f	=	$PS_f + TAX_f + CCT_f$	
CCT_f	=	$EQN_f * CTAX^*$	
TRA_r	=	$CTAX * (EM_r - TAR_r)$	

with

CTAX	=	the uniform carbon tax in US\$ / tC
EM_r	=	CO_2- emissions in tC of region r in the abatement coalition
TAR_r	=	CO_2- permits in tC of region r in the abatement coalition
EM_{fr}	=	CO_2- emissions due to fuel f in region r in tC
EQN_f	=	CO_2- emission factor of combusting fuel f in tC / GJ
QD_{fs}	=	demand for for fuel f by sector s in GJ
PD_f	=	user price of oil/gas and coal (\$ / GJ)
PS_f	=	supply price of oil/gas and coal (\$ / GJ)
TAX_f	=	domestic taxes on oil/gas and coal (\$ / GJ)

With ET, the net transfers via the current account are determined by the difference between targets and realised emissions, and the carbon shadow price, as in

$$TRANSFER_r = (TAR_r - EM_r) * CTAX$$

with

$TRANSFER_r$ = the net transfers via the current account due to ET.

This value is negative for net importers and positive for net exporters. Note that in case of ET, the sum of the transfers within the trading block is zero (it is pure reallocation of income and emissions).

Technical appendix: CDM and JI in WorldScan

WorldScan contains two options to change production technologies of existing capacity. One option is to scrap part of existing capacity and to replace it by capacity with new technology. The other option is what we named retrofitting of existing capacity: By adding more capital one can reduce one of the other input, keeping total capacity unchanged. WorldScan includes the retrofitting option, because it is a relevamnt mechanism: it is normally more efficient than scrapping existing capacity and replacing it by completely new capacity. It might be expected that such a CDM is efficient in the sense that it actually decreases energy demand in the receiving country compared the a business-as-usual baseline. Efficiency in terms of location of CDM projects will be achieved in the model by assuming equal marginal costs of emission reductions.

Box 2: Implementation of JI in WS

Retrofitting investments change input intensities, but do not alter the size of output capacity. Substitution possibilities of retrofitting investments are specified as a CES function with a substitution elasticity of 0.5. This leads to the following isoquant.

$$E = \left[1 - \frac{\alpha_k R}{\alpha_e K_0 + R}\right] E_0 \qquad R \geq 0$$

where	E	energy input after retrofitting	E_0	energy input before retrofitting
	R	retrofitting investments	K_0	capital stock before retrofitting

In each region and each sector cost minimization, under restriction of the isoquant, determines the optimal amount of retrofitting investments. In formulas:

min! $C = p_e E + p_k R$

where p_e = energy price,
p_k = capital cost
$p_k = (r + \delta)p_i$
with r = real interest rate
δ = rate of depreciation
p_i = price of investment goods

This results in R*, which minimizes the costs of retrofitting investments

$$R^* = \max\left\{0, \left[\frac{\alpha_k p_e E}{\alpha_e p_k K}\right]^{1/2} - 1\right\}\alpha_e K$$

The purpose of CDM is to reduce CO_2 emissions by financing retrofitting investments. Optimal retrofitting investments from this perspective are derived from minimization of a different cost function:

min! $C = p_c\, q\, E + p_k R$

where p_c (shadow) price of carbon emission
q emission coefficient

This results in R',equal to the optimal CDM investments

$$R' = \max\left\{0, \left[\frac{\alpha_k p_c q E}{\alpha_e p_k K}\right]^{1/2} - 1\right\}\alpha_e K$$

The actual retrofitting investments equal

$$R = \max\{R^*, R'\}$$

A necessary condition for CDM-investments is that those investments would otherwise not be made. Actual CDM-investments are therefore defined as additional investments.

$$R^{JI} = R - R^* \qquad \text{with } R^{JI} = \sum_f R_f^{JI}$$

Transfers to the host country are the yearly capital costs to finance the CDM-investments

$$T = \sum_f (p_k)_f R^{JI} \quad \text{where T transfers to compensate for CDM-investments}$$

Emission rights that are earned because of CDM are computed as the additional emission reduction, compared to the situation with only normal retrofitting investments.

$$Z = q\left[E(R^{JI}) - E(R^*)\right] \quad \text{with Z emission rights, earned because of CDM}$$

Transfers from the donor countriesequal the regional share of GDP times the total transfers to NA-1:

$$T_r = Y_r / \sum_a Y_a \cdot \sum_q T_q \quad \text{with a the subset of A-1 countries and q the NA-1 countries}$$

Box 3: The effects from limits on trade: a simple theoretical example

Let us assume two small open economies, denoted by country 1 and country 2.In both countries, the marginal costs P(i) is a function f(.) of emission reduction ER(i). ER(i) is the percentage reduction of emissions compared to 1990. Take the simple linear function where the marginal costs depend only on the reduction percentage:

P(1)=2ER(1) and P(2)=ER(2)

Now assume that allowances are tradeable, and that they are traded at a uniform trade price,

P=P(1)=P(2)=20

The upper part of Figure A shows that the costs are the same for both countries and represents a "feasible" set of targets - being the outcome of the negotiation process. The resulting emission reductions ER(i) will be equal to

ER(1)=20/2=10ER(2)=20/1=20

Now let us assume that emission imports are restricted of two countries. An illustration is given in Figure B. Both countries are also assumed to be small players on the permit market, implying that the permit price will not be affected by any restriction. If 75% of the reduction target must be realised domestically,

we find

ER(1) = 0.75 * ERT(1) = 33.8, P(1) = 2ER(1) = 67.5

ER(2) = 0.75 * ERT(2) = 37.5, P(2) = ER(2) = 37.5

The costs compared to the full trade case - denoted by the two areas below the marginal costs functions - are not equally distributed among the two countries.

If 50% of the reduction target must be realised domestically, or

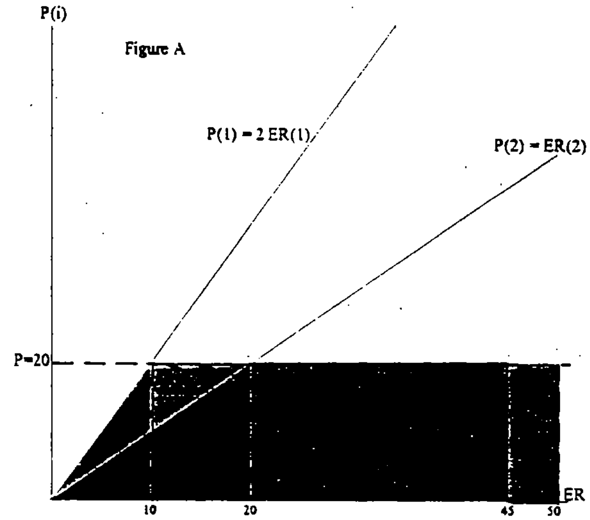
ER(1) = 0.5 * ERT(1) = 22.5, P(1) = 2ER(1) = 45

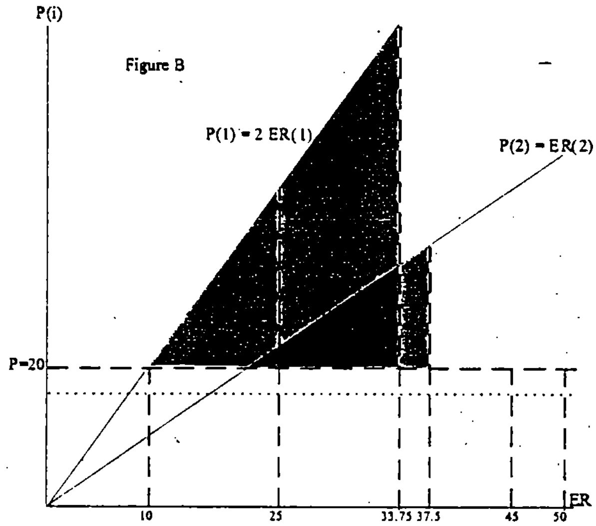
ER(2) = 0.5 * ERT(2) = 25.0, P(2) = ER(2) = 25

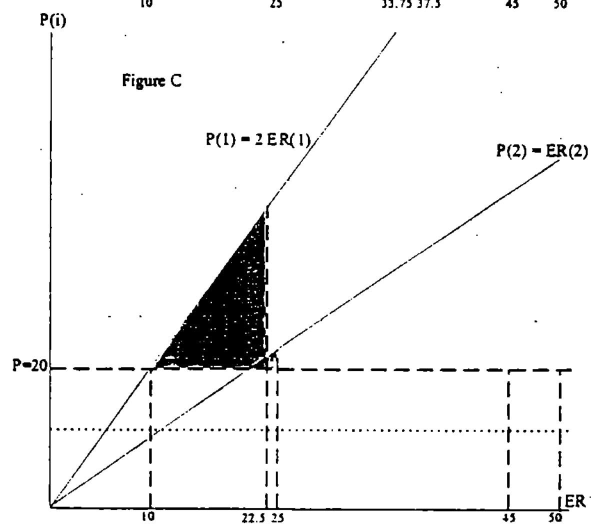
The costs are now almost zero to country 2, as can be seen in Figure C.

In principal we can calculate a cut-off point, being equal to the level at which country 2 is indifferent compared to free trade. The restriction percentage on trade equals the percentage at which country 2 will trade as much as in the case of free trade (50 minus 20). Country 2's burden must be equal to the free-trade case, while the burden for country 1 can be calculated. At the cut-off point country 1 is rationed in its demand for permits at the going international price, while country 2 is not. Any restriction percentage below 56% will impose costs on both countries with generally higher costs for country 1.

When the countries are not small, the price for emission permits will be affected by the changes in demand. As compared to the full trade case, demand restrictions will, upon impact, lead to at most the same level of demand, where lower demand can lead to a lower permit price, indicated by the dashed lines in Figures B and C. The cut-off point will be larger compared to the previous cases.







References

Barrett S. (1998), The Credibility of Trade Sanctions, ...

Barrett S. (1995), The strategy of joint implementation in the Framework Convention on Climate Change, UNCTAD/GID/10, Geneva.

Bollen, J.C. and A.M. Gielen (1997), Multilateral Emission Reduction, Fondazione Eni Enrico Mattei, Nota di Lavoro 97.XX, Venice, Italy.

Carraro C. and Siniscaldo (1997),

Chichilnisky G. and G. Heal (1995), Markets for tradeable CO_2-permits - principles and practice, OECD Economics Department Working Paper No. , , Paris, France.

COP (1997), The Kyoto protocol, web page ....

Geurts B.M.E, A.M. Gielen, R. Nahuis, P.J.G. Tang, and H.R. Timmer (1997), WorldScan, project report to the National research Program on Global Air Pollution and Climate Change, Project No. XXX, Bilthoven, The Netherlands.

Gielen A.M. and J.C. Bollen (1998), Internationally Cost-effective Emission Reduction, Report to the Dutch Ministry of Environment, CPB Netherlands Bureau for Economic Policy Analysis, Den Haag, The Netherlands.

Gielen A.M. and C.K. Koopmans (1998), The Economic Consequences of Kyoto, CPB Report 98/1, CPB Netherlands Bureau for Economic Policy Analysis, April 1998, Den Haag, The Netherlands.

Hertel T. (1996), Global Trade Analysis, ...

Hertel T. (1998), website GTAP, ...

IPCC (1996), Climate Change 1995, ...

Koutstaal (1998), ...

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Return to 1990: The Cost of Mitigating United States Carbon Emissions in the Post-2000 Period

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ABSTRACT

The Second Generation Model (SGM) is employed to examine four hypothetical agreements to reduce emissions in Annex I nations (OECD nations plus most of the nations of Eastern Europe and the former Soviet Union) to levels in the neighborhood of those which existed in 1990, with obligations taking effect in the year 2010. We estimate the cost to the United States of complying with such agreements under three distinct conditions: no trading of emissions rights, trading of emissions rights only among Annex I nations, and a fully global trading regime.

We find that the marginal cost of returning to 1990 emissions levels in the United States in the absence of trading opportunities is approximately $108 per metric ton carbon in 2010. The total cost in that year is approximately 0.2 percent of GDP. Emissions reductions are accomplished via energy conservation across a broad range of residential, commercial, industrial and transportation activities and by replacing coal fired power stations with natural gas facilities.

International trade in emissions permits lowers the cost of achieving any mitigation objective by equalizing the marginal cost of carbon mitigation among countries. This is sometimes referred to as "where" flexibility. "Where" flexibility allows least expensive emissions reductions to be undertaken first, regardless of where they occur among trade participants.

For the four mitigation scenarios in this study, economic costs to the United States remain below 1% of GDP through at least the year 2020. This was the case even in the scenarios where the United States met its mitigation targets without international trading of carbon permits.

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INTRODUCTION

More than 160 nations have signed the Framework Convention on Climate Change (FCCC). That agreement required Annex I nations,[1] the developed nations of the world plus economies of the Former Soviet Union and Eastern Europe, to undertake measures to return emissions to 1990 levels or below in the year 2000. The parties to the FCCC met in Berlin in the Spring of 1995 and determined that additional measures were required to implement the ultimate objective of the FCCC, "*to stabilize the concentration of greenhouse gases in the atmosphere at a level which would prevent dangerous anthropogenic interference with the climate system.*"

Subsequent to the Berlin discussions, nations of the world have begun to consider measures that would set quantifiable emissions limitation requirements in the post-2000 period for Annex I nations. Various measures have been considered. The purpose of this paper is to explore the economic consequences of efficient policy instruments—carbon taxes or tradable emissions permits—which might be employed to achieve a variety of targets in the post-2000 time frame.[2] Using the Second Generation Model (SGM), we estimate the costs to the United States of complying with four Annex I mitigation scenarios under three permit trading regimes. Specifically, we examine the carbon taxes required for emissions mitigation and provide measures of the costs of mitigation.

We begin by describing the variety of policy options to be considered and our general approach to modeling those policies. We then review some of the necessary assumptions for this exercise, as well as the structure and calibration of the SGM. Finally, we discuss the results of our analysis, including time paths of emissions and measures of cost.

APPROACH

The SGM was used to simulate the impact of mitigation policies on the United States economy. The SGM is a computable general equilibrium economic model that projects economic activity, energy consumption, and carbon emissions for the United States and 11 other world regions. A more complete description of the SGM follows in the next section.

Scenarios

Four scenarios were constructed that reduce carbon dioxide emissions in Annex I countries by 2010. Figure 1 shows United States emissions paths for the four scenarios and the reference case

[1] Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Czechoslovakia, Denmark, European Economic Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and the United States.

[2] In the United States, efforts were undertaken by the Interagency Analytical Team (IAT), and results were summarized in United States Government (1997). The Second Generation Modeling team was one of three modeling teams that participated in the evaluation of potential emission mitigation measures under discussion. Note that the results presented in this paper differ from SGM results presented under the auspices of the IAT. The IAT effort assumed higher rates of technical change induced by a response to policy implementation. This study does not make the same assumptions.

in million metric tons of carbon (MMTC). The reference case, or baseline scenario, is what we project will happen in the absence of a mitigation policy. In each mitigation scenario, allowable emissions are reduced linearly from the reference level in 2000 to the emissions target in 2010. The four policies, designated 'M_', are listed below.

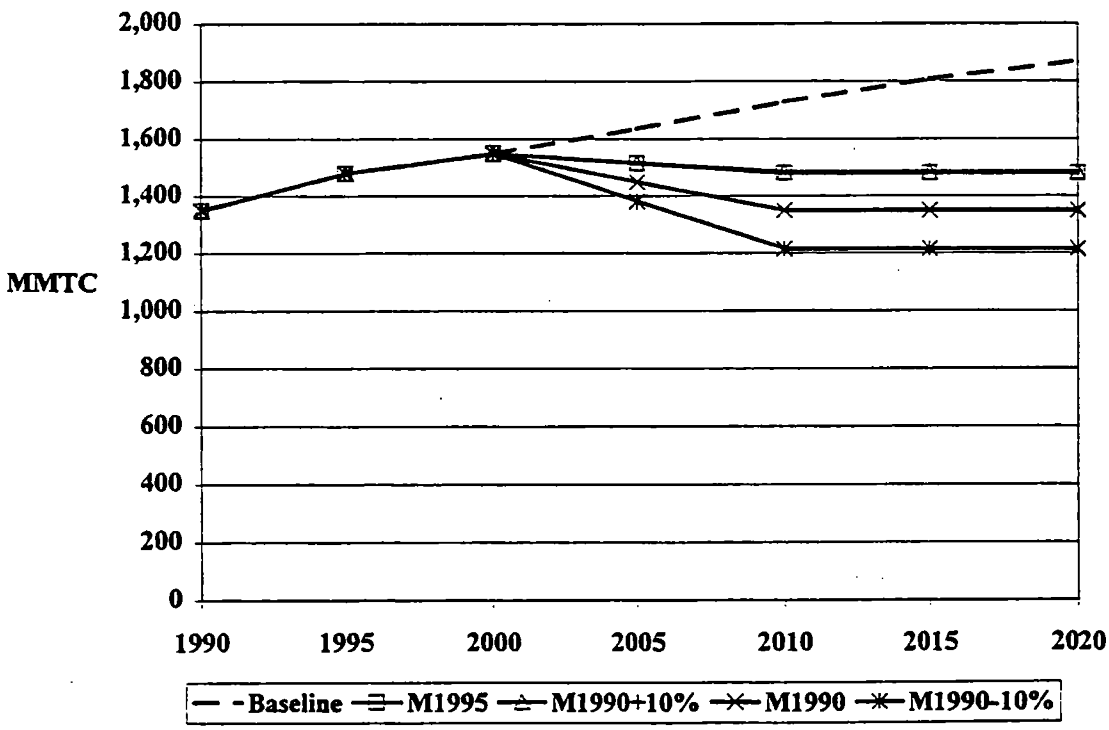
M1990 — Emissions from Annex I regions must be no greater than 1990 emissions levels beginning in the year 2010.

M1990+10% — Emissions from Annex I regions must be no greater than 10% above 1990 emissions levels, beginning in the year 2010.

M1990-10% — Emissions from Annex I regions must be no greater than 10% below 1990 emissions levels, beginning in the year 2010.

M1995 — Emissions from Annex I regions must be no greater than 1995 emissions levels beginning in the year 2010.

Figure 1. Carbon Dioxide Emissions Scenarios for the United States



The four emissions mitigation scenarios each define a set of emissions rights for the Annex I countries. In a mitigation scenario, countries must possess permits, or rights to emit, for every million metric ton of domestic carbon dioxide emissions. Three emissions permit trading regimes were modeled under each mitigation policy: independent emissions mitigation, Annex I joint mitigation, and Annex I mitigation with global permit trading. The 12 SGM regions listed in Table 1 provide the necessary global coverage to simulate these trading systems. Carbon taxes were used to constrain emissions for each of the policy-trade combinations.

Table 1. Regions in the SGM

Annex I	Non-Annex I
United States	China
Canada	India
Western Europe	Mexico
Japan	South Korea
Australia	Rest of World[3]
Former Soviet Union	
Eastern Europe	

In the independent mitigation case, each Annex I region must individually meet its required emissions targets without trading permits across regions. The SGM computes a time series of carbon taxes for each country that are just large enough to reduce emissions to the target level.

With Annex I joint mitigation, a common carbon tax is applied to all Annex I regions to meet the overall Annex I emissions target. However, regions are allowed to trade permits amongst themselves so long as the total constraint is met in each time period. Regions may only emit more carbon than their allocated emissions rights allow if another Annex I region is willing to sell a corresponding number of its permits, thereby forcing the seller region to reduce its domestic emissions beyond the required target.

In the global trading case, emissions rights are allocated to Annex I regions at the same levels as in the Annex I trading case. Under global trading, however, the Annex I regions are allowed to purchase permits from each other and from non-Annex I regions so long as the global emissions constraint is met. The global constraint in each period is composed of the Annex I constraint and the sum of the non-Annex I regions' reference level emissions in that period. The SGM is used to determine a global carbon tax just large enough to meet the global emissions target.

In none of the above scenarios and trading combinations are non-Annex I regions forced to constrain their emissions below reference levels. No mitigation targets or emissions trajectories are imposed on those regions. Under the global permit trading regime, non-Annex I regions participate in the market for carbon permits only when it is to their economic benefit to do so. These regions are allocated permits equal to their projected reference emissions, so they are only required to reduce their emissions by an amount equal to the number of permits they wish to sell.

Eastern Europe and Former Soviet Union Permit Allocations

While carbon dioxide emissions in most regions are anticipated to continually increase over time beyond 1990 levels, this is not true for the Eastern Europe and Former Soviet Union regions. Emissions in these regions have declined since 1990. Their reference case emissions trajectories reflect this decline from 1990 to 1995 and then increase slowly from 1995 onward. The

[3] The Rest of World includes Latin America, Africa, and other Asian countries.

downturn in emissions poses a special problem when allocating emissions rights. Two approaches to permit allocations for the regions have been discussed in recent months. The first allocates permits based on the stated policy scenario (e.g., M1990 allocates permits based on 1990 emissions level) so that permits are allocated to them in the same way as they are to other Annex I regions. Because of the decline in emissions in those regions from 1990 to 1995, however, this approach results in emissions permits being granted to Eastern Europe and the Former Soviet Union in the policy years that are greater than their reference level emissions. These 'paper credits' are equal to the difference between the lower post-1990 emissions and the policy-level (i.e., 1990) emissions. For example, the Former Soviet Union's reference emissions level in 2010 is 836 MMTC, significantly lower than its 1990 emissions of 1050 MMTC. If granted permits equal to its 1990 emissions, it would receive 214 MMTC worth of permits more in 2010 than its projected emissions, giving it 214 MMTC worth of permits to sell without incurring any emissions reductions of its own.

The second approach to allocating permits to Eastern Europe and the Former Soviet Union is to grant permits equal to reference level emissions in each period until the projected path is constrained by the policy. For example, in the M1990 case, the Former Soviet Union would be granted permits equal to its projected reference emissions through 2020 because emissions in the policy years never recover to 1990 levels.

For the purpose of this exercise, we chose to emphasize the latter approach in allocating emissions to Eastern Europe and the Former Soviet Union. This reference allocation scheme ensures that the stated Annex I emissions targets are achieved in both the independent mitigation and permit trading scenarios. For the purpose of comparison, we also include a short discussion of the impacts of the mitigation policies utilizing the first approach.

MODEL OVERVIEW

The SGM is designed specifically to address issues associated with global change. The model is designed to perform the following types of analysis:

1. Provide estimates of future time paths of environmentally important emissions associated with economic activity.

2. Provide estimates of the economic cost of actions to reduce greenhouse gas emissions.

Sectors

The SGM has nine producing sectors and twelve inputs to production. The inputs are land, labor, capital, and the nine produced goods. Economic detail is maintained in the energy supply and transformation sectors that are important for greenhouse gas emissions projections, but aggregated elsewhere into one large "everything else" sector.

Five different fuels are used for producing electricity, resulting in five subsectors for the electric generating sector. A separate economic production function, of the constant elasticity of substitution (CES) functional form, is used for each sector or subsector. Capital investment decisions depend on an assumed lifetime of capital for each sector or subsector. Capital lifetimes range from 15 years in the oil, gas, and coal production sectors to 70 years for hydroelectric power. The relative size of each production sector and subsector is shown in Table 2.

Table 2. Producing Sectors in the SGM

	Producing Sector	Gross Output in 1985 (millions of 1985 $)	
1	Agriculture	468,618	
2	Everything Else	5,086,486	
3	Oil Production	64,171	
4	Gas Production	45,804	
5	Coal Production	20,006	
6	Uranium Processing	2,195	
7	Electricity Generation	165,800	
	a. oil		10,959
	b. gas		34,152
	c. coal		85,930
	d. nuclear		21,370
	e. hydro		13,389
8	Petroleum Refining	145,015	
9	Gas Transmission and Distribution	105,330	

Market Clearing

In the SGM, markets are said to *clear*. In other words, the SGM solves for the set of prices for all markets (or sectors) in the modeled economy so that demands and supplies of each market are in equilibrium. The set of prices in which the equilibrium holds is called the *market-clearing* price set. In an equilibrium model like the SGM, markets are linked to other markets through the market-clearing process. For example, a change in the demand for coal will have an effect on not just the price of coal, but also the prices of oil, gas, and, at least indirectly, the prices of all markets in the economy.

Carbon permit prices and taxes are also solved for by the SGM as part of the market equilibrium. Emitters of carbon pay a tax based on the carbon content of the fuels they combust. The SGM finds the carbon price such that the amount of carbon emitted is just equal to the carbon constraint of the region or group of regions under a carbon emissions limitation constraint.

Carbon Taxes and Revenue Recycling

The SGM uses a carbon tax within each region to provide an economic incentive for the economy to substitute away from carbon. Revenues obtained from the carbon tax can be very large, and how the revenues are recycled, or redistributed to the economy, makes a difference in the final economic cost. For this exercise, we assume that all carbon tax revenues are recycled back to consumers through a lump-sum government transfer.

For the cases where emissions rights are traded between countries, each SGM region is allocated an initial number of carbon emissions permits based on the stated mitigation policy (e.g., 1990 emissions levels for the M1990 scenario). Carbon permits can then be traded between countries at a price that clears the global market in these permits.

Modes of Operation

All of the SGM regions were initially developed as single-region models with a base year of 1985. Each regional model operates in five-year time steps to the year 2050, with results reported here to 2020. Most of the single-region models were developed in collaboration with experts from that country. It is possible to run all of the regions individually or simultaneously in a global model with international trade. The three modes of operation for the SGM are:

1. Single Region
2. Global with Partial Market Clearing
3. Global with Full Market Clearing

Single-region operation. For each SGM region, all produced goods are classified as being tradable, nontradable, or traded at a fixed quantity. When SGM regions are operated independently, a fixed world price is assumed for certain tradable goods; regions may import or export as much of that good as desired at that fixed world price, subject to an overall balance of payments constraint. For all nontradable goods, the quantity of trade is fixed in advance. The following assignments are used when the United States model is operated independently:

Numeraire Sector:	everything else (price always equals 1)
Fixed World Price:	crude oil
Fixed Trade Quantities:	agriculture, coal, nuclear fuel, refined petroleum, electricity
Nontradables:	distributed gas, land, labor

For each region, the large 'everything else' sector is the numeraire, with its price fixed at 1 for all time periods. The prices of the other sectors in the economy are reported relative to this fixed value. The 'everything else' good is a tradable good for all regions. An exogenous balance-of-payments constraint is specified in advance for each region. Most regions are assumed to move linearly from a historical trade balance in 1985 to balanced trade by 2005.

Given a trial set of prices, the SGM computes supply and demand for all producing sectors and primary factors of production. Markets for the nontradables and goods traded at fixed quantities are brought into equilibrium by searching for a set of prices that equate supply and demand. Prices are adjusted until supply and demand are within 0.01% of each other.

Global model with partial market clearing. The global version of the SGM is used when there is at least one market that must clear globally. For the scenarios described in this paper, that market is tradable carbon emission permits. The model searches for a global carbon tax, which can be interpreted as a world carbon permit price, that clears the market for permits.

Each region is initially allocated a number of carbon permits and may trade those permits at the world permit price. Some regions will be sellers of permits and some will be buyers. After trading permits, all regions must hold permits equal to the domestic level of carbon emissions.

All regions are still subject to a period-by-period balance of payments constraint. The model does not allow borrowing to pay for carbon emissions permits. Imports of permits must be paid for with exports of some other good.

Global model with full market clearing. There are no longer any markets with a fixed world price. A set of world prices is found that clears all world markets. Also, world markets can be created for goods that were traded in fixed quantities in the single-region model.

All of the scenarios described in this paper were run in the second mode, global with partial market clearing. This mode was chosen for two reasons. The first is that we chose to adopt a fixed time path of world oil prices for SGM model runs that were completed for the United States Government during the spring of 1997. This meant that the world oil market would not be allowed to clear in the model. The second reason is that model results are often easier to interpret when some variables in the model remain predetermined over time.

Data Requirements

Three types of data are used to construct and calibrate each region of the SGM:

1. Economic and Demographic Data
2. Energy Balances
3. Technology Descriptions

Economic data include input-output tables and supplemental information from the national income accounts. Population projections were obtained from the World Bank. Energy balance tables were obtained either from the International Energy Agency or from government agencies within a region.

Input-output tables describe, in value terms, the flow of goods between industries and consumers in an economy. However, a model concerned with quantities of carbon emissions must also be concerned with quantities of energy. An input-output table alone is not sufficient to determine the quantities of oil, gas, coal, electricity, and refined petroleum that are produced and consumed. Supplemental information on energy quantities is required to map currency units from an input-output table to energy units needed to calculate levels of carbon emissions. We combine economic input-output tables with energy balance tables to create a hybrid input-output table with units of joules for energy products and real dollars for all other products. Miller and Blair (1985) provide a general description of, and the motivation for using, hybrid input-output tables.

Individual energy technologies are characterized by the annualized cost of providing an energy service. Data needed to determine the annualized cost include capital cost, equipment lifetime, annual fuel requirements, the interest rate, and other annual maintenance and operating costs.

REFERENCE CASE AND CALIBRATION

The cost of reducing greenhouse gas emissions is dependent on the reference case. The higher the growth rate of emissions in the reference case, the greater the cost of returning to 1990 emissions. Therefore, much effort is expended to create an acceptable reference case before running any of the mitigation scenarios.

Results for this study are reported for the years 1990 through 2020. The United States reference case was closely calibrated to the Annual Energy Outlook 1997 (AEO97). Since AEO97 projects only up to the year 2015, projections beyond 2015 are SGM model results and are not calibrated to any other established projections. Projections of carbon emissions, population, gross domestic product (GDP), energy consumption, and electricity generation for the United States are described below.

For the other global regions, economic and energy consumption growth rates were roughly calibrated to regional projections from the World Energy Outlook 1996 (WEO96). For the Eastern Europe and Former Soviet Union regions, projected energy consumption levels were adjusted downward from the WEO96 projection to reflect recent events. Population projections for all regions with the exception of the United States were set exogenously based on the World Population Projections 1994-1995, published by the World Bank. The United States population projection was set according to AEO97 projections. As mentioned earlier, the international crude oil price trajectory was also taken from the AEO97. Prices for all other fuels and goods in the model were determined endogenously.

The general calibration procedure was to first match GDP growth by adjusting parameters that control total factor productivity in the 'everything else' sector. Then energy consumption by fuel was calibrated by adjusting input-specific technical change parameters. Carbon emissions are an output of the model derived directly from primary energy consumption by applying fuel-specific emission factors.

Carbon Emissions

In 1990, total carbon dioxide emissions from the combustion of fossil fuels in the United States were 1,350 million metric tons of carbon. Model results show that total carbon dioxide emissions continue to rise as fossil fuel consumption increases and emissions reach 1,871 million metric tons by 2020. This amounts to a 39 percent increase in total emissions and an emissions growth rate of 1.1 percent per year. Reference case carbon emissions were shown earlier in Figure 1.

Gross Domestic Product

The two most important determinants of GDP are population growth and rates of change in productivity. Total population levels for the United States were taken directly from AEO97. United States population grows from 250 million in 1990 to 323 million in 2020. This represents an annual population growth rate of 0.85 percent per year.

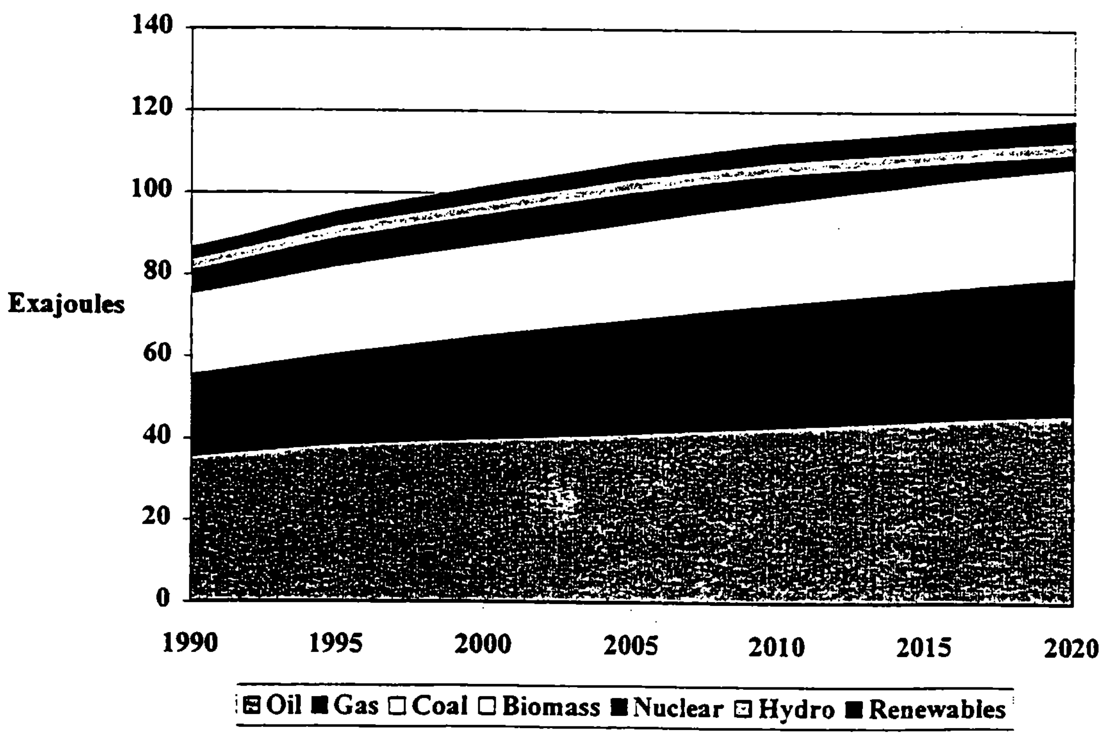
GDP for the United States was matched to AEO97 projections by changing the total factor productivity parameter for the 'everything else' sector. Beginning with the 1990 GDP of 6.1 trillion dollars, the economy grows at nearly 2 percent annually to reach 10.6 trillion dollars by 2020.

Energy Consumption

Total energy consumption from 1990 to 2015 was calibrated to within 2 percent of projections from AEO97. Energy consumption by fuel is shown for the United States in Figure 2. Total consumption increases from 86 EJ in 1990 to 118 EJ in 2020. This increase represents an average annual growth rate of 1.1 percent over that period. The annual growth rate in energy consumption declines over time and by 2020 decreases to 0.5 percent per year.

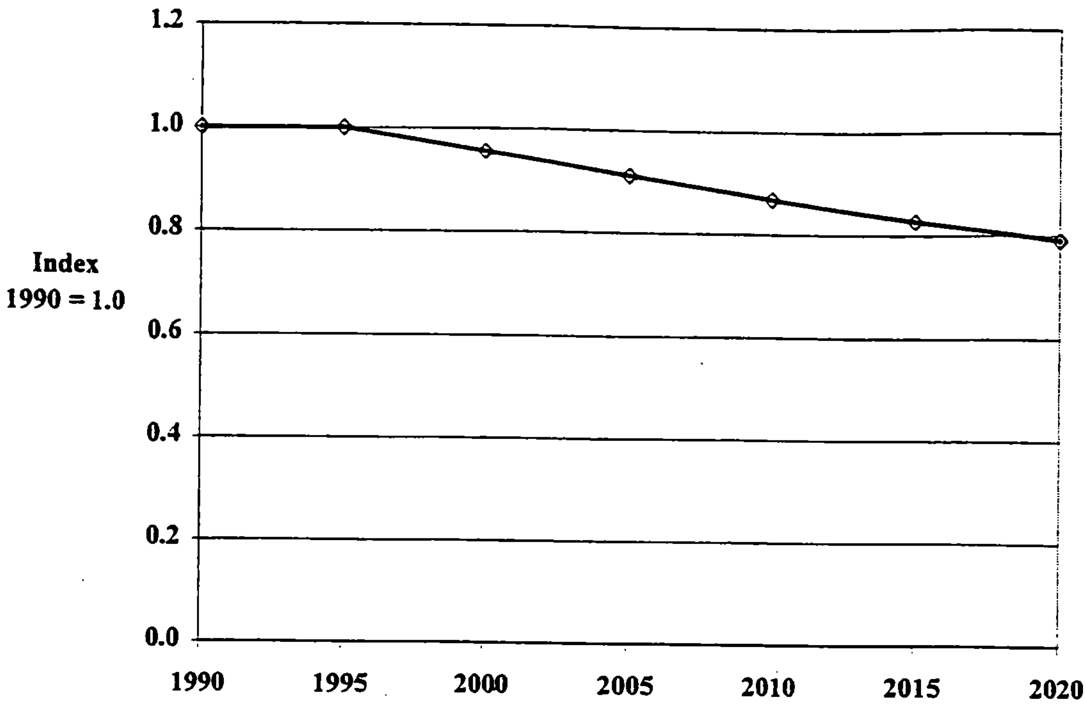
Petroleum remains the major source of energy through 2020, but its share of total consumption declines over time, giving way to natural gas and, to a lesser extent, renewable energy sources. Coal is the third largest source of energy and its consumption grows steadily at slightly less than 1 percent per year. Nuclear energy's contribution to energy consumption declines over time.

Figure 2. Energy Consumption – United States Reference Case



Energy consumption does not grow as fast as GDP, which results in the energy-GDP ratio falling over time at an average annual rate of 1.0 percent per year. Figure 3 shows the energy-GDP ratio generated by the SGM for the United States reference case.

Figure 3. Energy-GDP Ratio – United States Reference Case



Electricity Generation

Projections of electricity generation are similar to those of the AEO97. Total electricity generated in 1990 is nearly 11 EJ, which grows at 1.5 percent per year to reach 17 EJ by 2020. The major source of electricity is the combustion of coal; however, electricity generation from natural gas plays a significantly larger role with time. In 1990, electricity generation from coal contributed 53 percent of the total generation, while that from natural gas combustion contributed 17 percent of the total. By 2020, the shares of electricity generation from coal and natural gas are closer. Electricity generation from coal and natural gas comprise 44 and 34 percent shares of the total, respectively. Highly efficient and low-cost natural gas combined cycle power plants incorporated into the SGM contribute to the growth of natural gas as the choice fuel for electricity generation. Nuclear power's contribution to the overall demand for electricity declines with time as existing power plants are retired and no new additional plants are constructed.[4] Renewable energy sources for electricity generation include hydroelectricity, solar photovoltaics and others. Generation of electricity from renewable sources increases slightly from 1990 to 2020; however, renewable energy's share of total electricity remains below 10 percent of the total.

[4] The assumption of no new starts reflects a de facto nuclear moratorium. Were nuclear power to be allowed to compete against other energy forms on the basis of price alone, the model would continue to build new facilities.

COST OF EMISSIONS MITIGATION

Although this exercise employed the 12-region version of the SGM, discussion of results in this paper will focus on the United States. The SGM provides output on regional GDP and its components and a detailed description of the composition of energy supply. In this analysis, we focus on the broad economic impacts to the economy. Specifically, we discuss the permit prices required to meet the various mitigation requirements and the costs to the United States economy of undertaking such policies. We also discuss the impacts of the domestic carbon taxes on energy consumption.

Permit Prices

Table 3 shows the permit prices by trading regime required for the United States to meet its emissions targets under the four mitigation scenarios. Permit prices in the United States must reach $108 per metric ton of carbon to reduce United States emissions to 1990 levels in 2010 in the independent mitigation case. This price increases significantly with the tighter constraint imposed under the M1990-10% case. Permit prices in the M1995 and M1990+10% scenarios are very similar as only 5 MMTC separate the constraints in the two cases in 2010.

Table 3. United States Carbon Taxes Required to Meet Policy Goal Eastern Europe & FSU Allocated Reference Case Permits (1992 US$ per Metric Ton of Carbon)

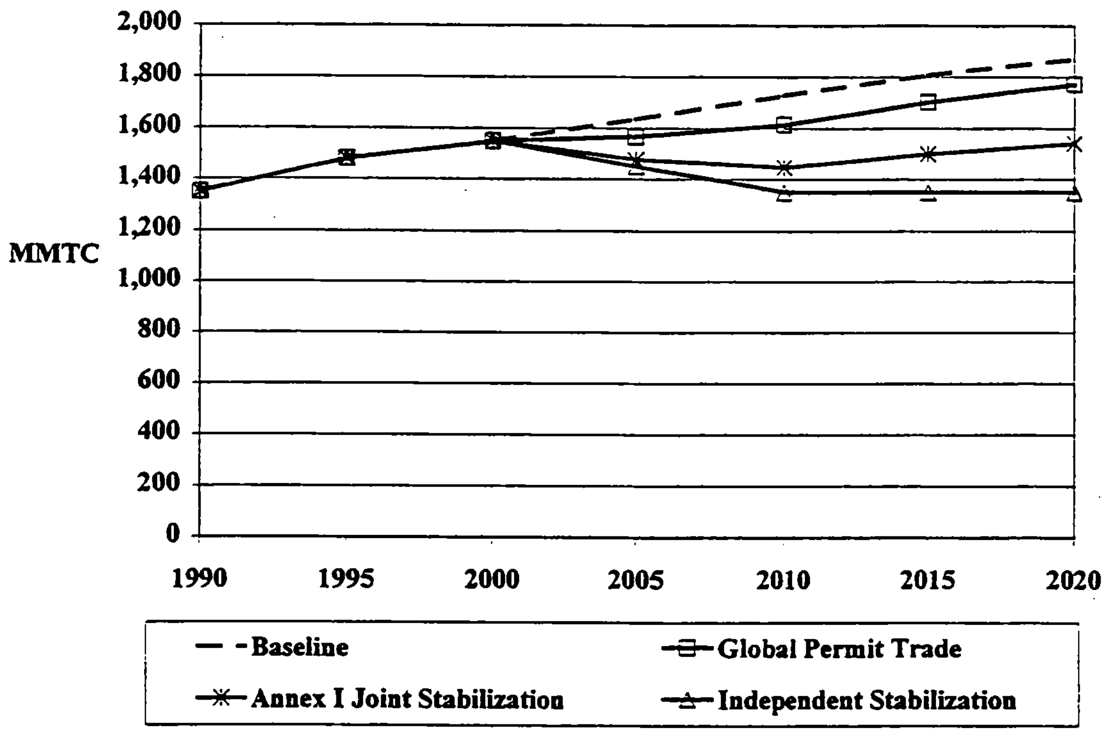
	Independent Mitigation		Annex I Joint Mitigation		Annex I Mitigation with Global Trade	
	2010	2020	2010	2020	2010	2020
M1990	108	170	72	87	26	27
M1990+10%	60	110	42	58	16	18
M1990–10%	173	260	109	122	38	36
M1995	61	112	70	106	26	32

Permit prices fall as more regions are included in the market for carbon permits. In the independent emissions mitigation case, carbon emitters in the United States may undertake emissions mitigation options available only within the United States. In the Annex I joint and global permit cases, however, regions are included that have mitigation options with significantly lower costs, thereby lowering the marginal cost to the carbon permit market of meeting the desired emissions targets. As we will discuss, this 'where' flexibility in meeting emissions targets has a significant impact on costs as well as permit prices.

A fixed emissions target and an increasing reference case emissions level imply both a rising percentage emissions reduction and a rising price of meeting the fixed emissions target. Increasing population in the United States, and the economic growth that accompanies it, put upward pressure on emissions that, in turn, forces larger shifts away from coal toward natural gas and renewable energy sources. The availability of relatively inexpensive abatement options in the developing world allows the permit price to remain relatively constant over time in those cases.

As the permit prices decrease across trading regimes, the United States purchases increasing quantities of permits from abroad, thereby enabling it to emit more than its allocated permits alone would allow. Figure 4 shows United States emissions for the M1990 case across the three trading regimes. Under the independent emissions mitigation regime, the United States is limited to emitting only what it is allocated under the scenario, its 1990 emissions level. With Annex I trading, however, the United States purchases 209 MMTC worth of permits in 2010 and 244 MMTC in 2020 from the Former Soviet Union and Eastern Europe. The purchases increase to 316 MMTC and 436 MMTC in 2010 and 2020, respectively, under the global trading regime. Again, 'where' flexibility reduces the amount by which a permit-buying region must reduce its emissions and, therefore, reduces the cost to the region.

Figure 4. United States Carbon Emissions – M1990 Cases

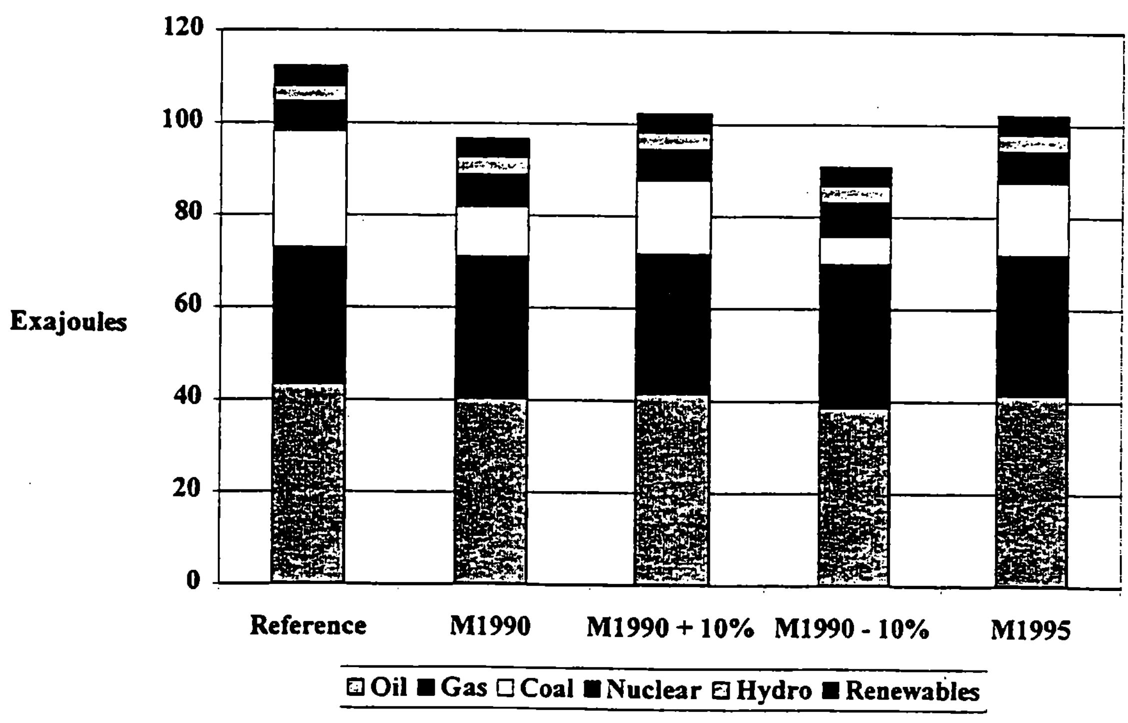


The M1995 Annex I trading case is the only case in which the United States sells permits to other regions. The permit price under independent mitigation in 2010, as shown in Table 3, is less than that shown under Annex I trading. Because the United States can mitigate emissions less expensively in 2010 than other Annex I regions, it reduces its emissions beyond the required 1995 target and sells permits to other Annex I regions. By 2020, however, the United States begins to purchase permits from Eastern Europe and the Former Soviet Union.

Energy Consumption

Emissions mitigation is achieved primarily through two mechanisms: energy conservation - reduction in total energy consumption - and replacement of coal-fired capacity with less carbon-intensive fuels such as natural gas and renewables in the electricity sector. In the no-trading cases, fuel switching from coal to natural gas and renewable fuels in the electricity generation sector accounts for roughly 60 percent of the reduction in total emissions. Energy conservation makes up the remaining 40 percent of the reduction. The domestic carbon tax of $108 in 2010 in the M1990 case results in a reduction of total energy consumption by 14 percent relative to the reference case. Consumption of coal drops by 57 percent while consumption of petroleum drops by 7 percent. Consumption of natural gas, however, increases by 4 percent due to fuel switching. Figure 5 shows energy consumption by fuel in the year 2010 for the four mitigation scenarios. Note that even when emissions are returned to 1990 levels, the scale of the total energy system still exceeds the 1990 energy consumption level of 86 EJ. The fuel switching mentioned above allows the emissions targets to be met without reducing total consumption by the same percentage as the required reduction in emissions.

Figure 5. United States Energy Consumption in 2010



Fuel substitution in the electricity sector results in the share of electricity generated from coal dropping from 45 percent in the reference case to 20 percent in the M1990 case. The reduction in electricity generation from coal is compensated for by increased generation from natural gas. The share of electricity generation from natural gas increases from 29 percent in the reference case to 51 percent M1990 case.

As discussed above, the domestic cost of stabilizing emissions at 1990 levels in 2010 without trade is $108 per metric ton of carbon. This cost roughly reflects the cost of abandoning existing coal-fired power generation capacity and replacing it with a new combined-cycle natural gas-fired unit. A $108 per metric ton tax adds approximately $0.02 per kilowatt-hour to the operations and maintenance (O&M) cost of power generation in a coal-fired plant. This additional cost makes the O&M cost of the coal plant higher than the levelized cost of installing a new gas-fired combined-cycle unit, roughly $0.05 per kilowatt-hour. The $108 tax, therefore, provides an emissions mitigation plateau for permit prices that is not exceeded until most of the existing coal capacity is replaced.

Certain caveats apply to the discussion above concerning the marginal cost of substituting natural gas-fired electricity generation capacity for existing coal-fired capacity. The cost analysis requires that the tax be levied indefinitely. If the tax policy is believed to be only temporary, the amount of substitution is likely to be much less substantial and the tax level required for stabilizing emissions could be higher. The tax level required for mitigation also depends on the cost of developing the infrastructure necessary to supply natural gas to potential new users. Extending pipelines to particular areas, for example, might increase the cost of gas enough so as to discourage switching from coal-fired plants in those areas.

Cost Calculations

A very convenient way to characterize the response of any SGM region to a carbon tax is by constructing a marginal cost of carbon curve. Figure 6 is a scatter plot of various carbon taxes applied to the United States economy and the corresponding reduction in carbon emissions. Data points plotted in Figure 6 are from the four independent mitigation scenarios for the United States. Note that a positive tax is required to achieve any reductions in carbon emissions.

The marginal cost curve is used to calculate one measure of cost that we will call the *direct cost*. For any level of carbon emissions mitigation, the direct cost is defined as the area under the marginal cost curve up to that amount of mitigation.[5] While the first units of emissions reductions are very inexpensive, successive units become more and more expensive. So, as the constraints on emissions become tighter across cases and over time, the cost of mitigation increases. Figure 7 shows the direct costs for the United States for the four independent mitigation scenarios. Direct costs are shown at 5-year intervals through 2020 as a percentage of GDP. These costs are plotted as negative numbers.

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[5] Note that these costs do not include the costs of establishing a domestic or international permit trading system nor do they include the transaction costs associated with permit trading among firms and/or regions.

Figure 6. Marginal Cost of Carbon

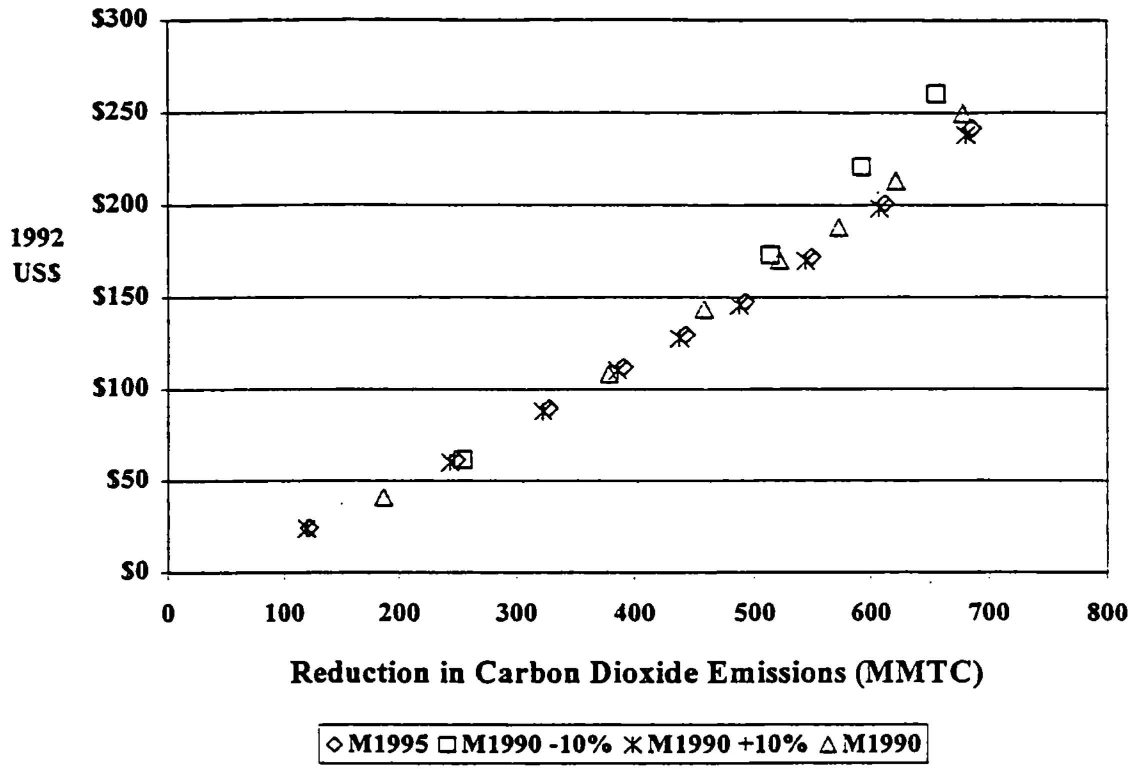


Figure 7. Cost of Emissions Mitigation – No Trading

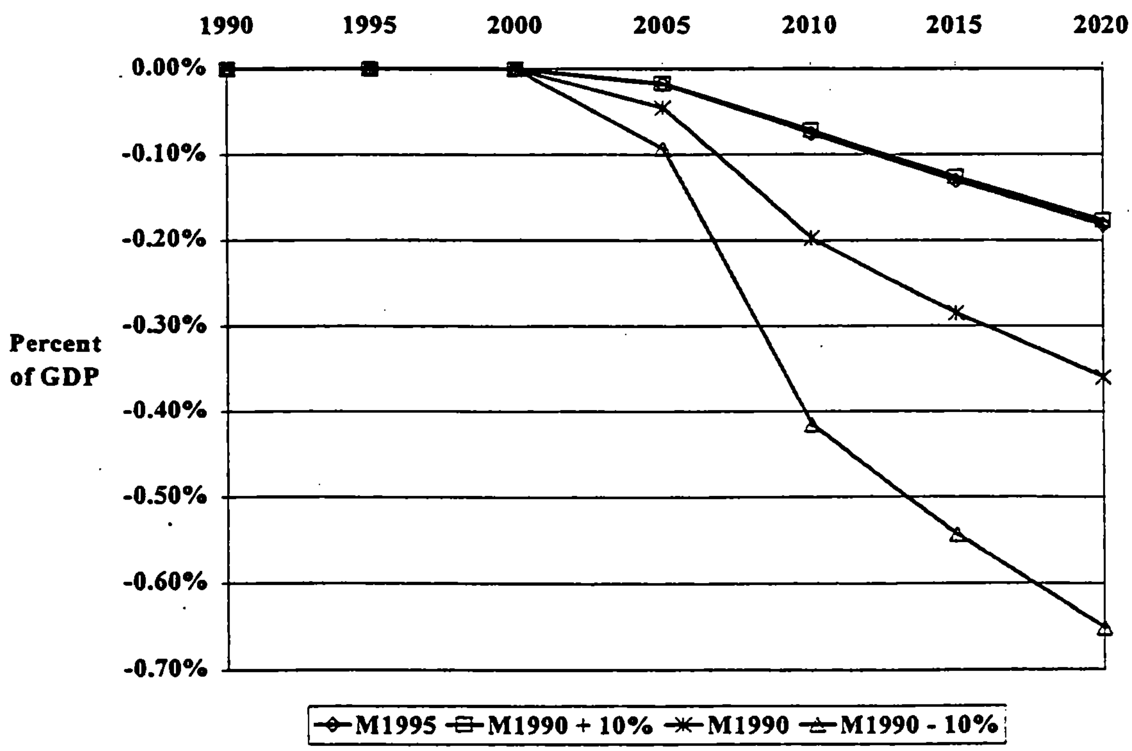
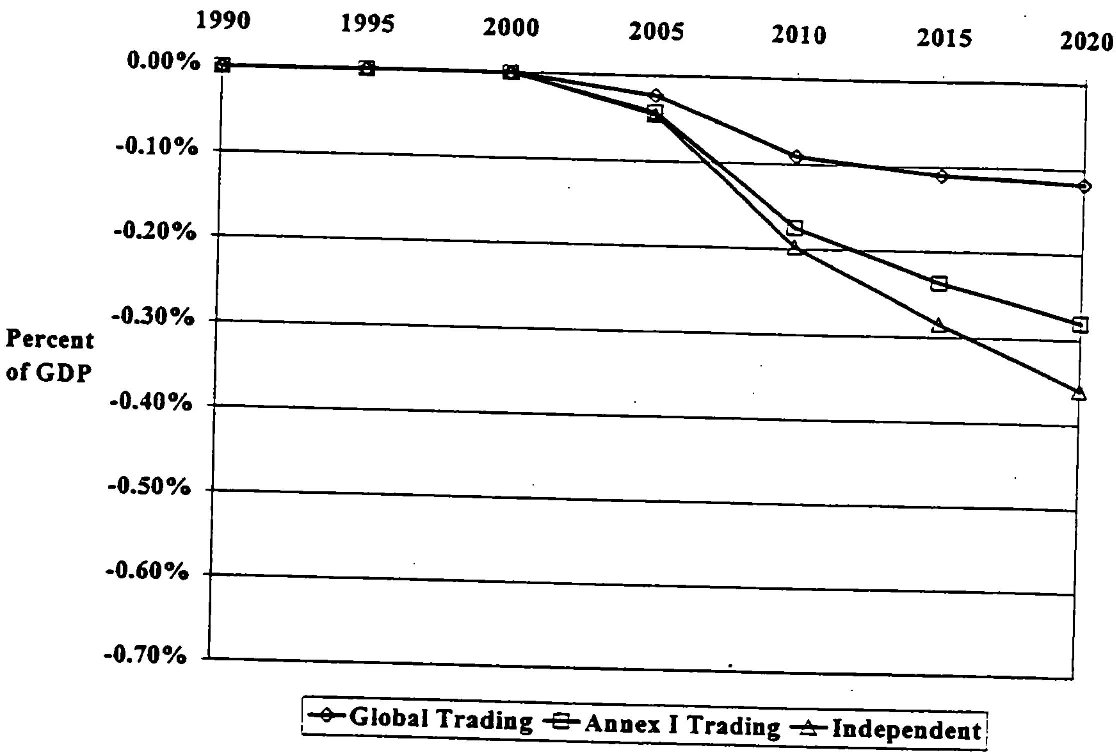


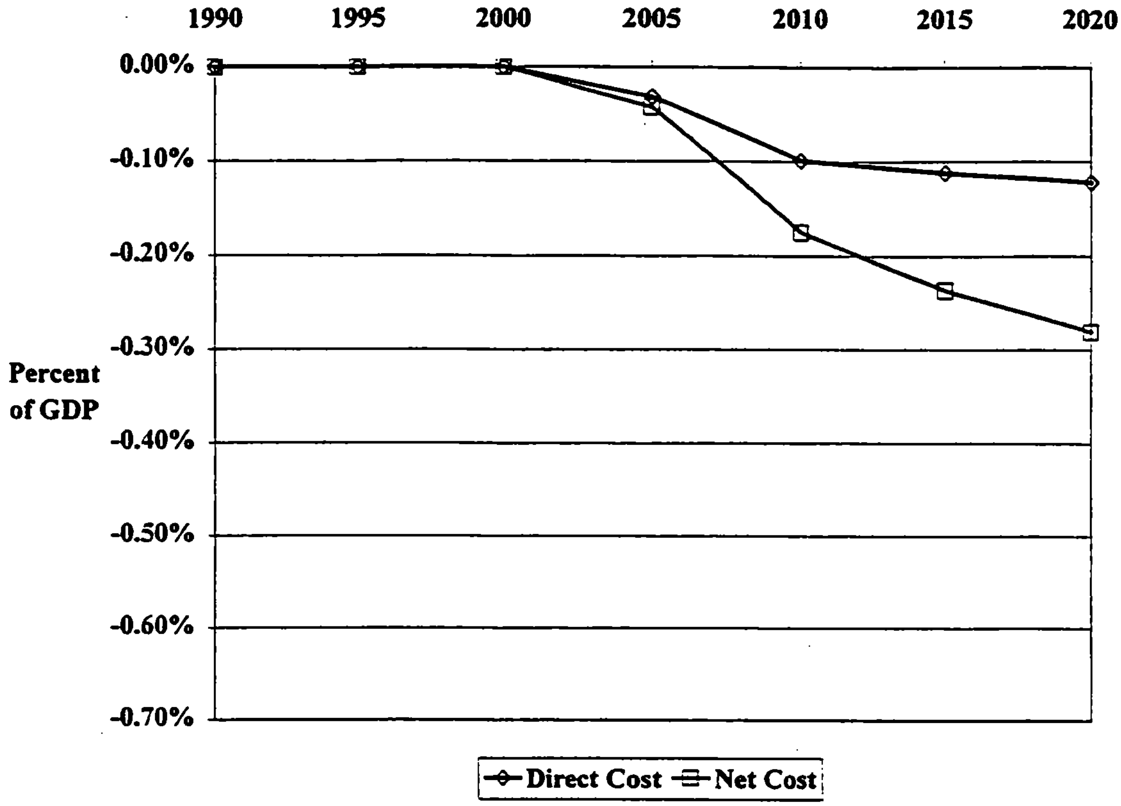
Figure 8 focuses on the M1990 case and shows how costs to the United Sates are reduced with trade in emissions permits between countries. The 'independent' cost line shown in Figure 8 is the same as the M1990 cost line in Figure 7. In 2010, costs are reduced somewhat with Annex I trading and reduced by about one-half with global trading. In later years, the flexibility in where emissions reductions are undertaken impacts mitigation costs even more significantly.

Figure 8. Illustration of 'Where' Flexibility – Costs for M1990 Cases



Cost calculations for the emissions trading cases are different than in the independent case. Costs for the trading case take into account the value of permits traded. For a buyer of permits, such as the United States, net cost includes the direct cost plus expenditures on carbon permits. A breakdown of these two cost components is shown for the M1990 Annex I trading case in Figure 9. Direct cost is roughly half of the net cost. The remaining cost, the difference between the 'direct cost' and 'net cost' lines in Figure 9, is the value of emissions permits that would be purchased from other Annex I countries.

Figure 9. Cost Breakdown – M1990 Annex I Trading Case



Impact of Alternative Permit Allocation Approach

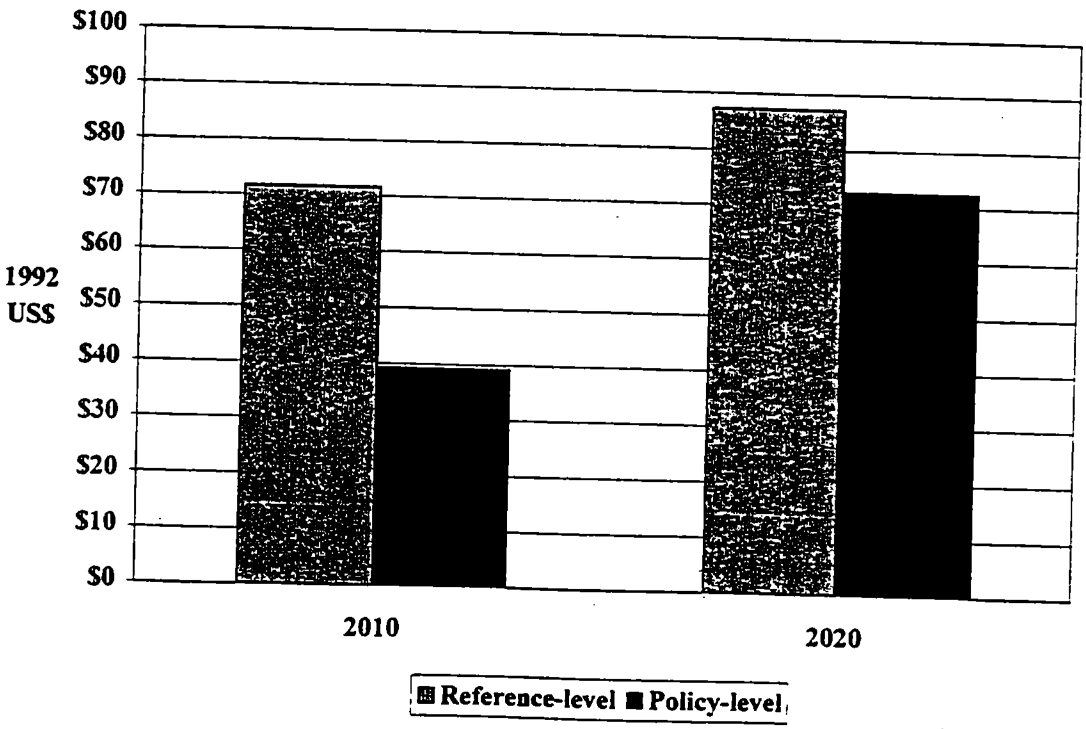
The results discussed thus far have been based on the assumption that Eastern Europe and the Former Soviet Union are allocated permits equal to the minimum of their reference-level emissions and the policy-level emissions. This section will discuss the impacts of an alternative permit allocation method in which Eastern Europe and the Former Soviet Union are granted permits equal to their policy-level emissions in every period. Recall that 'policy-level' refers to the emissions target set by the chosen mitigation policy. For example, the policy-level emissions in the M1990 case would be 1990 level emissions starting in 2010, and for the M1995 case they would be 1995 level emissions beginning in 2010. This assumption results in the 'paper credits' discussed earlier that significantly impact the permit prices required to meet Annex I emissions targets in the Annex I and global trading cases.

Table 4 shows the permit prices required to meet the policy goal under the policy-level permit allocation approach. The prices required for independent mitigation in the United States do not change from Table 3 above because the paper credits in those cases are not available for purchase outside Eastern Europe and the Former Soviet Union. Permit prices also remain unchanged under the M1995 case because by that time the two regions have already suffered the worst of their economic downturns so that emissions levels are at their lowest point in the 1990 to 2020 time frame. The permit prices under the other trading scenarios are significantly less under this allocation approach, however, because the regions are able to sell the paper credits without incurring any cost domestically. In the M1990 case in 2010, the paper credits allocated to Eastern Europe and the Former Soviet Union account for 37 percent of the emissions reductions necessary for the remaining Annex I regions to meet their target emissions. This addition of permits available for purchase reduces the permit price by $33, or by 46 percent, relative to the permit price under the reference-level allocation approach. Figure 10 shows the difference in permit prices for the M1990 case with Annex I trading between the two permit allocation approaches in 2010 and 2020. Note that the difference decreases over time as emissions in Eastern Europe and the Former Soviet Union approach the policy goal.

Table 4. United States Carbon Taxes Required to Meet Policy Goal - Eastern Europe and the Former Soviet Union Allocated Policy-level Permits (1992 US$ per Metric Ton of Carbon)

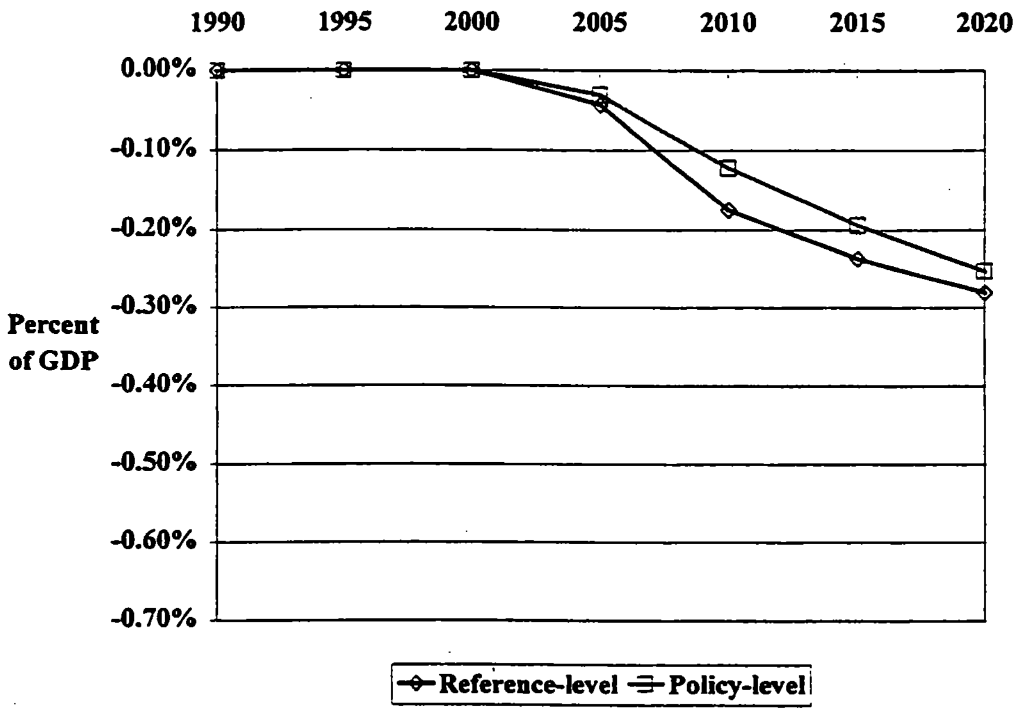
	Independent Mitigation		Annex I Joint Mitigation		Annex I Mitigation with Global Trade	
	2010	2020	2010	2020	2010	2020
M1990	108	170	39	73	15	22
M1990+10%	60	110	6	35	2	11
M1990–10%	173	260	88	124	31	36
M1995	61	112	70	106	26	32

Figure 10. Permit Prices under Alternative Permit Allocation Methods for Eastern Europe and the Former Soviet Union – M1990 Annex I Trading Case



The lower permit prices under the policy-level approach result in lower total costs of emissions mitigation to the United States. In the M1990 Annex I trading case, costs as a percentage of GDP are reduced from 0.18 percent under the reference-level allocation approach to 0.12 percent under the policy-level approach in 2010. Figure 11 shows costs as a percentage of GDP for the M1990 Annex I trading case for both allocation methods.

Figure 11. Cost to the United States of Emissions Mitigation under Alternative Permit Allocation Methods for Eastern Europe and the Former Soviet Union – M1990 Annex I Trading Case



DISCUSSION

In this section, we summarize some of the insights gained from our modeling activities using the SGM. First, economic costs depend a great deal on our assumptions about future carbon emissions. Second, several measures of cost are available from the SGM. Third, the distribution of costs among countries in a system of global permit trading is sensitive to assumptions on exchange rates as well as the initial allocation of permits. Fourth, any system of global trade in carbon permits implies potentially large transfers of wealth from one region to another. Finally, we discuss how some of our assumptions affect the results on costs.

Role of Reference Emissions in Shaping Marginal Mitigation Costs

All of the results in this study depend on assumptions used to create a reference emissions scenario from the present to 2020. The amount of mitigation required to return to 1990 levels depends directly on reference case emissions for each region. In the Annex I trading cases, carbon permit prices are particularly sensitive to reference scenarios for potential sellers of permits, especially Eastern Europe and the Former Soviet Union.

Among the Annex I countries, projecting future carbon emissions is especially uncertain for Eastern Europe and the Former Soviet Union. Of particular importance is when emissions in these regions will once again reach 1990 levels. If this point is reached before 2010, then we model Eastern Europe and the Former Soviet Union just as any other Annex I country. If this point is reached after 2010, then emissions restrictions are not binding in the two regions until that point in time.

Measuring and Reporting Costs

At least two measures of cost are available from the SGM and from other models as well. The first measure, which we call the *direct cost*, can be thought of as either a deadweight loss or the integral under the marginal cost curve for carbon. Using either approach, direct cost is approximately equal to one-half of the carbon tax (or permit price) times the reduction in carbon emissions. For the permit trading cases, direct costs are then adjusted by the value of transfer payments required to purchase or sell permits. This measure of net cost is simple to construct and is comparable across models.

Of ultimate interest, however, is the net impact on some broader measure of economic activity (such as GDP) or on economic welfare (such as real consumption). There are many reasons why the change in GDP (or real consumption) is different than direct cost net of transfer payments. These other components of cost include the effects of pre-existing distortionary taxes, changes in terms of trade, and how tax revenues are recycled. In addition, measurement of GDP (or real consumption) depends on the choice of index and base year used to construct that index. This reflects real-world problems in constructing a quantity index for GDP when relative prices are changing.

Foreign Exchange Rates

Permit prices for the global permit trading cases are very sensitive to assumptions about exchange rates. And while the United States follows a largely free market approach to exchange rates, most developing nations do not. Therefore it may be perfectly reasonable to assume that over the long-term the United States exchange rate with other free market trading partners would tend toward the purchasing power parity rate, this assumption is questionable with other partners. This is particularly true for developing countries where market exchange rates, in local currency per U.S. dollar, can be three to five times the corresponding exchange rate based on purchasing power parity. A global permit price of $100 per metric ton translates, at market exchange rates, into a much higher relative price in the developing countries than in the United States.

Exchange rates based on purchasing power parity are usually used to compare income levels between countries, but market exchange rates must be used for goods actually traded between countries. This creates a potential problem for developing countries considering participation in a global permit trading program; carbon permits would be traded at market exchange rates, while

GDP losses are better measured using purchasing power parity. For developing countries, losses in GDP could be greater than the value of carbon permits sold.

International Transfer Payments

We have modeled an international system of carbon permit trading that implies potentially large wealth transfers from buyers to sellers of permits. These transfers also change the pattern of other goods traded internationally. For a buyer of permits, this annual transfer of wealth is equal to the annual quantity of permits purchased times the world market price of the permits. The size of these transfers depends directly on the initial allocation of permits between countries. The initial allocation determines not only the amount of permits traded by each country, but also whether a country is a buyer or seller of permits.

For this study, the initial allocation of permits among Annex I countries is simply the emissions targets defined by the four mitigation scenarios. Non-Annex I regions were allocated permits equal to reference case emissions. These four mitigation scenarios represent only a few of the many possible ways of setting global emissions limits and allocating emissions rights among countries to meet those limits. Each allocation implies a different pattern of wealth transfers among countries.

Each region in the SGM is assigned a period-by-period balance of payments constraint. Buyers of carbon permits must, therefore, export more of other traded goods than otherwise to pay for the purchased permits. Conversely, sellers of permits use the permit revenues to increase imports of other goods.

Sensitivity of Costs to Model Assumptions

Economic costs reported by the SGM for the United States are sensitive to many of the model inputs. These include the choice of exchange rate, the inclusion of paper permits, and the method of revenue recycling.

If purchasing power parity exchange rates were used instead of market exchange rates for the developing countries, then any given world permit price would translate into a lower carbon tax in that country's local currency. For global trading cases, this would increase the global permit price needed to meet a global emissions limit, and the SGM would report higher costs for the United States.

For Eastern Europe and the Former Soviet Union, carbon permits were allocated based on their reference case, and not on 1990 emissions. If we had allocated permits based on 1990 levels, these extra 'paper credits' would create a less-stringent Annex I target. The model would then report a lower permit price for the trading cases, and a lower cost to the United States.

In this study, we assumed that all revenues from a carbon tax would be recycled as a lump sum to consumers. Another option is to use the carbon tax revenues to offset other taxes. This has the potential to reduce overall costs, since carbon tax revenues would displace other distortionary taxes.

KEY OBSERVATIONS

Economic costs are reduced with a permit-trading program that equalizes the marginal cost of carbon between countries. The least expensive emissions reductions are taken first, regardless of where they occur. Costs shown in Figure 8 provide a good example of the importance of this 'where' flexibility.

For the four mitigation scenarios in this study, economic costs to the United States remain below 1% of GDP through at least the year 2020. This was the case even in the scenarios where the United States met its mitigation targets without international trading of carbon permits.

Each region in the SGM can be characterized by a marginal cost of carbon curve, as was shown in Figure 6. This shows the approximate carbon tax required for any given level of carbon emissions reduction. For the amount of emissions reductions needed in 2010 to return to 1990 levels, a carbon tax of $108 per metric ton of carbon is required.

REFERENCES

Edmonds, J.A., H.M. Pitcher, D. Barns, R. Baron and M.A. Wise. 1993. "Modeling Future Greenhouse Gas Emissions: The Second Generation Model Description," in *Modelling Global Change*, Lawrence R. Klein and Fu-chen Lo, eds. United Nations University Press, New York.

Fisher-Vanden, K.A., R. Baron, J.A. Edmonds, H.M. Pitcher, R.D. Sands and M.A. Wise. 1993. *Calibration of the Second Generation Model*, draft report. Pacific Northwest National Laboratory, Washington, D.C.

Fisher-Vanden, K.A., P.R. Shukla, J.A. Edmonds, S.H. Kim, and H.M. Pitcher. 1997. "Carbon Taxes and India," *Energy Economics* 19, 289-325.

Hibiki, A., and R.D. Sands. December 1996. "Estimating the Impact of a Carbon Tax Using the Second Generation Model of Greenhouse Gas Emissions for Japan," in *Global Warming, Carbon Limitation, and Economic Development*, A. Amano ed. Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba, Japan.

International Energy Agency (IEA). 1996. *World Energy Outlook: 1996 Edition*. Organization for Economic Cooperation and Development, Paris, France.

International Energy Agency (IEA). 1997. *Energy Balances for OECD and Non-OECD Countries*, data provided on floppy disk. Organization for Economic Cooperation and Development, Paris France.

Miller, Ronald E., and Peter D. Blair. 1985. *Input-Output Analysis: Foundations and Extensions*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

United States Department of Energy, Energy Information Administration (EIA). December 1996. *Annual Energy Outlook 1997: with Projections to 2015*. DOE/EIA-0383(97), Washington, D.C.

United States Government. May 1997. *Economic Effects of Global Climate Change Policies: Results of the Research Efforts of the Interagency Analytical Team*, draft report.