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1

Divider Title: _____

Date: July 3, 1997

To: Alicia Munnell
Jeff Frankel

From: Tom Rhoads

RE: CEA Comments on Climate Change Sectors Summary Paper

Jeffrey Hunker wrote a paper on the sectoral implications of climate change policy for the Assistant Secretaries Group. I have noted some concerns and various editorial comments.

I can write a memo in your names to the White House Climate Change Task Force that provides these comments and any others that you may have. Dirk Forrister has indicated that the deadline for comments is today.

- Generally: Tables 1-6.

AEO97 does not provide actual data for emissions and energy consumption for 1997. The figures reported in the current document as 1997 data are merely estimates based on projections in AEO97 for emissions and energy consumption growth and should be reported as such.

- Page 1: Paragraph beginning "Total U.S. greenhouse gas emissions..."

The draft U.S. Climate Action Report (U.S. CAR) indicates that U.S. GHG emissions in 1995 were 1,559 MMTCe with gross emissions of 1,676 MMTCe. The current document reports figures inconsistent with those from U.S. CAR (1,557 MMTCe and 1,674 MMTCe, respectively). Consistent reporting of data across documents is required.

- Page 2: Table 1.

The heading of the third column should read:
"Percentage of Total ~~1995~~ 1997 Emissions"

- Page 4: Table 4.

The title of Table 4 should read as follows:

"Total 1997 and ~~2015~~ 2010 Building Energy Consumption By End-Use (in Quads)"

- Page 4: Paragraph beginning "Currently, numerous opportunities exist..."

"By tightening the building shell...consumers can experience ~~substantial monetary gains through greater savings as a result of lower~~ in their monthly utility bills."

- Page 5: Barriers to Adoption section

"Despite the ~~proven~~ cost effectiveness of these and other energy efficiency technologies, ~~it is clear that they~~ these technologies are not ~~widely~~ always adopted by consumers. This is perhaps due to a number of institutional, organizational, and other barriers. The

existence or availability of a financially attractive technology sometimes does not by itself....

- Page 7: Economic Modeling Results for the Industrial Sector section

The IPCC Working Group III report details many mitigation cost studies that estimate economic losses due to reducing CO₂ emissions. Admittedly, there is no consensus in the economic literature regarding the effects of reducing CO₂ emissions. However, the real possibility that a mitigation strategy will cause economic losses is an issue that must be stressed in the current document. As it stands, the current document provides a one-sided description of the possible positive effects of reducing CO₂ emissions. Including greater detail on the available literature that estimates economic losses from reducing CO₂ emissions will provide a more accurate picture of the current state of economic research.

- Page 8: Paragraph beginning "A second and central concern..."

"...producers might lose market share to competitors from non-Annex I countries (those countries not characterized by industrialized economies) under a climate treaty that affects Annex I but not ~~Annex II~~ non-Annex I countries."

- Page 19: Paragraph beginning "As state-by-state restructuring takes place..."

"Cost reduction ~~will~~ is expected to continue to occur through R&D advances...."

- Page 20: Table 6.

The heading of the third column should read:

"Percentage of Total ~~1995~~ 1997 Emissions"

Date: July 3, 1997

To: Judi Greenwald
White House Climate Change Task Force

From: Jeffrey Frankel, CEA
Tom Rhoads, CEA

RE: CEA Comments on Climate Change Sectors Summary Paper

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White House Climate Change Task Force

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

cc: Ann
JAF
JS
AM
JBL

MEMORANDUM TO: ASSISTANT SECRETARIES GROUP

FROM: Dirk Forrister, Chair
White House Climate Change Task Force

SUBJECT: ATTACHED SECTORS SUMMARY PAPER

As you may recall, the Assistant Secretaries Group charged Jeffrey Hunker to write a paper on the sectoral implications of climate change policy. The attached paper is a much shorter version of the Sectors paper we received a month ago. My thanks to Jeff Hunker, Skip Laitner, and the many staff from all of the agencies who have worked on this paper over the past six weeks.

We would appreciate your review of the new draft. Please provide comments to Judi Greenwald of our Task Force by Thursday, July 3. Our fax number is 343-1163. Judi's new e-mail address is greenwald_j@btgcinema.com. My plan is to incorporate your comments and forward the paper to Katie McGinty and Dan Tarullo for their consideration the following week. This paper will be used as part of the discussions with individual industry and labor representatives on how we minimize the impacts and maximize the opportunities of climate change mitigation policies. Thus your immediate attention would be much appreciated.

Where do 1997 AEO97 figures come from?

OPTIONAL FORM 99 (7-90) *please be sure both recipients get this fax. Thanks*

FAX TRANSMITTAL		# of pages 30
To Alicia Munnett	From VIRGINIA GERSEVERI	
JEFF FRANKEL	Phone 233-9796	
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* This fax will be transmitted in 2 parts
* ~~the~~ cover page → p. 16
p. 17 → 25.
Please be sure to combine parts one and two.

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

A Pre-Decisional Draft
Do Not Cite or Quote

June 30, 1997

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Introduction

In a June 27, 1997 speech to a United Nations environmental conference, President Clinton acknowledged that "concentrations of greenhouse gases in the atmosphere are at their highest levels in more than 200,000 years and climbing sharply." If that trend does not change, the President noted that the resulting climate changes would "disrupt agriculture, cause severe droughts and floods and the spread of infectious diseases." In underscoring the fact that no nation can escape the danger of climate change, the President stated that: "We must create new technologies and develop new strategies like emissions trading that will both curtail pollution and support continued economic growth. We owe that in the developed world to ourselves, and equally to those in the developing nations. Many of the technologies that will help us to meet the new air quality standards in America can also help address climate change. This is a challenge we must undertake immediately."

Drawing on the guidance of the President's statement to the United Nations, it is clear that any future climate change policies adopted by the United States should be anchored by a technology-based investment strategy. Such a strategy will focus on the diffusion of cost-effective technologies that are now available but underutilized, even as we continue efforts to develop new technologies. Yet, the sectors of the economy vary widely in how they produce goods and services. For that reason, the impact of future climate policies — as well as the technologies available to respond to those policies — will also vary widely. This is true for both the sectors as a whole and for the individual firms within those sectors. For policy makers and for business and labor leaders, it is important to understand these different impacts and opportunities.

Sources of U.S. Greenhouse Gas Emissions

Greenhouse gases include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). Chlorofluorocarbons (CFCs) and partially halogenated fluorocarbons (HCFCs), a family of human-made compounds, their substitutes hydrofluorocarbons (HFCs), and other compounds such as perfluorinated carbons (PFCs), are also greenhouse gases. Of these gases, CO₂ accounts for the largest share by far of all anthropogenic emissions and is primarily the result of fossil fuel combustion for energy use. The greenhouse gas emissions are typically measured in "carbon equivalents," according to their respective "global warming potential."

? Total U.S. greenhouse gas emissions in 1995 were 1,557 MMTc (million metric tons of carbon equivalent), with gross emissions of 1,674 MMTc offset by 117 MMTc of carbon sequestered by the nation's forests. Since 1990 energy-related carbon emissions have increased by about 10 percent to 1,467 MMT in 1997. They are expected to grow 1.2 percent annually, reaching 1,722 MMT by 2010.

Draft
U.S. CAR
reports
1,559 MMTc
and
1,676 MMTc

U.S. Carbon Emissions by Fuel

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

? 32.5 ?

Table 1. U.S. Carbon Emissions by Fuel Type

	1997	Percentage of Total 1997 Emissions	2010	Percentage of Total 2010 Emissions
Petroleum	613	42%	730	42%
Natural Gas	335	23%	412	24%
Coal	519	35%	579	34%
Other (includes methanol and liquid hydrogen)	0	0%	1	0%
TOTAL	1467	100%	1722	100%

Source: EIA Annual Energy Outlook 1997

1997 figures are estimates

U.S. Carbon Emissions by End-Use Sector

End-use sectors include the following: residential and commercial (collectively called "buildings"), industrial, and transportation. Emissions from each of these sectors are roughly equally distributed among the three: buildings (35%), industry (33%), and transportation (32%). These shares are projected to remain fairly constant through the year 2010 and beyond. The most diverse of the end-use sectors is that of industry, which consists of farming, agricultural services, fisheries, forestry, mining, construction, and manufacturing.

Table 2. U.S. Energy-Related Carbon Emissions by Major End-Use Sector

	1997	Percentage of Total 1997 Emissions	2010	Percentage of Total 2010 Emissions
Buildings	512	35%	576	33%
Industry	471	33%	548	32%
Transportation	485	32%	598	35%
TOTAL	1467	100%	1722	100%

Source: EIA Annual Energy Outlook 1997

Energy End-Use Sectors

The Buildings Sector

Residential and commercial end uses combined to consume 35 percent of the nation's total energy requirements in 1997. The major components of energy use within the buildings sector are summarized in Table 3 on the following page.

Table 3. 1997 Building Energy Consumption by End-Use

End Use	Percentage of Total
Space Heating	26%
Space Cooling	9.4%
Water Heating	10.8%
Refrigeration	4.9%
Lighting	14.9%
Cooking	2.6%
Other Appliances	31.5%
Total	100%

Source: EIA Annual Energy Outlook 1997

Residential primary energy use per household has declined only two percent in the period 1979 to 1995. According to the Energy Information Administration's *Annual Energy Outlook 1997* (AEO97), total energy consumption in the residential sector is projected to increase by 9 percent between 1997 and 2010. Most of the growth in this sector is expected to occur in the "other uses" category, which includes items such as electronic equipment and small appliances. Not surprisingly, therefore, most of the increase in energy demand during this period is attributed to greater use of electricity.

Measured in terms of energy use per square foot of building space, the commercial sector has witnessed improvements in energy efficiency on the order of 30 percent between 1979 and 1992. However, total energy consumption has been rising over the past two decades as a result of overall growth of the commercial sector. Future energy demand is also predicted to increase by 9 percent in the period 1997-2010. As is the case with the residential sector, end-use products such as office equipment and consumer electronics account for the majority of net growth in energy demand through 2010.

Table 4 summarizes the category of end-use energy in the combined buildings sector for the years 1997 and 2015.

2010

Table 4. Total 1997 and 2015 Building Energy Consumption By End-Use (in Quads)

	1997	2010	Percent Change
Space Heating	8.77	8.85	0.9%
Space Cooling	3.17	3.09	-2.3%
Water Heating	3.63	3.69	1.5%
Refrigeration	1.67	1.42	-14.6%
Lighting	5.04	5.04	-0.2%
Cooking	0.87	0.89	2.3%
Other Uses/Appliances	10.62	13.84	30.3%
Total	33.77	36.81	9.0%

Source: EIA Annual Energy Outlook 1997

Table 4 shows that most of the growth in building energy demand will occur in the "other uses" category, growing by 30 percent in the period 1997 through 2010. This category currently accounts for nearly 32 percent of total building energy use and is expected to increase to 38 percent in 2010 as small appliances and office equipment continue to penetrate the market. In the residential sector, this category of end-uses includes personal computers, dishwashers, clothes washers, and dryers. For the commercial sector this includes office equipment such as personal computers, monitors, fax machines, copiers, printers, scanners and multifunction devices. Additional products included in the "other" category include new telecommunications technologies, medical imaging equipment and vending machines.

Factors Shaping Industry Response

Currently, ~~numerous~~ opportunities exist to improve the level of energy efficiency within the buildings sector. By tightening the building shell and installing properly sized, energy efficient heating and cooling equipment, consumers can experience ~~substantial monetary gains through greater savings as a result of lower~~ monthly utility bills. In addition to saving money, consumers can benefit from improved overall comfort resulting from better indoor air quality, superior lighting, and reduced noise levels. However, the savings are often hard to verify, sometimes varying from building to building. Although consumers have clearly accepted improved insulation levels and some other energy savings features, it is not clear whether or when the more complicated or advanced savings opportunities will achieve significant market penetration.

Technology Options

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

- Better insulation of building shells
- Better control systems for regulating the use of energy consuming equipment (time and temperature controls by zone, energy-use optimizers, energy management systems)

- High efficiency heat pumps
- Heat pump water heaters
- Decreased hot water requirements through better designed clothes washers and dishwashers
- Increased motor/compressor efficiencies for refrigerators
- High efficiency lighting - fluorescent fixtures, electronic ballasts, control systems
- Substitution of lower-carbon fuels (on a full fuel-cycle basis)
- Reduced air infiltration practices, including improved duct work
- Energy efficient windows
- Whole house design that allows for substantial equipment downsizing

Barriers to Adoption

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

- Potential buyers of products need to know about the technology
- Potential buyers need clear, reliable information on the performance and economic benefits of the technology
- Potential buyers must be the ones to see the benefits of lower energy bills
- Service providers and users of the technologies must have expertise to appropriately design for, install, and operate the technology
- Sources of capital must understand the low-risk nature of these investments

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

The Industrial Sector

The industrial sector consists of an extremely diverse set of business enterprises — both in terms of products and processes. It includes agriculture, mining, construction and manufacturing. Even within individual subsectors, a range of activities exist that have vastly different energy use patterns and carbon emission profiles. Agriculture includes, for example, both ranching and farming. Mining includes the extraction of both energy and non-energy mineral resources. Construction ranges from the building of new homes, offices, highways, and power plants to the maintenance and repair of those same facilities. Finally, the manufacturing subsector incorporates a range of industries that produce beer, paper, and clothing on the one hand, and aluminum ingots, plastic resins, cars, and

computers on the other. Energy requirements for each of these industries are as different as the products they produce.

Trends in the Industrial Sector

Broadly speaking, industrial activity will grow by about 2.35 percent annually in the period 1997 through 2010. Yet, from the perspective of energy use and overall carbon emissions, there are significant differences within the many subsectors. For convenience, such activity can be categorized into those subsectors which are energy-intensive and those which are not. Output in the energy-intensive industries — including chemicals, petroleum refining, pulp and paper, glass, cement, iron and steel, and aluminum — will grow by 1.34 percent annually through 2010. The energy intensity of those subsectors will decline by only 0.53 percent. In contrast, output in the non-energy-intensive industries will increase by 2.65 percent annually while their energy intensity will decline 1.23 percent per year. Despite the more rapid decline in energy intensity, the more rapid growth in economic activity means that overall energy use (and, hence, increases in carbon emissions) will increase more quickly in the non-energy-intensive industrial subsectors.

Table 5. 1997 Comparison of Energy Intensive and Non-Intensive Industrial Subsectors

	Output (Billions of 1987 Dollars)	Annual Growth Rate	Energy Use (Trillion Btus)	Energy Intensity (1000 Btus per Dollar of Output)	Annual Change in Energy Intensity
Energy- Intensive	920	1.34%	17,197	18.7	-0.53%
Other	2,847	2.65%	17,224	6.1	-1.23%
Total	3,767	2.35%	34,421	9.1	-1.22%

Source: EIA Annual Energy Outlook 1997

Carbon emissions in the industrial sector are the result of two different types of processes. The first is the combustion of fossil-fuel resources while the second involves non-energy related production processes. The energy-related emissions, estimated to be about 471 MMT in 1997, account for about 96 percent of total carbon emissions. This includes emissions from electricity generation which are distributed across all the industrial sectors. According to the AEO97 forecast, this is expected to grow to 548 MMT by 2010, a 16 percent increase over 1997 levels. Unfortunately, emissions data for individual industrial sectors are not currently reported in any published sources.

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

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

- carbon dioxide manufacture
- aluminum production

One example of non-energy related process emission occurs in the production of cement. The calcination reaction which converts the limestone raw material into clinker generates direct emissions of approximately 11 MMT. This is based upon 1995 data, the latest available at this time. Total non-energy related processes contributed a total of perhaps 21 million MMT of carbon emissions in 1995.

Economic Modeling Results for the Industrial Sector

There are a variety of models and analyses which have been used to characterize the impacts of climate policies on the industrial sectors. A June 1997 study by a consortium of non-profit groups, for example, estimated that carbon emissions could be stabilized below 1990 levels with an overall net benefit to the economy. The reason is that cost-effective energy efficiency improvements and productivity gains were shown to offset the increased energy prices stimulated by proposed climate policies (*Energy Innovations*, 1997). The Interagency Analytical Team (IAT) also used aggressive technology investment assumptions in an analysis with the Markal-Macro model to show that the cost of energy services could actually be about 3.0 percent lower for all sectors in the year 2010 and beyond — despite the higher energy prices resulting from a cap in carbon emissions. This result contributed to a net positive (albeit small) GDP benefit showing up as early as the year 2000.

To analyze the impacts of climate policies on specific industries, however, the IAT employed the DRI/McGraw-Hill Inter-Industry Model. The model calculates production, detailed inter-industry transactions and trade for 246 industries, using production and trade data from the DRI Macroeconomic Model and detailed projections of changes in efficiency and productivity over time.

Under the "central stabilization case," which estimates the effects of stabilizing carbon emissions at 1990 levels from the year 2010 through 2020, direct emissions reductions in the industrial sector account for about 19 percent of total emission reductions (48 MMT) in 2010 and 21 percent (70 MMT) in 2020. Reductions in overall energy demand as well as improvements in industrial energy efficiency account for these reductions. Also under the central stabilization case, energy intensity across all industries initially declines at a rate of 2.6 percent per year vs. 1.5 percent in the base case and later slows to about 1.5 percent per year versus 0.9 percent in the base case.

One major area of concern is the effect of carbon constraints on the energy-intensive industries which account for only one-fourth of total industrial output but one-half of total industrial energy use. These concerns reflect both domestic demand, and international competitiveness.

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

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

Why we don't think this
will be bad for international competitiveness (but this
is not yet public)

There are
models
that indicate
economic
losses
⇒ IPCC

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

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

non-Annex I

The results of the DRI model provides a midpoint in the ranges of other studies, which either tend to predict that carbon stabilization policies would have only minimal impacts initially, and even a small positive in later years as energy-intensive industries begin to implement offsetting productivity investments, or which predict severe impacts that could perhaps drive large portions of these industries overseas, with little net effect on global emissions. The results from DRI analysis show that while a carbon stabilization policy would affect energy-intensive industries, the most dire predictions overstate the impacts of climate policies. For the policy cases, other than for oil and coal, the impacts on output for energy intensive industries relative to the base case are less than 1.9 percent assuming no international emissions trading, and less than 1.2 percent with international trading.

(those countries not characterized by advanced industrialized economies)

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

The IAT's DRI analysis did account for changes in terms of trade for U.S. industries. Under this analysis, non-Annex I producers (including China Mexico, Korea and Brazil), which currently account for about 40 percent of U.S. imports, would not be faced with energy price increases from a stabilization. If that were to occur, there would be an increase in imports from non-Annex-I countries and decreases of U.S. exports to the world market. Yet, the relatively rigid representation of substitution possibilities in production that characterizes the DRI model may overstate the effect of energy price increases on production costs. In contrast to the DRI model, models that have a more detailed and flexible representation of production technologies (such as general equilibrium models) or that represent technological shifts (i.e. from integrated steel mills to electrometallurgical mini-mills or from primary aluminum to secondary aluminum) would yield lower estimates of production cost increases. As the Markal-Macro results have shown, depending on the depth of technological substitution that is available to industries, the overall result may even show a slightly positive GDP benefit over time.

Factors Shaping Industry Response

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

Aluminum

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

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

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

Petroleum Refining

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

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

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

alkylation, and hydrogen production.

Glass

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

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

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

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

Steel

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

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

After a historical record of lagging technologically, the U.S. steel industry has begun to exhibit a high

rate of technological change, including direct smelting processes that replace the blast furnace and coke oven, and direct strip casting processes that replace the continuous caster and hot strip mill.

Chemicals

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

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

Pulp and Paper

The U.S. has the world's largest installed pulp, paper, and paperboard production capacity, some 86 million air-dry metric tons (ADMT) per year in 1993, or about 30 percent of global capacity. Manufactured products from the paper and allied products industry include newsprint, printing and writing paper, tissue, paper plates, card stock, corrugated cardboard, cartons, and construction-grade paperboard. The U.S. is home to close to 550 pulp and paper mills located in 42 states. Over the last twenty years or so, many of the smaller, older mills have been closed down and replaced with larger integrated mills. The integrated mills produce both pulp and paper and/or paperboard. The trend is toward larger size (over 2000 tons/day) plants with the capability to consistently process high-quality products at higher speeds.

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

There are major opportunities for improving the efficiency of process energy use in the pulp and paper industry. A number of new energy-saving process technologies such as digesters and paper or pulp dryers, are under development or recently commercialized and process heat integration analysis

has been applied in several mills. Most process specific changes that bring energy efficiency improvements also bring productivity and other improvements. Advanced biomass-based cogeneration systems, which would provide major improvements in efficiency over existing systems, are currently undergoing rapid development.

Cement

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

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

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

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

High-Growth Industries

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

- Some of these industries are growing more rapidly than the energy-intensive industries. Most of the growth (64 percent) in industrial energy use from 1997-2010 will be by non-energy-intensive industry subsectors (3.4 of 5.3 quads).
- Service Industries employ 77% of the U.S. workforce and account for 74% of GDP. The distinction between service and manufacturing industries is becoming increasingly blurred.
- Opportunities exist for new technologies in high-growth sectors that have capital turnover rates that are higher than those of energy-intensive industries. With high rates of capital turnover, the opportunities to accelerate the diffusion and acceptance of energy efficient technologies are

substantial, and can collectively lead to significant reductions in carbon emissions.

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

Non-Energy Minerals Industry

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

Construction

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

Much of the construction industry is labor intensive. Most construction work involves using small trucks to transport workers and materials, and hand and power tools, and physical labor to complete work. It is one of the least energy intensive industries in the nation. Energy costs (including selected power, fuels, and lubricants) account for approximately 1.6 percent of each dollar of business done in the construction industry as a whole. Nevertheless, there are important opportunities to reduce energy costs within the industry. These opportunities range from using more efficient motor vehicles to incorporating the use new building materials (e.g., laminated beams, recycled products, engineered lumber products such as roof and floor trusses, insulated wall panels, and modular components) that reduce both construction waste and costs.

Motor Vehicle and Related Industries

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

Focusing only on the automobiles industry, most analysts see little or no change in the sales of cars and trucks over the next few years. This means that competition will be fierce among the 26 firms

that serve the major developed markets worldwide, including the so-called Big Three automakers — Ford, Chrysler, and General Motors. Within a decade some analysts project that, either as a result of sharing manufacturing resources, or as a result of mergers and acquisitions, as few as 10 "mega-manufacturing alliances" may serve all of the developed countries.

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

Barriers to Adoption

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

For most industries, energy expenditures represent a minor portion of their operating costs, averaging less than two percent of value of shipments for the manufacturing sector. Industries such as primary aluminum, hydraulic cement and industrial gases are notable exceptions, with energy accounting for more than 20 percent of value of shipments. However, for some of the fastest growing industries, such as electronics and computers, energy expenditures represent only 1.2 and 0.6 percent of shipments respectively. In most industries, larger costs, such as labor and raw materials, receive attention before energy. For example, employee compensation averaged 24 percent of shipments in 1994.¹

Opportunities for energy efficiency improvements must compete with other issues for finite resources within a company. While capital is the most often cited resource, staff time may be of equal or greater importance. Downsizing is common when industrial companies undergo restructuring, resulting in fewer total personnel available to address all issues. When a choice must be made between addressing a potential emissions-compliance, production-reliability or product-quality problem, and identifying and implementing energy efficiency projects, the former receives the attention since failure to do so may result in the plant being shut down. One manifestation of this staffing constraint is the reduction in the number of corporate energy managers²

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

2. Ibid.

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

The Transportation Sector

Trends in the Transportation Sector

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

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

Contribution to Greenhouse Gas Emissions

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

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

Actual growth in VMT since 1990 has averaged 2.4 percent per year. Growth in VMT is a function of a number of factors, including demographic changes (e.g., more women in the workforce; immigration), land use patterns, the cost of driving each mile (now at an all-time low on an inflation-adjusted basis), among others.

Factors Shaping Industry Response

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

Technology Trends and Options

Three principal ways exist to reduce carbon emissions from light vehicles: (1) reduce ~~vehicle miles traveled~~ (VMT); (2) improve fuel economy; and (3) use fuels with lower life-cycle carbon emissions. *see earlier reference* Work developed for the "Car Talk" committee³ suggested estimated reductions of 445 to 585 MMT would be possible in the period 2005 to 2025 from a combined package of land-use and transit policies as well as efforts to improve overall fuel economy and reduce the carbon content of transportation fuels.

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

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

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

Alternative fuels — such as biofuels — are another large opportunity for reducing transportation carbon emissions. Federal R&D has brought down the cost of biomass ethanol (from \$3.60 per gallon in 1980 to \$1.20 per gallon today). Further research has the goal further cost reductions to under \$0.70 per gallon by 2005, competitive with oil at its current price. Estimated carbon savings from use of ethanol largely as a gasoline blend is 20 MMTC in 2010.

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

Agriculture

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

Contribution to Greenhouse Gas Emissions

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

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

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

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

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

Factors Shaping Industry Response

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

For every dollar of farm output, 12 cents is spent on energy with electricity accounting for 6 cents. This reflects the increasing reliance on electricity for operations such as grain handling and large-scale confined livestock production. Agricultural chemicals embody 6 cents of energy for each dollar of

output, spent mainly on natural gas and electricity. Nitrogen fertilizer is among the most energy intensive chemicals and its availability is a key to high agricultural productivity. Energy cost increases would directly increase both agricultural production costs and agricultural chemical manufacturing costs.

Technology Trends and Options

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

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

- Conversion of marginal cropland and pasture to forest: Forest growth currently offsets about 8 percent of total annual U.S. greenhouse gas emissions on a carbon equivalent basis. A number of studies have outlined the costs and economic benefits to U.S. agriculture resulting from strategies to mitigate U.S. greenhouse gas emissions by paying farmers to convert cropland and pasture to forest. Pulling the necessary quantities of land out of production, however, would raise land prices and would increase the cost of bidding land out of production.
- Promoting the use of management practices that increase the quantity of carbon stored in agricultural soils: Studies suggest that these sinks could technically offset a majority of U.S. greenhouse gas emissions, but economic analysis of such possibilities is limited.
- Using biofuels to replace fossil fuels: Because the carbon released in the burning of biofuels would be taken back up by the next crop, replacing fossil fuels with biofuels offers a means of increasing the amount of carbon that is recycled in the production and use of energy. The IPCC (1996) has estimated that for the world's temperate regions as a whole, carbon emissions could be reduced by 85 to 493 million tons per year by allocating 8 to 11 percent of their cropland to biofuel crops. While the United States' share of this is not addressed, the IPCC notes that the best mitigation opportunities are in areas with good agricultural land and surplus production.
- Further efforts to alter livestock management practices to reduce methane emissions: The most promising opportunities for reducing methane emissions in U.S. agriculture are in new management practices for the feeding of livestock and the handling of livestock waste (particularly cattle).

Energy Supply Sectors

Electric Power Generation

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

With several hundred billion dollars worth of combined capital investments, electric power generation

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

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

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

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

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

Contribution to Greenhouse Gas Emissions

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

is expected to continue

Table 6. Carbon Emissions from Electricity Generation (MMT)

	1997	Percentage of Total 1997 Emissions	2010	Percentage of Total 2010 Emissions
Petroleum	13	2%	12	2%
Natural Gas	55	11%	102	16%
Coal	454	87%	512	82%
Total	522	100%	626	100%

Source: EIA Annual Energy Outlook 1997

*Factors Shaping Industry Response*Restructuring

Restructuring of the electric power industry offers a unique opportunity to mitigate future emissions of CO₂ from this sector. Many states are currently considering or adopting retail competition for their electric power markets. This trend may be accelerated with federal legislation. Retail competition may lower the price of electricity by as much as 20-25 percent in certain regions and change the fuel mix of generation. Restructuring without new environmental policies is expected to favor the expanded use of existing coal plants. These plants are largely depreciated, and hence can generate electricity for low incremental cost. To mitigate the environmental impacts of competition and maintain the environmental benefits of current state level renewable energy and demand side management programs, a number of options have been adopted or are under consideration. These include:

- A "portfolio standard" for renewable energy: This would require that all generators meet a specified level of renewable generation either by undertaking such projects themselves or purchasing "credits" from others who have.
- A social benefit fund: Revenues from a charge on transmission service are used to subsidize energy efficiency projects, renewable, R&D, or low income consumers. California has adopted this approach.
- Information disclosure requirements: Generators could be required to disclose the emission profiles of their generation, facilitating the marketing of "green" (or, less polluting) electricity.
- Leveling of the playing field for air pollutant requirements: Many states are hesitant to adopt retail competition because they perceive that differing regional environmental requirements put their electric industry at a competitive disadvantage and will result in more pollution being transported into their states. Thus, additional environmental provisions to "level the playing field" — which could include greenhouse gas emission reductions — are currently being debated. Adaption of fuel neutral standards would promote utilization of lower emission systems.
- Special consideration for energy efficient and/or low emission technologies: This includes advanced gas turbines and micro turbines for cogeneration and self-generation, fuel cells, and renewable technologies.

Distributed Generation

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

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

Technology Trends and Options

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

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

- The next generation of natural gas technologies (including gas turbines and fuel cells) are projected to achieve energy conversion efficiencies of 70 percent or more by 2005.
- High efficiency coal-fueled power plants, such as integrated gasification combined cycle, are likely to realize efficiencies exceeding 55 percent and half the CO₂ emissions of current coal technologies.
- Renewable technologies — wind power, photovoltaics, solar thermal, and geothermal — have seen sharp cost reductions in the past two decades, some by a factor of ten.
- Options such as biomass gasification offer the ability to produce power with no net increase in CO₂ emissions. The growth of biomass offsets (sequesters) the CO₂ released in electric power production.

Petroleum

Contribution to Greenhouse Gases

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

Factors Shaping Industry Response

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

Coal

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

Contribution to Greenhouse Gas Emissions

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

Factors Shaping Industry Response

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

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

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

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

Nuclear Energy

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

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

Factors Shaping Industry Response

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

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

Natural Gas

Contribution to Greenhouse Gas Emissions

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

Factors Shaping Industry Response

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

- The DRI energy model shows a reduction in natural gas use relative to baseline on the order of 9 to 16 percent between 2005 and 2015.
- NEMS, despite simulating a somewhat larger reduction in carbon emissions from the energy sector, shows an increase in natural gas use relative to base of between 4 and 11 percent over this same period.

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

The key to cost-effective greenhouse gas reductions in 2010 lies in the large potential of developing and implementing energy efficiency technologies in each of the economic sectors. Within the industries which may be required to reduce their greenhouse gas emissions, there will be opportunities to gain competitive advantage through creatively meeting the environmental challenge. There will be opportunities for other industries as well. For example, companies and individuals in the architectural field can benefit as new building designs are needed to improve efficiency in both the residential and commercial sectors. In addition, industries that manufacture items such as heating and air conditioning equipment, office equipment, automobile parts, industrial equipment, and lighting, to name only a small fraction of potential industries, may also benefit under a climate change policy due to increased demand for these products. Finally, industries involved in the development of renewable energy technologies will also be at an advantage as interest in solar, wind and other sources of energy grows.

Conclusion

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

“Modeling Technological Change in Energy Demand Forecasting: A Generalized Approach,” DeCanio and Laitner

This paper supports the position that the current “investment” approach models (i.e. conventional models) of technology diffusion tend to yield substantially high implicit discount rates. This occurs since “accurate estimates of the implicit discount rate cannot be obtained from cross-sectional data if the diffusion process is dynamic.” Bias of the conventional forecasting methodology is pronounced for highly profitable, low-payback technologies in their early stages of adoption. Models such as this will tend to consistently underestimate the effect of new technologies being observed early in their life cycles. As such, the authors claim that this approach is not accurate, and offer a different approach where they assume that “the spread of new technology is conceived as the simplest possible type of diffusion process.” This is sometimes referred to as the Fisher-Pry (1971) model. Table 4 examines space heating technology and determines that even under pessimistic assumptions about diffusion, any of the technologies listed would show greater market penetration after five years than the maximum shares allowed by the conventional investment model. Under the conventional forecasting framework, superior technologies never achieve their long-run potential, and inferior technologies persist in the market long after they would typically be replaced.

Some policy implications:

- Conventional energy forecasting models are too conservative about the prospects for energy saving resulting from the diffusion of energy-efficient technologies.
- The “investment” model is biased against emerging technologies early in their diffusion cycle.
- These conventional models underestimate the potential of market-based or voluntary programs, while also making tax incentives appear less powerful than they really are.

**“The Diffusion of New Technologies: Evidence From the Electric Utility Industry,”
Joskow and Rose, Rand (1990)**

This paper examines technological innovations and their subsequent diffusion in the steam-electric generating industry. Hazard rate models, with special attention given to proportional and log-logistic models, are studied. A brief look at the data suggest that relative to IOUs (investor owned utilities), cooperative and government-owned utilities tend to be smaller, have slightly lower fuel costs, build fewer units, and adopt new technologies less frequently and later. Further, there is a marked difference in adoption rates by size of utility. Results for the 2400 psi technology model indicate that firm size has a positive significant influence on adoption probabilities, so larger firms are more likely to adopt the technology earlier than the small firm. Fuel prices (in particular 1972 prices) have a positive impact on adoption probabilities. Also, the hazard models suggest that, at least initially, adoption probabilities tend to increase over time. The model does not suggest that ownership structure has a significant influence on adoption probabilities. Evaluating the elasticities of the log-logistic model for the 2400 psi technology for an IOU at the sample midpoint of 1965 indicates that a 10% increase in utility size leads to a 13.6% increase in the hazard rate (see Figure 5 for elasticities of hazard rates, 2400 psi). Compare these results to 10.7% for the Weibull proportional hazard model and 7-8% for the double-censored model (sample means for 1970 size and 1972 fuel cost variables) for the same 10% increase in utility size. Results for the supercritical technology are somewhat noisier. The size of the utility again has a positive and significant impact on adoption probability. Time is also significant, as the supercritical hazard rate path looks like a “stretched out” version of the 2400 psi path. Nothing else of note was statistically significant in the model. The elasticities of the hazard rates are 1.08 for the double-censored model (10% increase in utility size yields a 10.8 % increase in hazard rate) and elasticities are 20-30% higher for the proportional hazard and the log-logistic models.

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1/21/97

“Modeling The Processes of Technological Innovation and Diffusion: An Overview of Issues,” Greening and Khrushch, 1996

This paper takes a general look at modeling the process of innovation and diffusion. Of note, the authors suggest that the diffusion process has been described with the characteristic S-shaped or logistic type of path. This appears to be fairly consistent across the technologies studied. The authors make one conclusion that the processes of innovation and diffusion do not occur in a linear progression.

“Regrets or No Regrets--That is the Question: Is Conservation a Costless CO₂ Mitigation Strategy?” Adam Rose and Shih-Mo Lin, *The Energy Journal*, (1995)

This paper develops a CGE model that essentially demonstrates that conservation would have a slightly negative effects on the US economy overall, while also having substantial negative effects on most energy industries. The GE framework is able to address some issues that a partial equilibrium framework cannot. First, if energy conservation savings are passed on to other industrial customers, there may be the possibility of further rounds of price reductions. However, the reduction in energy use would likely lower production levels in the coal, oil, gas, refined petroleum, and electric and gas utility industries. This would have the impact of promoting energy conservation through reduction in economic growth instead of improving energy efficiency. Using a 20-sector CGE model, the authors assume simple conservation measures that would reduce baseline emissions in the US by 12.8% (optimal response to a call for 20% global emissions reduction and an equilibrium permit price of \$38.35). This would result in a reduction of real GDP in 2000 by 1.44%, while only cutting energy use by 3.32% (due to substitution effects) and cutting CO₂ emissions by 3.44%. Further, employment, investment, and welfare (as measured through compensating variation) all are adversely affected by the conservation measures. Similar results hold for a modified conservation program as well as cases of implementing a carbon tax or permit trading system. The latter two cases do, however, result in considerable reductions in energy use and in CO₂ emissions over the base conservation case. Sensitivity analysis also demonstrates negative impacts on real GDP and employment. The authors conclude that conservation should not be oversold as a costless CO₂ mitigation strategy while noting that these results pertain only to the short run.

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1/23/97

"The Costs of Reducing U.S. CO₂ Emissions—Further Sensitivity Analyses," Manne and Richels (1990)

The authors note that "clearly, the AEEI parameter is highly controversial." They doubt that an AEEI of 1.5 (annual rate of change) is sustainable over a long period. This would exceed the U.S. GDP growth for much of the 21st century while implying that a rising GDP would be accompanied by falling energy demands during many decades of stable energy prices. The question arises: What would cause energy demand to go down even though there are stable energy prices? Critics of an earlier paper by the authors claim that by only considering AEEI values as high as 1.0 may be overly pessimistic in addressing the prospects for energy efficiency improvements. *Note that a low AEEI value does not necessarily imply a low overall rate of energy efficiency improvements since in addition to the AEEI effect there is also the effect of rising energy prices on demands.* This means that we can have autonomous and/or price-induced efficiency improvements, and some focus should be given to determining the degrees of impacts that each have. Unlike autonomous improvements in energy efficiency, the contribution from price-induced conservation is not costless.

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1/23/97

"The Berlin Mandate: The Design of Cost-Effective Mitigation Strategies," Richels *et al* (1996)

The Framework Convention states that "policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible costs." The authors address two ways to promote this objective. In the first, emissions reductions are allowed to take place *where* it is cheapest to do so. In the second, reductions take place *when* it is cheapest to do so. The paper only focuses on costs of emissions reduction and not on the benefits. The four energy-economy models that the authors examine are: CETA, EPPA, MERGE, and MiniCAM (refer to paper for further description). These models employ a GE formulation of the global energy and economic system. One point that comes forward is that the stabilization of global emissions will eventually require the participation of developing countries. Also, all four models differ in their estimate of the order of the magnitude of the economic impacts. This occurs in large part due to the differences in the baseline emission levels. As such, a main result of the paper suggests that the costs of mitigation can be substantially reduced through international cooperation (tradeable permits system) and the optimal timing of emission reductions. This flexibility can reduce costs by as much as 80% or more, which could lead to trillions of dollars of savings in mitigation costs. However, knowing this only brings to light some further questions: How should we divide up the savings achieved through international cooperation? How do we guarantee that all parties maintain a credible path toward fulfilling emission reduction requirements?

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1/23/97

“Learning By Doing: Pulling the Benefits of Energy Efficiency Technologies into Climate Change Strategies,” Laitner (1997)

This paper offers several methods that appear to be successful at enhancing the diffusion of technology so that energy efficiency can be realized. These include (1) selling productivity benefits, (2) scaling down the costs, (3) learning by doing, (4) banking on R&D, (5) promoting new institutional arrangements, (6) informing the market, and (7) capturing nonmarket benefits. The author points out that there are numerous studies that demonstrate the benefits of accelerated investment in energy efficient technologies. Since there have been no studies done on quantifying the magnitude of the opportunity costs of implementing these technologies (i.e. a GE model), the author suggests that “a second best solution may be good enough.” There is nothing more explicit on the rate of technology diffusion. However, there are some interesting trends in the table on page 10 (Energy Modeling Comparisons). Effectively, it appears that large R&D expenditures are necessary and sufficient to develop new technologies in order to achieve an average annual change in energy usage of 0% (approximately) or below 0% and to achieve decreases in carbon emissions. What incentives will produce these results?

1/24/97

"The Cost of Stabilizing Global CO₂ Emissions—A Probabilistic Analysis Based on Expert Judgments," Manne and Richels, *The Energy Journal* (1994)—Comments on earlier draft of paper.

The Energy Modeling Forum from 1993 compared a diverse group of energy-economic models that employed different methodologies. While these models generated vastly different results concerning the future of economic growth and energy usage, all of them yielded remarkably similar results when standardized so as to employ common numerical inputs. This illustrates an important point. While it seems appropriate that different results are achieved through using different methodologies, it is somewhat disconcerting that the results are sensitive to even modest changes in the underlying factors that are inherently uncertain. As such, it appears that the choice of methodology is secondary to the choice of values for population growth, energy intensity, technical progress, etc. The authors proceed to elicit responses from a group of experts in the field to generate inputs for their Global 2100 model. The authors wanted to collect estimates of certain parameters to use in their Global 2100 model without relying on the literature. However, the question arises as to where the experts collect the information that is used to create their predictions (i.e. are they influenced by the figures that are generated in the literature?). The following question was one of five questions asked of the experts:

What will be the average global rate of AEEI over the next century?

The responses generated the data on page 11, providing a range of values for the AEEI. One item of note is that when energy costs are a small fraction of total output, ESUB is approximately equal to the absolute value of the price elasticity of demand.

Summary of Energy Efficiency Literature (AEEI and ESUB)

Estimates of values of the AEEI have been an issue of much debate in recent years. The values vary over a rather large range. Laitner (1997) claims that estimates of AEEI over 2.0 will require large R&D expenditures. Further, Manne and Richels (1990) claim that an AEEI of 1.5 or above is unlikely to be sustainable over a long period. Some critics argue that assuming that the AEEI cannot exceed 1.0 is incorrect as it is too pessimistic in its implications about prospects for energy efficiency improvements. A report by the EMF (September 1996) indicates a range for declines in aggregate energy intensity for the economy of 0.6% to 1.0%. The estimates exceed 1.0% for several models that exclude the industrial sector and fall to about 0.4% for one model focusing on industry alone (p. 12). These results are comparable with assumptions about the AEEI found in other economic models. Forecasts from the AEO97 indicate a range of AEEI between -0.7% and -1.0% (see Table 1, p. 6, AEO97). Estimates of the cost of abating carbon dioxide emissions have been sensitive to the AEEI. Greater AEEI in the baseline contributes to lower baseline CO₂ emissions, thus making it easier and less costly to achieve a specific emissions level based on historical targets (p.11). Refer to John P. Weyant, *Journal of Economic Perspectives*, Fall 1993, 7(4): 27-46.

Manne and Richels (1994) determined that while various energy-economic models yield vastly different results, the models all generate comparable results when standardized so as to employ common numerical inputs. While it seems appropriate that different results are achieved from using different methodologies, it is somewhat disconcerting that the results are sensitive to modest changes in factor inputs that are inherently uncertain. This indicates that the choice of methodology is secondary to the choice of values for population growth, energy intensity, technical progress, etc. As such, the authors survey a number of experts in the field to elicit their predictions on what the global rate of AEEI will be over the next century. The responses are as follows:

<u>Percentile</u>	<u>Minimum</u>	<u>Maximum</u>	<u>Average</u>	<u>Median</u>
10	-0.50	0.75	0.20	0.23
30	-0.10	1.00	0.45	0.45
50	0.10	1.30	0.70	0.68
70	0.00	1.50	0.97	0.90
90	0.90	2.00	1.38	1.20

The authors further note that when energy costs are a small fraction of total output, ESUB (elasticity of price-induced substitution) is approximately equal to the absolute value of the price elasticity of demand. The EMF (1996) also reported that the models indicate that energy demand would fall by only 3 to 8% after 20 years with a 25% increase in delivered energy prices. A change in energy demand of 3% translates to an

elasticity of -0.12 while that of 8% relates to an elasticity of -0.32. The EMF compared some other energy demand models, where the long-run elasticity ranged from -0.3 to -0.7 when measured at the wholesale or refinery level (i.e. the secondary level). After adjusting for differences between secondary (industrial) and average delivered energy prices for all sectors, estimates range from -0.4 to -1.0 (see "Aggregate Elasticity of Energy Demand," EMF, *The Energy Journal*, April 1981, 2(2): 37-76).

Further studies indicate additional insights. Large R&D expenditures are necessary and sufficient to develop new technologies that will allow average annual energy usage and carbon emissions to decrease (Laitner 1997). In terms of reducing carbon emissions through CO₂ mitigation, Rose and Lin (1995) use a CGE model, indicating that conservation would have slightly negative effects on the overall U.S. economy and substantial negative effects on most energy industries. Richels *et al* (1996) determine that the costs of CO₂ mitigation can be reduced through cooperation (i.e. tradable permits system) and the optimal timing of emission reductions.

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1/28/97

"Limits on the Economic Effectiveness of a Carbon Tax," Robert Kaufmann, 1991, *The Energy Journal*, 12(4):139-144.

This paper briefly examines the extent to which certain fuel prices are expected to increase relative to other fuels when a carbon tax is placed on them. A tax of \$30 per ton of carbon will have varying effects on the change in the price of natural gas relative to oil in different OECD countries. This ratio ranges from 0.90 (a 10% decrease in the price of natural gas relative to oil) to 4.01 (approximately a 300% increase in the price of natural gas relative to oil). The author offers two implications in this paper for research and policy. First, analysts must use end-user prices explicitly to accurately assess the effects of a carbon tax on CO₂ emissions. Wellhead prices are significantly lower than end-user prices and using these prices to drive energy demand equations probably overstates the ability of a carbon tax to reduce emissions of CO₂. Second, to increase the economic effectiveness of a carbon tax, it may be useful to levy the carbon tax as a rate that could be based on a rate determined for natural gas. This would have the benefit of not causing such a large negative impact on the coal industry due to the large increase in the price of coal relative to oil or gas.

“A biophysical analysis of the energy/real GDP ratio: implications for the substitution and technical change,” Robert K. Kaufmann (1992), Vol. 6, 35-56.

Biophysical economists focus on developing economic models where energy and matter are the only primary inputs; this is in a manner consistent with the laws of thermodynamics. Upon factoring in the effects of thermodynamics, two primary effects are realized. First, at the macro level, the E/GDP ratio overstates the reduction in energy use since it does not account for changes in the types of energy used and the types of goods and services produced. Second, at a less aggregated level, typical analyses of sectoral energy intensity will exclude the energy used to produce capital and support labor. This will tend to underestimate the amount of energy used by a sector to produce a good or a service, and will overstate the ability of substitution to reduce total energy use. One study (Pimentel *et al*, 1973) determined that the amount of energy used directly as energy to grow a bushel of corn in the U.S. dropped 14.6% between 1959 and 1970. However, upon factoring in the energy used to produce the pesticides, fertilizers, tractors, and other nonenergy inputs to corn production, the energy used to grow a bushel of corn increased by 3%. Estimates from this paper for elasticities of substitution for France, Germany, Japan, and the UK range from -0.045 to -0.389. This is well below those elasticities estimated in previous studies (which range from -0.2 to greater than -1.0). The author claims that the smaller elasticities determined in this paper are an indication that indirect energy costs of labor and capital comprise a significant amount of the energy that is saved directly through substitution.

"The Economics of Strategies to Reduce Greenhouse Gas Emissions," Lisa J. Cameron, Harry L. Foster, W. David Montgomery, 1997.

In examining the literature concerning the costs of implementing climate change policies, the authors focus on the lack of attention given to market failures and market barriers in the literature. Policy intervention is not required when market barriers, which include hidden costs, difficulties, or disadvantages perceived by users, are present because there are profit incentives to reduce or eliminate these transaction costs. Policy intervention can be useful when market failure—a situation where conditions are in place that prevent the correct price signals from reaching decision makers—exists. Of course this is only helpful when the benefits of a policy outweigh the costs of its implementation. If adoption of energy-efficient technologies is not taking place due to the presence of market barriers, then "no regrets" strategies do not exist. Government intervention is unnecessary and likely to be counterproductive in this situation. However, if non-adoption of these energy-efficient technologies is due to market failure, then "no regrets" strategies have the potential to overcome the market failure and improve economic efficiency. The authors provide three energy market failures: (1) underprovision of information with public goods attributes; (2) moral hazard in landlord-tenant relationships; and (3) the divergence of energy prices from marginal costs. There are a number of market barriers that are cited: (1) costs of conservation incurred but not accounted for; (2) differences in qualitative attributes between alternative products; (3) reluctance to spend resources on determining how a particular technology will work on own premises; (4) rationally high consumer discount rates; and (5) heterogeneous energy usage patterns. The authors conclude by stating the need for future research to distinguish between the impact of market failures and market barriers on the diffusion of particular energy-efficient technologies.

1/30/97

“Overview of Greenhouse Gas Mitigation Options,” EPA

The focus of this paper is to examine the various possible greenhouse gas mitigation options in order to begin to develop a domestic mitigation program that will be consistent with the outcome of the likely agreement in Kyoto in December 1997. There are four major mitigation options that EPA examines: (1) R&D, (2) market transformation programs, (3) standards and regulations, and (4) emissions trading. Since R&D can be “partially” characterized as a public good, government support should be provided for developing energy efficiency technologies as the market will not provide the optimal level of R&D. Further, there are large environmental benefits that are not captured by markets even though it is valued by society. This would indicate that government assistance with R&D expenditures is required since it is addressing a market failure. In addressing market transformation programs, EPA refers to three oft-cited studies—NAS, OTA, and National Council for an Energy-Efficient Economy—indicating that the technological potential already exists to achieve cuts in energy consumption levels by 20% or more at a net economic benefit (this, in part, refers to the AEEI). EPA claims that the economy cannot realize these levels since there are “institutional, organizational, and other barriers that work against the diffusion of energy efficient technologies.” EPA further states that standards for appliances can expand markets for energy efficient technologies, thereby reducing “information barriers.” One reason for EPA making this claim is that “many consumers do not consider energy efficiency when making purchases [of appliances].” This is an indication of bounded rationality, and therefore should be treated as a market barrier, requiring no intervention. Finally, EPA mentions that emissions trading programs would be an effective means of reducing emissions, in part because these programs offer correct incentives to conduct R&D for pollution abatement technologies.

MEMORANDUM

COUNCIL OF ECONOMIC ADVISERS

Date: February 5, 1997

To: Jay Shogren

From: Tom Rhoads

RE: "Policy Implications of Greenhouse Warming," NAS (1991)

The Synthesis Panel concludes Chapter 6, which offers a mitigation analysis, by suggesting that the U.S. could reduce its greenhouse gas emissions by between 10 and 40 percent of the 1990 level at very low cost. Upon examining the source of these figures, it becomes apparent that some issues should be addressed. First, the maximum feasible potential emissions reduction associated with the mitigation options that are labeled "net benefit" (cost less than or equal to zero) or "low cost" (cost between \$1 and \$9 per ton of CO₂ equivalent) assumes 100 percent implementation of each option in reasonable applications and is an optimistic "upper bound" on emissions reduction. Based on this optimistic "upper bound," the Panel determined that the U.S. could reduce greenhouse gas emissions by a little more than one-third of their total 1990 greenhouse gas emissions. The Panel's lower bound of 10 percent emissions reduction is determined by arbitrarily assuming that this reduction could proceed at a cost of between \$10 and \$20 per ton of CO₂-equivalent emission reduction. One potentially disturbing issue is that NAS documents various questionable geoengineering mitigation options. Some of these mitigation options rely on emitting particulate matter, such as stratospheric soot or dust, in order to block sunlight and prevent further global warming. While NAS admits that not much is known about the consequences of these options from a scientific perspective, they do contradict EPA's plans for stricter regulations on particulate matter emissions.

Judi Greenwald

343-0487

International Competiveness

⇒ for Janet

John Thomas EPA

excerpt from WTT^{CC} Task Force

we need an
⇒ accurate representation

⇒ literature review

fear of #'s

* Asst Sec Mb - Tomorrow

what analysis is needed internal
- what needs to go out?

The IPCC Working Group III report details many mitigation cost studies that estimate economic losses due to reducing CO₂ emissions. Admittedly, there is no consensus in the economic literature regarding the effects of reducing CO₂ emissions. However, the real possibility that a mitigation strategy will cause economic losses is an issue that must be stressed in the current document. As it stands, the current document provides a one-sided description of the possible positive effects of reducing CO₂ emissions. Including greater detail on the available literature that estimates economic losses from reducing CO₂ emissions will provide a more accurate picture of the current state of economic research.

- Page 8: Paragraph beginning "A second and central concern..."
"...producers might lose market share to competitors from non-Annex I countries (those countries not characterized by industrialized economies) under a climate treaty that affects Annex I but not ~~Annex II~~ non-Annex I countries."
- Page 19: Paragraph beginning "As state-by-state restructuring takes place..."
"Cost reduction ~~will~~ is expected to continue to ~~occur~~ through R&D advances...."
- Page 20: Table 6.
The heading of the third column should read:
"Percentage of Total 1995 1997 Emissions"

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Dancing Around a Dilemma

**Global warming promises to become a large
and gushing source of national hypocrisy.**

By Robert J. Samuelson
(C) 1997 Newsweek, Inc.
Wednesday, July 9, 1997; Page A23
The Washington Post

Global warming may or may not be the great environmental crisis of the next century, but -- regardless of whether it is or isn't -- we won't do much about it. We will (I am sure) argue ferociously over it and may even, as a nation, make some fairly solemn-sounding commitments to avoid it. But the more dramatic and meaningful these commitments seem, the less likely they are to be observed. Little will be done. I wouldn't stake my life on that, but I don't see how it could turn out otherwise.

Democracies can't easily make present sacrifices to avoid future menaces. We require (it seems) a clear and present danger, if not a crisis, to stir us to action. This is why we won't soon mobilize against global warming. The politics simply won't compute. To do something effective would require a heavy energy tax or its equivalent. A good round figure for a tax is \$100 per ton of carbon; this would raise gasoline prices an estimated 26 cents a gallon and electricity and natural-gas rates by almost 30 percent. The idea would be to dampen energy use and the emission of greenhouse gases (mostly carbon dioxide) from the burning of fossil fuels (oil, coal, gas).

To put it mildly, the odds of Congress's passing such a tax are low. The problem with global warming is that we don't know yet whether it represents a genuine national threat and, if so, how large. Congress might conceivably react to a legitimate threat, even if distant. But it won't impose pain on voters for no obvious gain to solve a hypothetical problem. And if the United States won't, neither will anyone else. We generate the most greenhouse gases, about

22 percent of the annual total. Other countries won't squeeze themselves to preserve our lifestyles.

I talked last week to global-warming believers and skeptics. Despite policy differences, they tend to agree about the modest state of current knowledge. Here's what we know. Since the dawn of the Industrial Age (say 1800), the concentration of carbon dioxide in the atmosphere has risen about 30 percent. In the past century, average surface temperatures have increased one degree Fahrenheit (.5 degree Celsius). The widespread suspicion is that these trends are connected. Industrial and transportation emissions increased carbon dioxide, trapping more heat in the atmosphere and raising temperatures. The rival theory is that the small temperature rise is a natural climatic variation.

Now, here's what we don't know:

We don't know how much -- or if -- temperatures might rise in the next century. In 1995 the United Nations' Intergovernmental Panel on Climate Change predicted that average temperature might increase between 10C and 3.50C, with the best guess at 20 degreesC. Even this huge variation is hedged with qualifications and isn't accepted by many scientists, because it's based on admittedly crude computer simulations of climate.

We don't know -- despite much scare talk -- what the effects of warming might be. The computer models can't predict the exact impact on regions or precise shifts in storm patterns. Warmer weather might make some areas more attractive, and others less. Hotter weather could depress crop output in some places and raise it in others.

We don't know how to prevent warming. Once greenhouse gases reach the atmosphere, they tend to stay there. So stabilizing annual emissions isn't enough; they have to be cut sharply. But economic growth requires more energy, and fossil fuels provide 85 percent of all energy. Without a breakthrough in alternative energy -- nuclear, solar, something -- no one knows how to lower emissions adequately without ultimately crushing the world economy. (By 2050, emissions might have to drop 50 percent or more from expected levels.)

The idea that global warming is a certain calamity simply isn't proven. Anyone who thinks otherwise should read Richard A. Kerr's superb story in the May 16 issue of Science magazine, "Greenhouse Forecasting Still Cloudy."

In it, he illuminates the doubts that plague computer modeling of climate. By altering a few assumptions, one model cuts its forecast of global warming caused by a doubling of CO₂ concentrations from 5.20 degreesC to 1.90 degreesC. Based on present knowledge, the best way of coping with warming -- if it happens -- would be to adapt to it. Change would probably occur over decades. If sea levels rose because oceans warmed, coastal areas would erect retaining walls -- or people would move. Farmers would adjust crops to new weather.

I write all this as someone who actually favors an energy tax, mainly for national-security reasons (to cut dependence on insecure Mideast oil). I believe that, within limits, we could improve energy efficiency without wrenching changes in lifestyles or high economic costs. Well, we had two oil crises in the 1970s and fought a war in the 1990s over oil. None of these events spurred a major energy tax, and global warming would ultimately demand a bigger tax. (A \$100-per-ton carbon tax, for example, might only cut CO₂ emissions back to 1990 levels by 2010.)

What I conclude is that global warming promises to become a gushing source of national hypocrisy. President Clinton recently fulminated to the United Nations about the dangers of global warming without specifying how the United States might combat it. Late this year, an international conference will try to fashion a global treaty. Already 65 senators have signed a resolution sponsored by West Virginia Sen. Robert Byrd rejecting any treaty that doesn't demand emission cuts by poor countries (China, India, etc.). But these countries have -- temporarily -- been exempted for good reasons. They didn't cause most greenhouse gases, and penalizing their development would perpetuate their poverty.

The difference between Clinton and Byrd is less than it seems. Clinton wants to seem engaged without doing much; Byrd et al. want to find a respectable reason (i.e., poor countries aren't participating) for being disengaged. Hardly anyone wants to admit candidly the uncertainties of global warming. It's politically incorrect to question whether this is a serious problem that serious people ought to take seriously. But it would be political suicide to do anything serious about it. So shrewd politicians are learning to dance around the dilemma.

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**is your monitor
on the fritz?**



EXECUTIVE OFFICE OF THE PRESIDENT

29-Apr-1997 03:03pm

TO: (See Below)

FROM: Stephen R. Seidel
Council on Environmental Quality

SUBJECT: Reminder: ACEEE, NRDC, etc Briefing: Wednesday at 9:15

Just a reminder that the briefing by ACEEE, NRDC, and UCS is scheduled for tomorrow (Wednesday) at 9:15 in room 472. They will be presenting the results from their new study on the potential to reduce carbon dioxide emissions through energy efficiency and renewables using the NEMS model.

They will be available until 10:30 or so for those who may not be able to make the beginning part of the meeting.

Distribution:

TO: Mark J. Mazur
TO: David B. Sandalow
TO: Jason F. Shogren
TO: Rosina M. Bierbaum
TO: FAX (9343-0487, Dirk Forrister)
TO: Robert J. Tuccillo
TO: T J. Glauthier
TO: FAX (9647-0217, Rafe Pomerance)
TO: Linda L Lance
TO: Wesley P. Warren

Tom -
I can't go to this -
If Jay doesn't
attend, could you
go and then let
us know what
happened? Thanks,
Mark

4/30 - Briefing
Methodology & Results from an Energy + Climate Strategy Study for the US
(America's Energy Choices II) - Energy Innovation - out in
ACEEE, NRDC, UCS, ASE, Tellus. early June in advance
of G-7 summit

AEC I - 1991 $\Rightarrow$ NORMATIVE

Package of policies to $\downarrow$ US carbon emissions
(2010 reduce, 2030 substantially reduce)

Concerns

Env. quality
Dependence on fossils

Behavioral approach

$\Rightarrow$ tax/subsidy reforms

consumer choice drive "hurdle rates" + least cost protocols

Buildings, Industry, Transportation, electricity generation.

efficiency, Combined Heat & Power (CHP) $\Rightarrow$ causes emissions $\downarrow$ at 2010

Substantial $\downarrow$ in energy ^{intensity} ~~efficiency~~ in industrial sector

costs - technology costs
benefits - fuel savings

Total annual leveled costs = \$11.5 b. (1993 \$)

Total annual leveled fuel savings = \$28 b

Total annual leveled net benefits = \$16.5 b (out to 2010)

by 2010 about \$40 billion (1993 \$) cumulative
net benefits)

Can I $\Rightarrow$ How fast is energy efficiency increasing?
get this
number?

Subsidies reforms - what were these?

There is now fairly wide scientific consensus that anthropogenic global warming is occurring. While uncertain, the effects of climate change on crop yields, sea levels, disease patterns, and storm frequency could nevertheless be far-reaching. For the policy maker, climate change offers a somewhat imposing set of complications: potentially irreversible damages or costs, a very long planning horizon, long time lags between emissions and effects, a global scope, wide regional variations, and multiple greenhouse gases of concern. The United States is currently engaged in international negotiations to limit greenhouse gas emissions with the goal of signing an agreement in Kyoto, Japan in December 1997.

Within the Administration, an interagency process has been established to determine the economic impacts of mitigating emissions. In examining potential domestic impacts, the analysis expects to focus on the effectiveness of various emissions targets and timetables in achieving the stated goal of emissions reductions. The analysis will further permit a comparison of the projected economic output accompanying each of these alternative targets and timetables with the projected "business-as-usual" growth path.

The United States has established three principles to guide its involvement in climate change negotiations. First, consistent with the view that stabilizing greenhouse gas concentrations will require concerted emission reduction efforts on the part of all countries, the United States expects that an appropriate strategy would establish limits on emissions for developed and developing countries throughout the world. Second, policy makers within each country must have the flexibility to determine strategies that will achieve individual goals for emissions reductions. Particular emphasis is placed on using market mechanisms to achieve these emissions reductions in a cost-effective manner. The United States encourages flexibility in attaining these emissions requirements through market based incentives such as tradable permits and joint implementation. Finally, the United States has supported "realistic, verifiable, and binding" targets as the only way to ensure international action on this issue.


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Op-Ed

Talk Central Section: discuss hot topics of the day online.

All Editorials and Op-Ed columns from this morning's Washington Post.

All editorials and commentary from Sunday's Washington Post Outlook section.

A Cold-War Solution for a Warming World

By Paul H. Nitze

Wednesday, July 2, 1997; Page A23
The Washington Post

A string of new studies indicates that we are witnessing the early signs of something potentially catastrophic: The earth's temperature is rising. Glaciers are melting, extremely heavy rainstorms have increased by 20 percent in North America this century, and spring has been arriving a week earlier in the Northern Hemisphere. The cause appears to be the emissions from the fossil fuels we burn to heat our homes, run our cars, power our industries and cultivate our farms.

The earth's climate has remained stable for the past 10,000 years, but global warming threatens the stability that fostered the development of modern civilization. Rapid warming could render whole forests more vulnerable to the ravages of disease, pests and fires, destroying watersheds. Rising sea levels, flooding, drinking-water shortages and the northward spread of tropical diseases could displace millions of people. The economic and human costs may devastate continents, creating a crisis larger, and possibly more enduring, than any in recorded history.

The question is no longer "Is our climate changing?" but "What can we do about it?" The cause and consequences of climate changes are global and require global response. The stakes are high, not only for those directly in harm's way of the physical effects of warming, but also for those who have staked their economic well-being on fossil fuels. To stabilize the world's climate will require reducing greenhouse gases by half during the next century, and countries need to begin to cut emissions soon if adaptations are to be made without disruption. But the challenge -- and required changes -- are of such scope and magnitude that courageous multilateral steps, beyond what has been accomplished even in our landmark arms-control agreements, are necessary.

Such bold steps also are essential if we are to address the looming threat to geopolitical stability posed by climate change. Just as arms-control treaties sought to limit and reduce the nuclear arsenals of the superpowers, creating an

environment of cooperation that encouraged the peaceful transition of Eastern Europe and the Soviet Union, world leaders must create similar, durable, international structures for limiting and reducing greenhouse pollutants while providing for an orderly transition to the use of the energy sources of the future.

Our best prospect for such an agreement is an international greenhouse-gas-emissions budget system. Nations would adopt internationally binding caps or budgets on pollution. Those which reduce emissions could earn emissions savings to bank for future use -- or to sell to others to meet their budget requirements. Over the long run, the innovative, technology-rich U.S. economy could benefit, with U.S. industry competing on an equal footing to offer pollution controls in world markets.

What would it take to create such a structure? To begin with, the United States must lead the way. If we promote the concept internationally, others will follow. Four key elements would make an agreement successful.

First, any agreement must encourage maximum participation, permitting all nations to earn or use tradable emissions credits at some level, whether by using energy more efficiently, switching to less environmentally damaging fuels, or planting and preserving forests that absorb pollution.

Second, to encourage developing countries to participate as soon as possible, industrialized countries -- especially the United States -- should speedily set an example by adopting these budgets. Industrialized countries also should find ways to make it easy for others to join in. One interim method would be for industrialized countries to provide incentives (such as credits) for their own companies to work with the industries in developing countries to reduce emissions.

Third, the agreement will need tools to enforce compliance. International -- and domestic -- support for a budget system will fade if it permits some countries to evade responsibility or imposes unacceptable disciplines on our own. A treaty should include a range of realistic options for deterring emissions profligacy. Violations could be identified by international inspectors along the lines of the U.N.'s International Atomic Energy Agency. Similarly, in response, economic measures such as sanctions or embargoes might be emplaced through the U.N. Security Council.

Finally, President Clinton should demonstrate his personal commitment to this effort. Just as he took the lead in furthering the Chemical Weapons Convention, so should he lead the battle against this new threat to global security. He should not be swayed by arguments that global agreements would spawn an intrusive international bureaucracy. Comparable criticisms were leveled at the

arms treaties and dispelled -- and the danger from not taking action is just as severe. Those agreements demonstrated that global problems could be solved through international agreement. Their lessons can help us limit and reduce the growing threat from climate change before we find ourselves facing catastrophe.

The writer, a former diplomat, is on the board of the Environmental Defense Fund.

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GLOBAL WARMING: THE HEAT'S ON BILL

Clinton searches for a middle ground where there may be none

During the 1992 campaign, Bill Clinton and Al Gore vowed to have the most environmentally friendly administration in history. Five years later, after pledging to lead the world in the fight against global warming, the Administration has gotten cold feet. In a June 26 address to the second U.N. Earth Summit, Clinton planned to duck setting specific targets for reducing greenhouse gases in the U.S., though he has to set a number by December. His dithering has prompted European leaders to cry foul. In his first U.N. speech, British Prime Minister Tony Blair warned: "No country can opt out of global warming or fence in its own private climate."

Why are Clinton and Gore dawdling on an issue they once championed? In a word: politics. Privately, the Administration worries that the cost of cracking down on emissions will be greater than business, labor, Congress, and the public are willing to pay. "Unless we move slowly and educate the American public, there could be a huge backlash," says an Administration official. "No one wants to put the President in that position."

TARGETS LOOMING. The Clinton Administration has yet to release its analysis of the costs of meeting an unofficial world goal of at least stabilizing emissions at 1990 levels by 2010. But a draft of the report obtained by BUSINESS WEEK spells out the Administration's math (table). While the overall impact on the U.S. economy would be negligible, the energy sector would be hit hard: By 2010, coal prices would more than triple, to \$80 a ton. Gasoline at the pump would jump 26¢ a gallon, to \$1.54 a gallon.

HOW CLINTON CALCULATES THE COST OF COMPLIANCE

In an early White House draft, here's the price tag for cutting greenhouse-gas emissions to 1990 levels by 2010:

HIGHER GAS PRICES

The retail price of gasoline would rise about 26¢ a gallon.

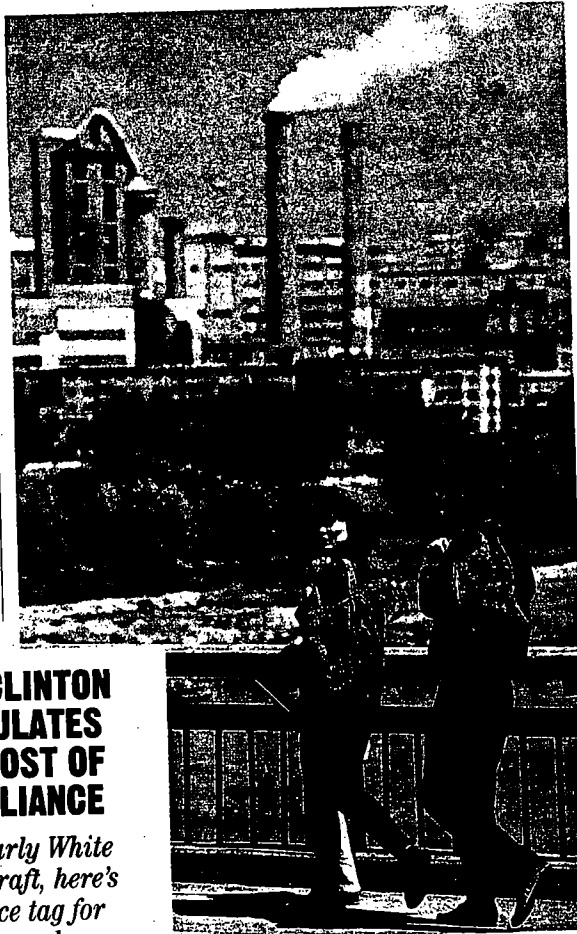
SOARING COAL COSTS

Coal prices, which are now \$27 a ton, would triple, to \$80.

A NICKED GDP

The added costs would slow economic growth slightly, lowering gross domestic product in 2010 by 0.15%.

DATA: CLINTON ADMINISTRATION
INTERAGENCY ANALYTICAL TEAM



BENXI, CHINA: A "discernible human influence" on climate

But time is running out for the Administration. The U.S.—which alone emits 20% of the world's greenhouse gases—will be faced with specific emission targets in December, when representatives from 167 industrialized countries meet in Kyoto to forge a binding plan to counter global warming. European governments are pushing to reduce emissions by 2010 to 15% below 1990 levels, but the Clintonites consider that goal unrealistic. Their position is not

vastly different from the stance assumed by Clinton's predecessor, George Bush, who refused to sign a similar greenhouse treaty in Rio de Janeiro five years ago.

Since then, scientific evidence of the greenhouse effect has been piling up. A 1995 report by the U.N.'s Intergovernmental Panel on Climate Change found that "the balance of evidence suggests that there is a discernible human influence on global climate." The scientists, who called for immediate action, predicted that the atmosphere would warm by 1.8 to 6.3 degrees Fahrenheit by 2100. That could cause disastrous flooding, food shortages, and extinction of plant and animal species. That prospect has even some business leaders concerned by the Administration's waffling. "It's frightening that this is being handled like a regular political issue," warns Paul H. O'Neill, chairman and CEO of Aluminum Co. of America.

WANNA TRADE? Clinton, who faces far more business leaders who oppose any emission treaty, is trying to broker an alternate deal. Under his strategy, companies in industrialized nations would buy and sell "carbon reductions." Like the pollution credits that are already traded in the U.S., they would allow a country whose emissions exceed its ceilings to buy rights from countries whose emissions are below their limits.

The Administration claims this could produce big savings: Without a trading scheme, it says, the cost of reducing a ton of carbon would be \$100, but the price falls to \$56 per ton if the U.S. trades with industrialized countries. The credits allow the U.S. to avoid the drastic emission cuts. But the plan is being met with skepticism abroad since it would allow industrial nations to continue polluting at unacceptable levels.

Environmentalists still want the U.S. to show leadership on the issue. "Clinton needs to stand up to special interests—expend a little political capital and do the right thing," says Daniel Lashof of the Natural Resources Defense Council. Ultimately, whatever Clinton decides to do about global warming, he's likely to get the cold shoulder.

By Mary Beth Regan, with Amy Borrus in Washington

Memorandum

To: Jeff Frankel, Jason Shogren
From: Quindi Franco, Tom Rhoads
Date: July 2, 1997
Subject: **Review of *Energy Innovations, A Prosperous Path to a Clean Environment*¹**

Summary

This summary is based on the executive summary (full report is scheduled for release sometime mid-July), as such, specifics on the analysis are superficial at best. The study shows that CO2 emissions by 2010 can be reduced to 10 percent below 1990 levels at a net benefit to the economy, reducing annual energy costs by \$530 per household and creating nearly 800,000 net jobs. All of this by enhancing energy efficiency, using new technologies, and tapping into domestic renewable resources through a set of sector specific, revenue neutral policies.

The “Innovation Path” -- Policies & Technologies

The study analyzes a set of policies that can “put the U.S. on an innovative, prosperous path leading to an economically and environmentally sustainable future... The approach involves setting fair performance standards, creating incentives, providing better information, and reducing transaction costs in order to foster investments in clean and efficient technologies.” The set of policies does not include an economy wide carbon or energy tax. Rather, the policies are sector specific (transportation, buildings, electricity, industry), and present no net increase in taxes or fees within any sector.

Examples of Sectoral Policies:

- Renewables Content Standards A credit-trading system requiring increasing percentages of electricity & motor fuels to come from renewable sources.
- Emissions Performance Allowances Caps on emissions of sulfur dioxide, nitrogen oxides, and carbon dioxide, with emissions allowances allocated to generators in proportion to their electrical output.
- Advanced Vehicles Initiative Stronger fuel economy and emissions standards, backed by rebates paid for by fees on gas guzzlers, market introduction programs and technology R&D.
- Investment Tax Credit 10 percent tax credit for investments in new manufacturing equipment, paid for by fees on purchased energy.

¹ “Energy Innovations, A Prosperous Path to a Clean Environment,” by Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists, June 1997.

- Market Introduction Incentives Technology demonstrations, manufacturer incentives, consumer education, and “market innovations” to reduce transactions costs.

Technologies Developed: fuel cells, advanced gas turbines, integrated green building designs, membrane technology, fuels and electricity from biomass, advanced wind turbines, photovoltaic modules.

Analysis

The National Energy Modeling System (NEMS) and the Long-range Industrial Energy Forecasting (LIEF) model were used to represent the different energy sectors. Results were then fed into a macroeconomic model (IMPLAN) to project GDP, wage, and employment impacts. NEMS and IMPLAN are federal government models. *Details as to how energy diffusion and innovation (and the costs associated with them) were modeled are unclear from information released so far.*

Results:

Along the “innovation path” (full adoption of the policy approaches described above), primary energy consumption is 15 percent lower than the present path by 2010, and 42 percent lower by 2030. CO2 emissions are 10 percent below 1990 levels by 2010. Oil and coal use decline, and an increasing share of energy is supplied from renewable sources (14% of energy need by 2010, almost doubling energy output from renewable sources). Wages, GDP, and employment all improve in the innovation path over the baseline.

Economic Benefits of “Innovation Path” (\$1993, versus business as usual)

	2000	2010
Incremental Investments (B\$)	28	73
Fuel Cost Savings (B\$)	38	131
Net Savings per Household (\$)	100	530
Avoided Petroleum Imports (B\$)	5	21
Cumulative Investments (B\$)	89	588
Cumulative Savings (B\$)	96	1005
Cumulative Benefit/Cost Ratio	1.1	1.7
Net Employment	n/a	773,000
GDP (B\$)	n/a	2.8
Income (B\$)	n/a	14

Memorandum

TO: Jeffrey Frankel, Jason Shogren
FROM: Quindi Franco, Cristian Santesteban
DATE: July 2, 1997
RE: Energy Efficiency, Energy Prices & AEEI Revisited

As you requested, we ran a series of regressions to look at the relationship between energy efficiency (E/GDP), energy prices, energy R&D, and time. We then constructed a small scenario to illustrate differences between our estimates and those of the IAT. After re-running the numbers in the scenario, our results have changed significantly from a previous memo (June 30). We are confident the numbers presented below are accurate. In brief, we find that while the total (price and time) impact of the our estimates is similar to the IAT results, the portion due to prices (and therefore the costs involved) is much greater.

Analysis of Historical Data

Geometric Lag Regression:

$$\ln(E/GDP_t) = \beta_0 + \beta_1 \ln(\text{Energy Price Index}) + \beta_2 \ln(E/GDP_{t-1}) + \beta_3(\text{Time})$$

Where the energy price index is a relative index of the CPI Energy Price Index over the general CPI. Data from 1959 through 1995.

Variable	Coefficient (std. error)
Price Elasticity (β_1) Short Run	-0.03855 (0.008)
Long Run	-0.76832
Lagged Energy Efficiency (β_2)	0.949 (0.042)
Time Trend (β_3) Short Run	-0.00031 (0.0006)
Long Run	-0.00627
$R^2 = .99$	

Energy R&D:

$$\ln(E/GDP_t) = \beta_0 + \beta_1 \ln(\text{Energy Price Index}) + \beta_2 \ln(E/GDP_{t-1}) + \beta_3(\text{Energy R\&D Intensity}) + \beta_4(\text{Time})$$

Where Energy R&D intensity is government funded Energy R&D over total R&D. Various forms of Energy R&D data (real R&D expenditures, and various lag times) generate roughly the same non-statistically significant results. This could be because our aggregate energy R&D

figures include substantial funding for energy production technologies; we are not isolating the component of Energy R&D that is specifically efficiency related.

Variable	Coefficient (std. error)
Price Elasticity (β_1) Short Run	-0.03075 (0.014)
Long Run	-0.71051
Lagged Energy Efficiency (β_2)	0.9567 (0.043)
Energy R&D (β_3) Short Run	-0.00619 (0.00878)
Long Run	-0.14307
Time Trend (β_3) Short Run	-0.00024 (0.00062)
Long Run	-0.00544
$R^2 = .99$	

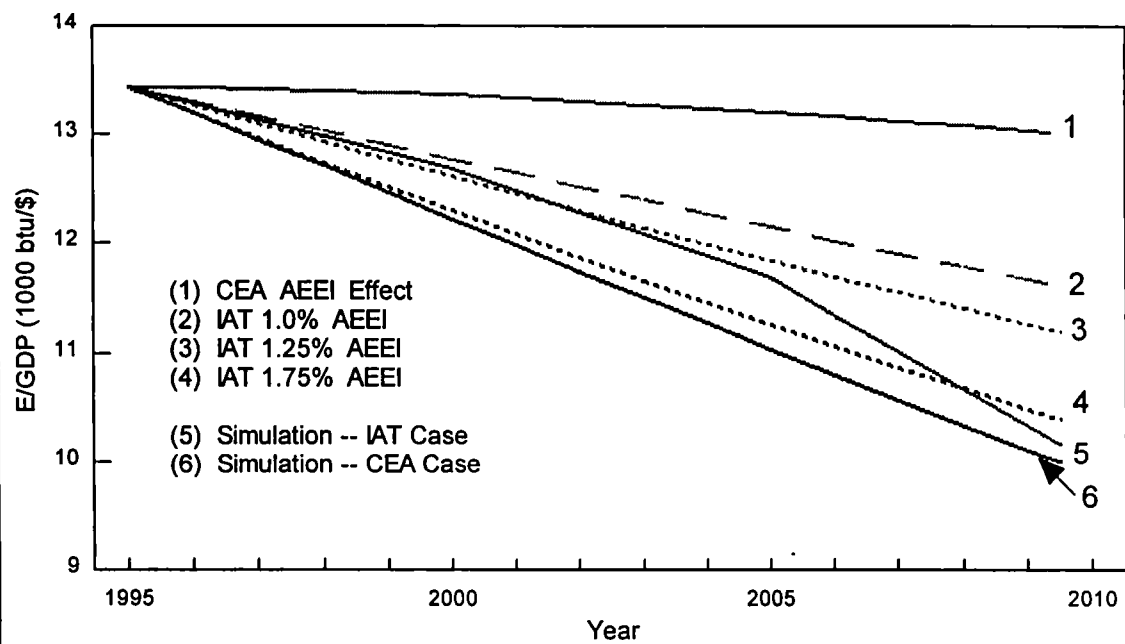
Scenario:

CEA CASE A \$100 per ton carbon tax is levied on all fuels in 1995; we assume this causes a 30% increase in energy prices (range in literature is 15% to 200%). Initial E/GDP of 13.45 (000btu/\$) in 1995, and a time horizon of 1995-2010. The long-run impact of the price increase is fully incorporated by 2010. The simulation uses the original regression estimates excluding energy R&D (lines 1 and 6 in the graph). Over this time period, the CEA estimated time effect is equivalent to an annual AEEI of 0.23 percent.

IAT CASE IAT results are from the most recent Markal-Macro simulations for stabilization at 1990 levels by 2010 under a 1.25% annual AEEI (5). This is a complex policy scenario and should only serve as a rough comparison to our simulation (the model estimates an implicit carbon tax of \$144 in 2010). The impact of the IAT AEEI assumptions (1.0% -- #2, 1.25% -- #3, and 1.75% -- #4) have been modeled continuously throughout the period (some IAT runs assume the rate starts at 1% in 2000, and increases to 1.25/1.75 by 2010).

Component	Drop in E/GDP (percent)	
	CEA	IAT
Time Effect (AEEI)	0.45 (23%) (1) in graph	2.31 (67%) (3) in graph
Price Effect (CEA)	3.1 (87%) from regression	-
Price + Other	-	1.14 (33%) implicit
Total	3.55 (6) in graph	3.45 (5) in graph

Energy Efficiency Improvements



Economic Effects of Global Climate Change Policies

Results of the Research Efforts of the
Interagency Analytical Team

June 1997

Introduction

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

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

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

Model Selection

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

At a public meeting last November, the IAT announced the selection of three models for its analysis. It decided to continue to use the DRI model, but also included two additional models. The Second Generation Model (SGM) and the Markal-Macro model. Each of these three models met the criteria of being available in the public sphere; being well documented; having a track

record of analysis in the climate change area; being widely understood within the energy-environment community; and of bringing a unique capability to the IAT's work. Used separately, but in concert with each other, they provide the broad analytical capability needed to examine the many complex economic effects of potential global climate change policies.

The DRI model is a large disequilibrium model of the domestic economy that is particularly well suited to identify transition issues based on short-run behavior embedded into a long-run model. The DRI macroeconomic model is linked to energy, regional, and industry sub-models so that macroeconomic effects of policies are translated into the effects on specific industries and regions of the country. The link to energy sub-models provides specific detailed information about the interaction of the energy sector with the rest of the economy. The DRI model also includes the interaction of the financial markets with markets for goods and services and enables the analysis of the interaction of fiscal and monetary policy with the rest of the economy.

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

The DRI and SGM models can be thought of as lying at opposite ends of an axis that measures time horizons. A second dimension of the climate change problem concerns the role of technology. Both DRI and SGM allow technological progress to move forward in response to the parameters of their models. But given the unpredictable character of innovation, the IAT concluded that a second approach would be helpful. The Markal-Macro model consists of an integrated energy supply and demand modeling system (Markal) and a macroeconomic model (Macro) useful for translating technological assumptions into economic outcomes. Thus, the Markal-Macro model is particularly useful in answering the question, "How do we get there from here?" Markal-Macro allows the user to control technology innovation and diffusion and its cost to the user in order to determine the levels of energy efficiencies that might be expected from a long-term policy announcement. This model also allows us to understand the implications of technology and its interaction with the economy, and helps us determine whether expected energy efficient technologies hold the key to continued economic growth.

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

The Base Case

The domestic energy and emissions baseline forecasts were taken from the Energy Information Administration's 1997 Annual Energy Outlook (AEO97) while the international baseline forecast was taken from the International Energy Agency's World Energy Outlook, except for the baseline forecast of the Former Soviet Union (FSU), which came from World Bank projections. The IAT then imposed, as best possible, consistency across the models with regard to projections of baseline GDP, total energy consumption, and carbon emissions. Once these were calibrated into the 3 models, the models solved for energy prices by fuel type. Thus, the baselines of the three models are consistent, but not identical.

Tables 1 and 2 summarize the IAT baseline. In the baseline, U.S. economic growth is projected to slow over the next several decades, as the retirement of "baby boom" workers slows labor force growth and reduces the economy's potential growth rate. Energy demand therefore grows somewhat more slowly than it now does. Energy intensity, measured as energy use per dollar of GDP (the E/GDP ratio), is a key ingredient in the AEO97 forecast, because it measures the growing efficiency with which the economy uses energy. In the 1970s and 1980s, the E/GDP rate of decline averaged almost 2 percent annually. Moderate price increases and the growth of more energy-intensive industries in the late 1980s lead to a slower decline of energy intensity--about 0.9 percent annually. The baseline projection used for this study incorporates a 1.0 percent annual reduction in energy consumption per unit of real output, which is taken from the EIA's Annual Energy Outlook. With these improvements included, energy demand grows at an annual rate of about 0.8 percent over the period from 1995 to 2020, tailing off at the end of the period as does economic growth.

Carbon emissions in the baseline are projected to increase by about 1.2 percent a year through 2010, and by 0.6 percent annually from 2010 to 2020, reaching 1805 million metric tons in 2020. In 1990, the year most frequently used in the negotiating process as the level of carbon to stabilize at, carbon emissions were 1,340 million metric tons, 22 percent below EIA's projection for 2010 and 21 percent below DRI projection for 2020.

Table 1: IAT Domestic Baseline

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

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

Table 2: IAT International Baseline

	Real Economic Growth (Annual)			Energy Growth (Quads)			Emissions Growth (MMTC)		
	1990-00	2000-10	2010-20	1990-00	2000-10	2010-20	1990-00	2000-10	2010-20
Australia	2.8	2.8	2.6	2.1	1.5	0.9	1.7	1.2	0.7
Canada	2.6	2.5	1.2	1.7	1.0	0.4	2.2	1.5	0.7
China	8.4	7.5	5.8	3.9	2.8	2.1	3.8	2.8	2.2
Former Soviet Union	-3.5	4.6	4.2	-3.5	1.8	1.2	-4.0	1.6	1.1
Eastern Europe	-4.5	4.2	4.3	-3.0	1.3	1.2	-3.5	1.3	1.2
India	4.1	4.4	3.5	3.9	1.3	3.1	4.7	2.0	2.9
Japan	2.1	1.7	0.9	2.2	0.9	0.1	2.1	0.9	0.1
Korea	5.0	5.9	4.4	4.0	3.1	2.4	2.6	3.3	2.9
Mexico	4.0	4.0	3.2	4.2	2.9	2.3	4.2	2.9	2.4
Western Europe	2.3	2.5	2.4	1.5	1.4	0.6	1.2	1.4	0.6
United States	2.1	2.2	1.4	1.7	1.1	0.6	1.4	1.1	0.8
Rest-Of-World	3.6	3.4	3.0	3.0	2.0	2.0	3.0	2.2	2.2

The "Plain Vanilla" Scenario

The IAT began its analysis of emissions reductions policies by examining one core emissions reduction scenario. Then we explored the economic effect of changes to this scenario. The central policy modeled -- the "plain vanilla" scenario -- is aimed at reducing carbon and other greenhouse gas emissions by freezing them at 1990 levels. (Reductions in non-carbon emissions, such as methane, are solved for outside the model.) The "plain vanilla" scenario pursues those reductions by issuing tradable emission permits at the earliest point of energy production. The policy is announced in 2000 and its restrictions are phased-in over a ten year period, so that the policy would take effect in 2010. The permits are initially auctioned, in a way that is revenue neutral, i.e., all revenues generated through permits would be recycled back through the economy through deficit reduction. The "Plain vanilla" scenario assumes no international cooperation, although this option is discussed later in the paper along with other alternatives and sensitivities.

Industry and regional effects, as presented here, show only the effects of the climate change policy on the industry's output (shipments plus inventory change). We considered this our first step in understanding the likely consequences of emissions reductions on industry. As the year goes on, the IAT hopes to provide further detail to the industrial analysis by examining jobs, international trade, industries comparisons between countries, and the possibility that domestic industries might relocate overseas due to increased costs.

The "plain vanilla" scenario incorporates a slight improvement in energy intensity (E/GDP) over the EIA/AEO baseline, which declines by 1.0 percent per year. This improvement comes about

because of “announcement effects” -- that is, the actions that take place because the climate change policy undertaken produces anticipatable increases in the future price of energy. The “announcement effect,” therefore, is what allows the model to distinguish between a change in future policy regarding carbon emissions and an exogenous shock, such as the two oil price increases in the 1970's. This leads to somewhat faster rate of diffusion of energy efficient technologies and a higher rate of innovation through R&D in anticipation of future higher energy prices. The IAT assumes an improvement in energy-intensity of 0.25 percent so that the total annual change in the ratio of energy to GDP is 1.25 percent per year. A faster technology alternative is also investigated. (More detail on energy-efficient technology improvement is provided later in this paper.)

Core Results

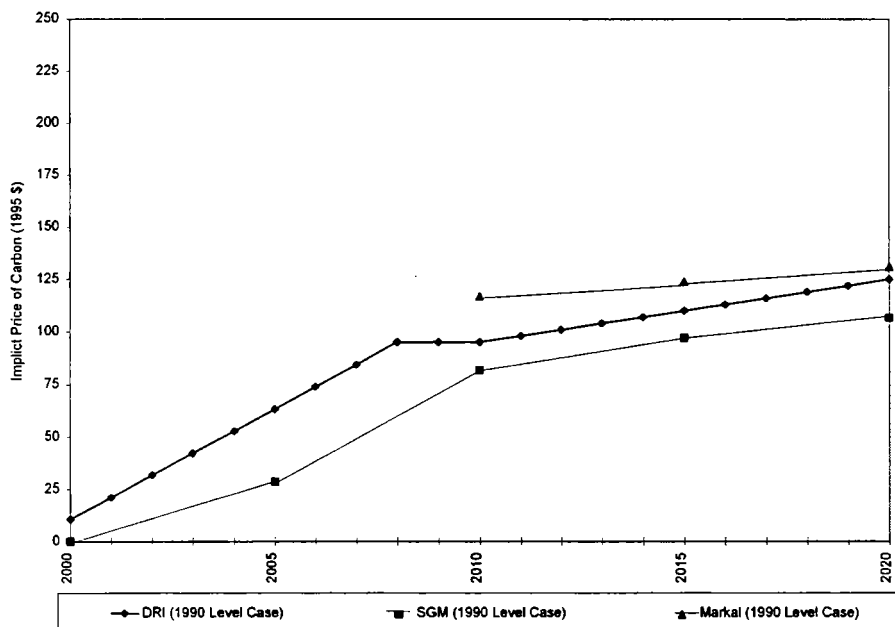
Estimates of permit prices are around \$100 in 2010 and rising slightly thereafter, and are consistent across models. While the three models used for this analysis vary in structure and often in terms of macroeconomic outcomes, they generate fairly consistent results as to the implicit price of carbon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

Table 3: The Implicit Price of Carbon (1995 \$) in 2010 and 2020

1990 Level Case		
	2010	2020
DRI-DRI Energy	95	125
SGM	82	107
Markal-Macro	130	122

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM and Markal-Macro permit prices are calculated using the rate of change in Carbon to GDP (C/GDP), which incorporate emission rates by the different fuel types.

**Figure 1 : Price Path of the Implicit Price of Carbon (1995 \$)
2010 to 2020**



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

The DRI model concludes that an implicit price of \$95 (1995\$) per ton of carbon in 2010 would result in stabilization. The Markal-Macro model estimated \$130 (1995\$) while the SGM model predicted about \$82 (1995\$), in 2010. A carbon tax of \$100 per ton is the equivalent of a price increase of 26 cents per gallon of refined petroleum product, of \$1.49 per thousand cubic feet of natural gas, of \$52.52 per ton of coal, and of 2 cents per kilowatt hour of electricity produced.

These models also agree that this implicit price of carbon grows somewhat over time. This reflects the fact that the 1990 emission ceiling becomes a progressively more binding constraint over time given projected growth in base case emissions. By the year 2020, the implicit price of carbon rises, in 1995 dollars, to \$125, \$107, and \$131 per ton in the DRI, SGM, and Markal-Macro respectively.

Sensitivity to the Emissions Target. The DRI model was used to analyze how changes in the level of emissions level allowed affect the implicit price of carbon. If the emission target for the year 2010 and beyond is raised (made less severe) to a level equal to 110 percent of the 1990 emissions level (that is, to a target of 1,472 million tons as opposed to 1,338 million tons), then permit prices drop almost by half -- to about \$50 per ton of carbon. The very large decline in the implicit price of carbon reflects the fact that additional emissions reductions are progressively

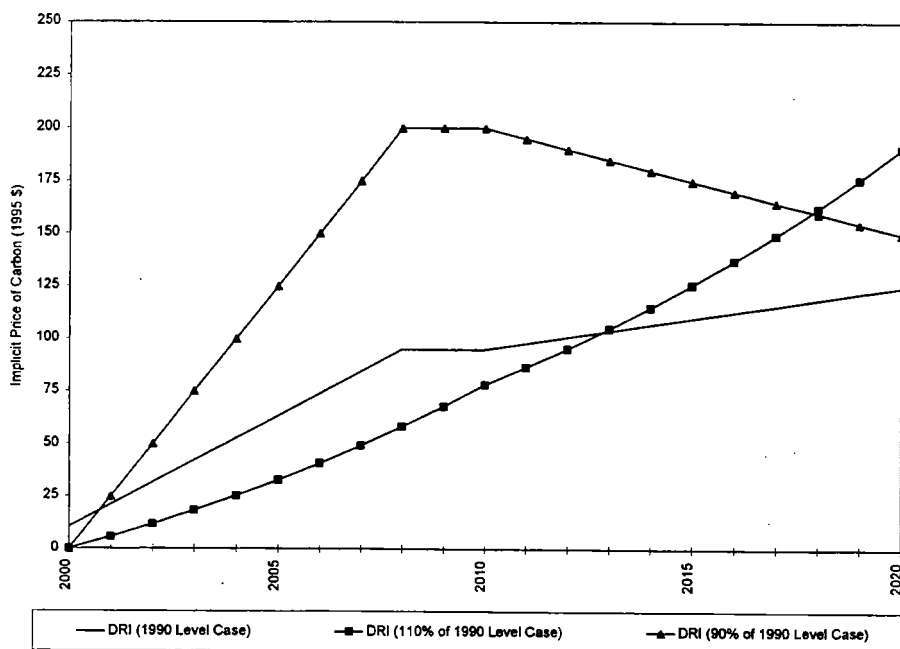
harder to find. On the other hand, a more stringent target, one that freezes emissions at 90 percent of their 1990 level in the year 2010 and beyond, leads to an implicit price of carbon of \$200 per ton in 2010 and \$150 per ton in 2020. Table 4 and Figure 2 describe the sensitivity of these results using DRI and SGM.

**Table 4: Sensitivity of the Implicit Price of Carbon
to the Stringency of the Emissions Target**

	2010	2020
DRI-DRI Energy		
Carbon Emissions 90% of 1990 Level Case	200	150
Carbon Emissions 110% of 1990 Level Case	50	85
SGM		
Carbon Emissions 90% of 1990 Level Case	n/a	n/a
Carbon Emissions 110% of 1990 Level Case	n/a	n/a

Note: 10 year phase-in with revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. SGM and Markal-Macro permit prices are calculated using the rate of change in C/GDP.

**Figure 2 : Sensitivity of the DRI Implicit Price of Carbon
to the Stringency of the Emissions Target --2010 to 2020**

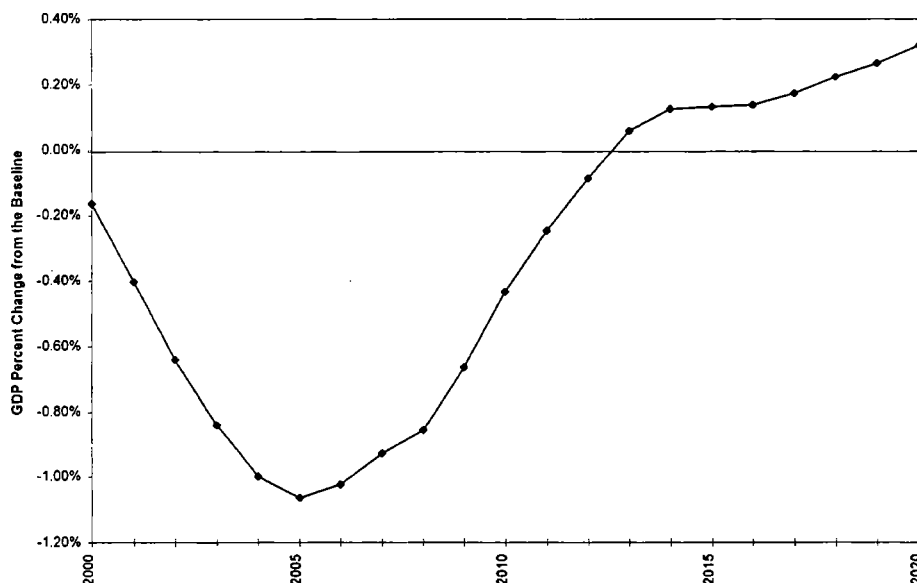


Note: 10 year phase-in with revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

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

Results from the DRI model are presented in Figure 3. The results indicate that there is an initial GDP loss as the emission-limiting policy begins to be phased in. These losses cumulate to a peak loss of 1.0 percent of total economic output in the year 2005 -- that is, the economy's growth slows until the size of the economy is, at worst, 1.0 percent smaller in that year. After 2005, the economy actually grows faster than it would have absent climate change policy and starts to make up the lost ground. By the year 2013, the economy is back to the point at which it would have been had no policy been enacted. In subsequent years, the economy is actually slightly improved -- this differential reaches 0.3 percent by 2020, the last year of the model run.

Figure 3: DRI 1990 Level Case--Gross Domestic Product



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

This improvement occurs in the DRI model because emissions reduction policies have some effects that favor savings and investment at the expense of consumption. If the government auctions off emissions permits, it acquires the wherewithal to reduce the deficit (or retire debt) and, in effect, increase the nation's savings. This allows the cost of capital to fall and favors investment. The marginal profitability of investment also rises under these policies because new investment allows firms to neutralize higher energy costs. In effect, capital is a long-term

substitute for energy and is favored after a transition period. Thus, the cost of investment falls and the incentive to invest is strengthened. This faster rate of investment (discussed in greater detail below) gives the economy a newer and larger capital stock: as a result the economy's ability to grow improves until it actually reaches a modestly higher growth path in the years following the transition.

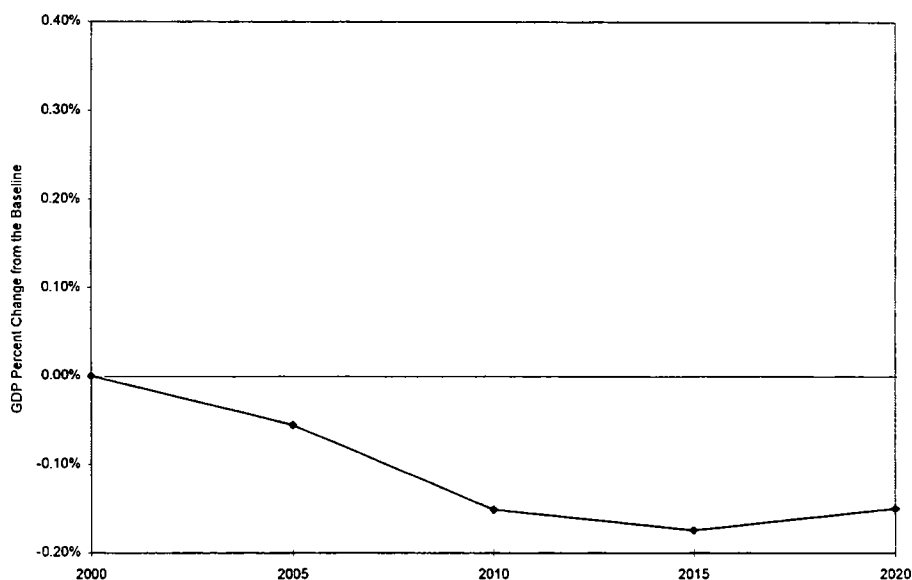
Figure 4 shows comparable results from the SGM model. Just as the DRI model focuses on short-term transition issues and may therefore tend to produce larger estimates of GDP losses, the SGM model moves quickly through these issues and focuses on longer-term prospects. The SGM model estimates peak losses for the economy of 0.17 percent in 2015, but the economy then stabilizes through 2020.

The two models offer a similar picture in some regards -- both show initial losses that are not very large (even the DRI peak loss is spread over five years). But they also differ in predictable ways, given their structure. Disequilibrium macro models, such as DRI, tend to identify deeper transitional losses and steeper transitional rebounds. Computable general equilibrium models, such as SGM, see more sanguine short-term effects and see the economy stabilizing after a more frictionless adjustment. A recent analysis by Dr. Robert Repetto and Dr. Dunkin Austin of the World Resources Institute examined about 162 analyses of climate change policy and found that this difference in structure can account for two-thirds of the difference in results, if environmental benefits are ignored.¹

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

¹ Repetto, Robert and Dunkin Austin. "The Cost of Controlling CO2 Emissions: A Guide for the Perplexed." *World Resources Institute*, June 1997 (Forthcoming).

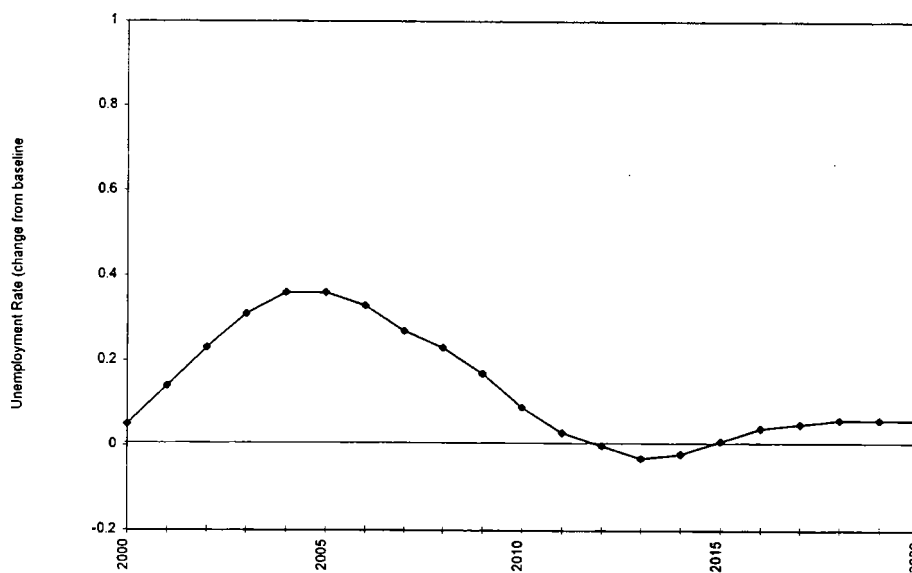
Figure 4: SGM 1990 Level Case--Gross Domestic Product



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

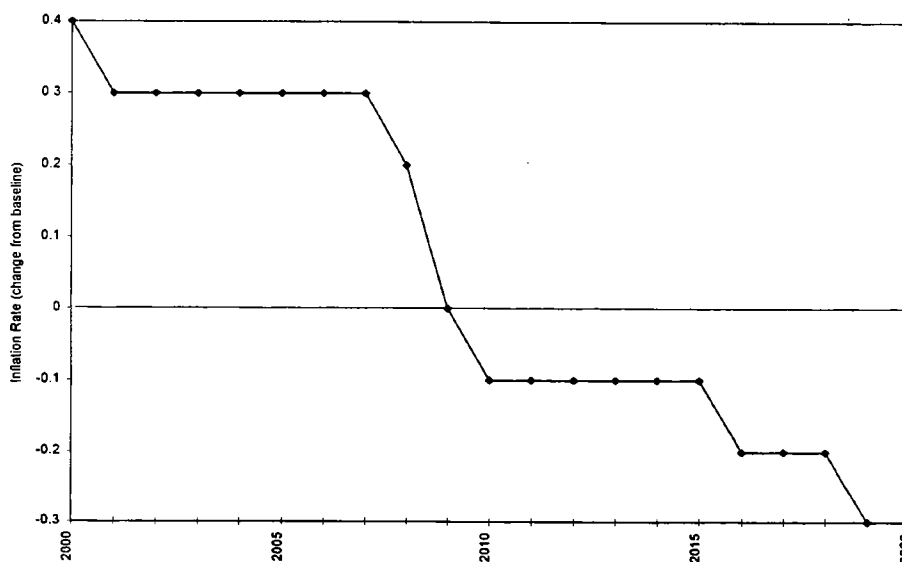
Unemployment and Inflation. The effect of the stabilization policy results in approximately a 0.2 percentage point increase in the unemployment rate from 2001 through 2011, as estimated using the DRI model. The unemployment rate first rises as GDP falls, but then returns to its pre-policy level by 2012, as shown in Figure 5. The inflation rate increases by about 0.3 percentage points until 2009, measured by the annual rate of change in the Consumer Price Index (CPI). The annual rate of change in the CPI reduces by about 0.1 to 0.2 percentage points per year through 2020, as shown in Figure 6.

Figure 5: DRI 1990 Level Case -- Unemployment Rate



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 6: DRI 1990 Level Case -- Inflation Rate

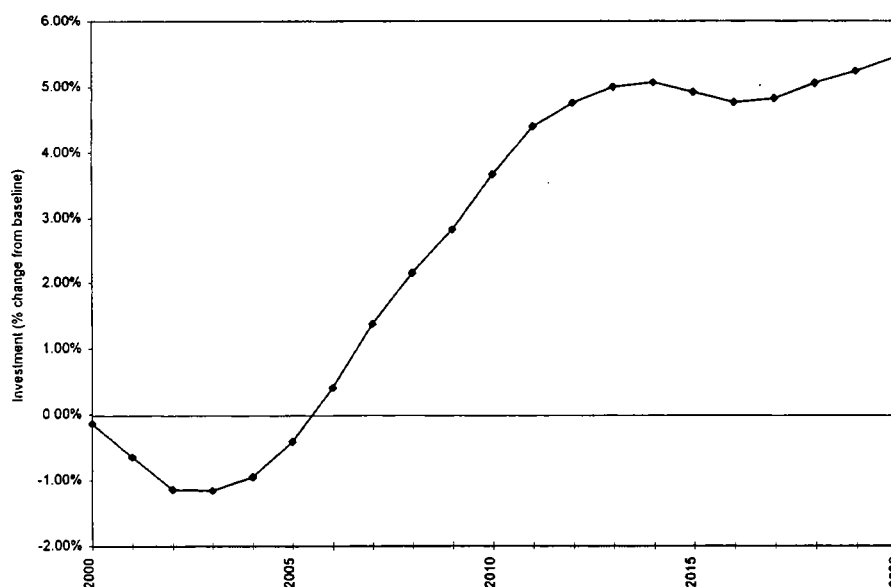


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

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

The DRI model suggests that investment under a climate change policy scenario begins to exceed investment in the baseline by 2006, as seen in Figure 7. By the time the policy is fully implemented in 2010, investment exceeds the baseline by about \$50 billion (1992\$), with this difference rising to about \$100 billion in 2020. Personal Consumption Expenditures (PCE), on the other hand, remain below the baseline throughout the forecast period, so that PCE drops by about \$80 billion in 2008, as seen in Figure 8. After the trough in 2008, PCE gradually moves toward baseline by 2020.

Figure 7: DRI 1990 Level Case--Investment

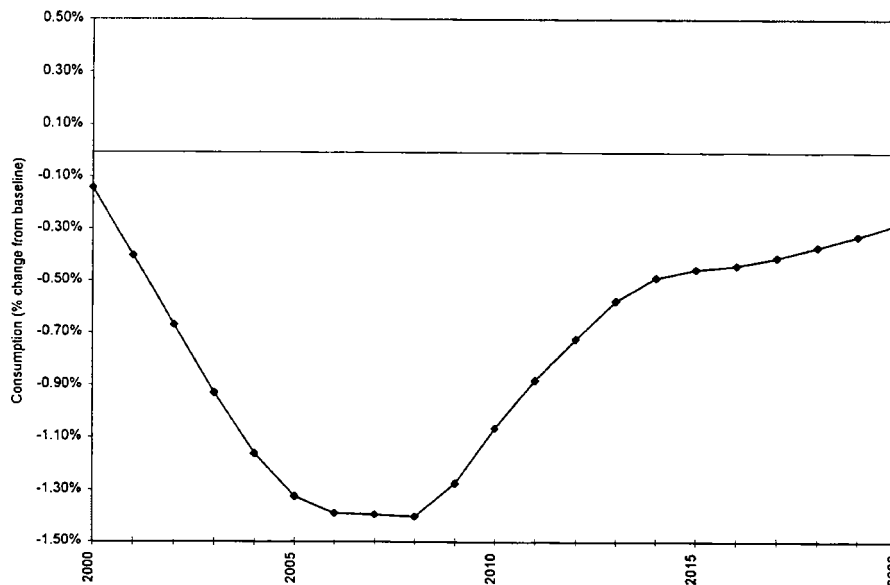


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

The faster rate of investment drives the rebounding of real economic growth in the later years of the model simulation. But it should be noted that consumption does not rebound in the same

manner, although it does recover from its peak losses, as seen in Figure 8. But consumption can be taken as the measure of economic activity that is closer to consumer "welfare" than total GDP, which includes investment, because consumption includes all activities that are of direct consequence to households. Thus, while increases in investment drive the economy's growth path back to and perhaps even above its original trend, it does so by diverting resources away from uses that allow consumers to enjoy them directly in the short term.

Figure 8: DRI 1990 Level Case--Consumption



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

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

Among fuels, demand for coal bears the brunt of greenhouse gas stabilization. Table 5 presents the effects of carbon-limiting policies on the economy's energy consumption and fuel mix. Using the DRI model, total energy consumption falls from 105 quadrillion Btus (quads) in the base case in 2010 to a level of 88 quads under the policy, a reduction of 16 percent in that year. By 2020, energy consumption in the economy has declined by 20 percent when compared to the base case for that year, from 109 quads to 87 quads. The table also shows comparable results using the Markal model, when the 1990-level emissions freeze produces a decline in projected energy consumption of 14 percent in 2010 and 20 percent in 2020.

**Table 5: Effects of Carbon Stabilization on
Energy Consumption and Fuel Mix (quadrillion Btus)**

	2010		2020	
	Base case	1990 Level Case	Base case	1990 Level Case
DRI-DRI Energy				
Total US Energy Consumption	105.3	88.2	108.9	86.7
Natural Gas	25.1	22.9	26.7	24.9
Oil	40.4	35.6	43.3	37.4
Coal	22.7	17.2	23.7	15.2
Markal-Macro				
Total US Energy Consumption	107.8	97.1	115.6	100.9
Natural Gas	29.0	22.8	35.1	25.8
Oil	43.4	36.2	45.0	35.8
Coal	22.5	16.0	24.6	11.1

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. Markal-Macro permit prices are calculated using the rate of change in C/GDP.

Both DRI and Markal demonstrate that dampened energy consumption and reduced carbon emissions are concentrated in coal use. As seen in Table 6, DRI results show that about 57 percent of the total emissions reductions in 2010 result from reduced demand for coal, 30 percent from oil, and 13 percent from natural gas. By 2020, 65 percent of emission reductions are generated from reductions in demand for coal. This translates to a 25 percent total emission reduction for coal in 2010 and a 36 percent reduction in 2020. Markal produces somewhat different results; it shows that about 42 percent of total emissions reductions in 2020 occur due to reduced coal use and 29 percent due to reduced oil use, and 29 percent due to reduced natural gas consumption. By 2020, coal begins to grow in importance.

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

Table 6: 1990 Level Case -- Percent of Total Emissions Reduction by Fuel

	2010	2020
DRI-DRI Energy		
Natural Gas	13	8
Oil	30	28
Coal	57	65
Markal-Macro		
Natural Gas	31	29
Oil	36	29
Coal	33	42

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. Markal-Macro permit prices are calculated using the rate of change in C/GDP.

On the demand side, according to DRI, about 46 percent of total emission reductions in 2010 result from reduced demand for electricity, 26 percent from reduced demand for transportation and 19 percent from reduced demand from the industrial sector, as shown in Table 7. The commercial and residential sectors contribute a combined 8 percent to the total of emissions reductions. The corresponding estimates obtained from the Markal model show that electricity uses account for [FORTHCOMING] percent of total reduction in emissions, and transportation, industrial, and residential and commercial uses for [FORTHCOMING] percent, [FORTHCOMING] percent, and [FORTHCOMING] percent, respectively.

Table 7: 1990 Level Case -- Percent of Total Emissions Reduction by Demand Sector

	2010	2020
DRI-DRI Energy		
Residential	5	4
Commercial	3	2
Industrial	19	21
Transportation	27	25
Electricity	46	47
Markal-Macro		
Residential	n/a	n/a
Commercial	n/a	n/a
Industrial	n/a	n/a
Transportation	n/a	n/a
Electricity	n/a	n/a

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP. Markal-Macro permit prices are calculated using the rate of change in C/GDP.

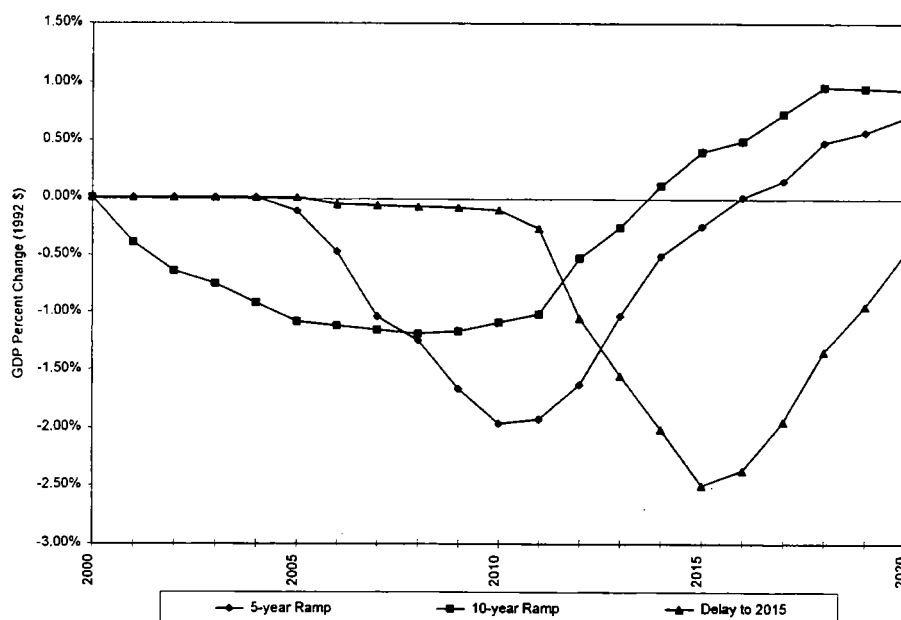
Thus, across models and when viewed from different perspectives, the center of the reductions in emissions obtained under the broadest strategies moves toward reducing utility consumption of coal. Reducing coal use under utility boilers is generally the largest, cheapest option to reduce carbon emissions in the economy. This is accomplished through better operating rates and through the substitution of gas-fired combined-cycle units for coal-fired units. The implicit price of carbon obtained in most model runs is usually the one that accomplishes this transition in electricity baseload. The range of carbon values -- generally about \$100 per ton -- is as high as it is because most coal-fired units are fairly old and already fully amortized. Thus, their costs consist of fuel and operating and maintenance expenses but not capital costs. The price of coal, therefore, must rise considerably to make coal-fired electricity more expensive than electricity generated by a new gas-fired plant that entails new capital costs.

Important Sensitivities

The following represents a number of variations from the "plain vanilla" scenario that the IAT analysts examined to address a number of factors that negotiators are likely to face in the global climate change policy process. These include the effects of: (1) timing, including different transition periods to full implementation and delaying implementation; (2) lower or higher emission level targets (the effects to permit prices were already discussed in a previous section); (3) revenue recycling options, including a comparing the deficit reduction case with revenues returned to consumers, returned to business, and a combination of returned to both consumers and investors; (4) the effects of the Federal Reserve Board reaction function on interest rates and the effect of the Price Expectation assumptions in the DRI model, (5) the effects of a policy announcement on technology innovation and diffusion as well as the steps needed to achieve a higher level of innovation and diffusion; (6) Annex I permit trading; (7) Joint Implementation with developing countries; (8) other collateral environmental benefits; and (9) effects on international trade.

A longer period for implementation, from 5 to 10 years in the 1990 level stabilization case in 2010, dampens negative effects to GDP while delaying implementation does little to improve GDP effects. The IAT examined differing effects on GDP of a 5-year and a 10-year implementation period for the stabilization "plain vanilla" scenario. These results are shown in Figure 9. A 10-year implementation or "ramp-up" period between 2000 and 2010 results in a maximum GDP loss of 1.19 percent in 2008 and a return to above the baseline in 2014. On the other hand, a 5-year ramp-up between 2005 and 2010 results in a maximum of a 1.96 percent loss in 2010 and a return to the baseline in 2016. Thus, shorter transition periods result in a more pronounced economic cycle in response to policy--a sharper downturn and deferred recovery.

Figure 9 : 1990 Level Case--Sensitivity to the Length of the Implementation Period and to Implementation Timing



Note: These simulations were conducted using DRI and the NEMs Energy Model and they do not conform in detail to those conducted using DRI and the DRI Energy Model. 5-Year and 10-Year Ramp to 1990 Levels in 2010; 1990 Levels in 2015 using a 5-Year ramp-up.

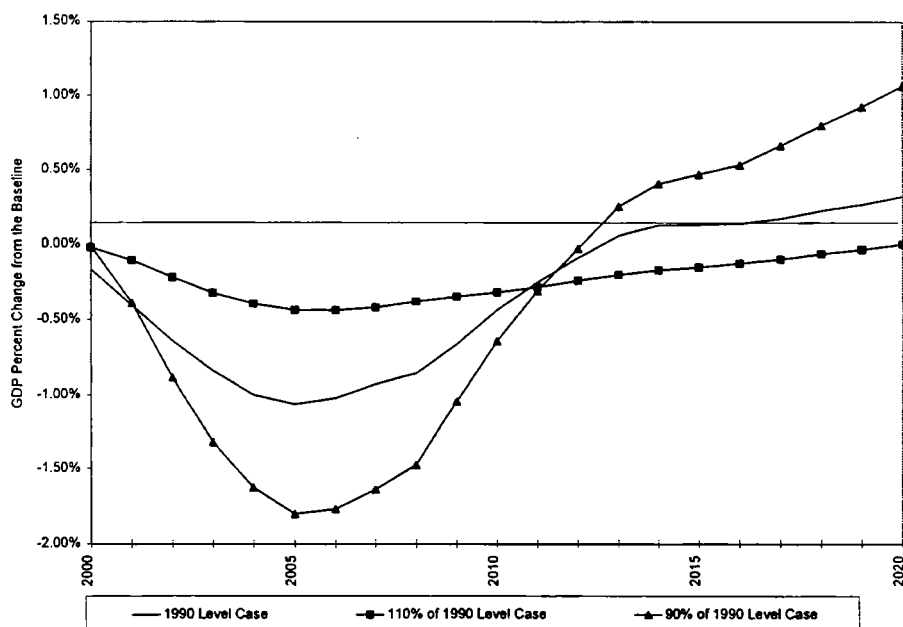
Figure 9 also shows the result of delaying the implementation by 5 years, to 2015 combines with the shorter 5-year ramp-up period. GDP effects for the delayed case are less severe in the initial period, but become greater than either the 5-year or 10-year ramp-up to stabilization in 2010 reaching a maximum of 2.5 percent in 2015 and never regaining the baseline GDP throughout the period.

Raising or lowering emission targets lead to obvious results --more stringent emission targets lead to greater economic losses while less stringent ones result in less severe impacts. As discussed briefly above, the IAT examined emissions targets that were both 10 percent above and 10 percent below the emissions levels of 1990. The implicit carbon prices in 2010 of the 110 percent of 1990 level case in 2010 are \$50, or approximately half the "plain vanilla" stabilization permit price. In 2020, permit prices rise to about \$85 compared with the \$125 permit price under stabilization. Alternatively, an emissions target of 90 percent of 1990 level results in an implicit price of carbon of \$200 per ton in 2010 and \$150 in 2020. Unlike in the other cases, the implicit price of carbon falls after 2010. This is because the initial price increase is large enough to set in motion a series of capital stock improvements, particularly in utilities, that reduce the ongoing level of emissions by enough to allow the implicit price to fall. Thus, this result is predicated on the idea that future price expectations could be wrong. In fact, if decision makers had perfect price expectations, the implicit price of carbon would lie somewhere between these two values over the period.

It is no surprise that the 90 percent of 1990 emissions case results in a more severe decline of GDP in the transition period. But what is surprising, and questionable, is that this scenario also has a greater long-term potential for economic recovery. As shown in Figure 10, GDP declines to a peak loss of 1.9 percent below the base case in 2005. It recovers to the base case level in 2013 and increases to 1.0 percent above the base case in 2020. The long-term rebound effect results from a greater amount of revenue recycled to deficit reduction (or debt retirement), which pushes interest rates down substantially and drives up investment.

This result is questionable. The DRI model, as discussed, is prone to depicting large effects of interest rates on investment. Thus, when confronted with a very large implicit price of carbon and, in turn, large amounts of forced saving, either through deficit reduction or by grandfathering these new property rights to firms, it produces much higher levels of investment and a higher long-term growth path. The reality is probably more moderate at both ends. In essence, this case appears to tax the ability of the model to manage these revenue flows.

Figure 10: Sensitivity of GDP to the Stringency of the Emissions Target



Note: 10 year phase-in with revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

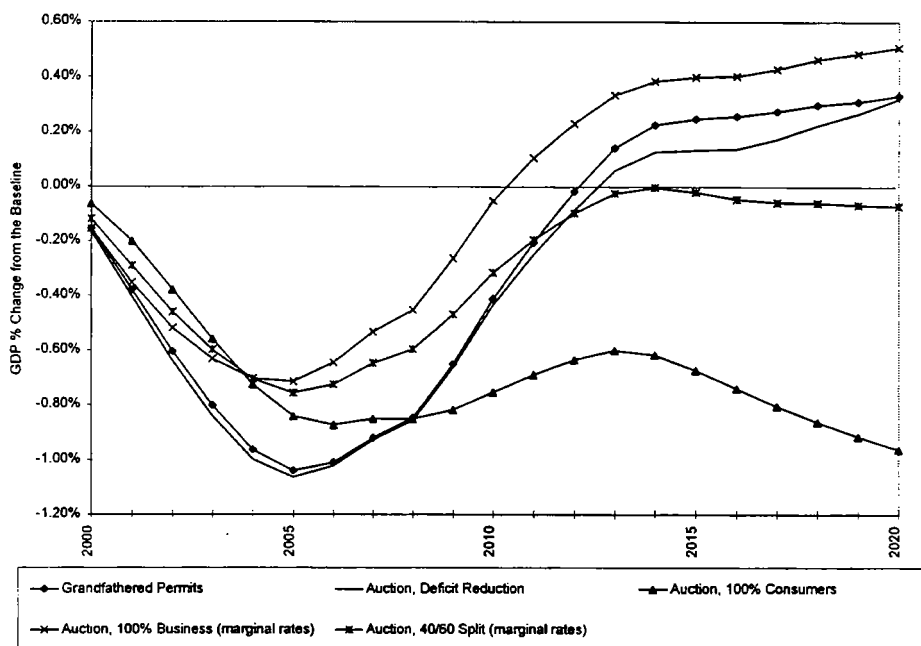
The portion of total emission reductions from coal and oil in both the 90 percent and 110 percent of 1990 Level Case, increases only slightly--about 5 percentage points--while total emission reductions from natural gas change significantly. In 2010, under stabilization, about 13 percent of total emission reductions are from natural gas. Under a 10 percent increase in the target (that is, a target of 90 percent of 1990 emissions), about 24 percent of total emission reductions are from natural gas. This occurs because the substitution of gas for coal in electric utilities is not

enough to achieve the bulk of the 90 percent (more stringent) target. Additional emissions reductions must be found, which forces the burden to be spread more evenly among fuel types and sectors.

Adopting a revenue recycling option that leads to investment in energy efficient capital leads to less impact on the economy during the transition and greater returns to the economy in the long term. The IAT looked at a number of revenue recycling policies in addition to the deficit reduction case. These options are depicted in Figure 11. These include:

- “grandfathering” permits to producers, meaning that every carbon-emitter would be allowed to pollute at their 1990 level. The permits allowing them to do so would then be traded freely, allowing a least-cost response to the problem to emerge;
- a 100 percent recycling of any revenues from permit auctions to consumers through a reduction in the personal income tax;
- a 100 percent return to business through a reduction in the marginal rates of the corporate income tax or through lump-sum rebates; or
- a 40/60 split to consumers and businesses, in proportion to their shares of energy use, either through a tax rate reduction or a lump-sum return.

**Figure 11: DRI 1990 Level Case --
GDP Sensitivity to Revenue Recycling Options**



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

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

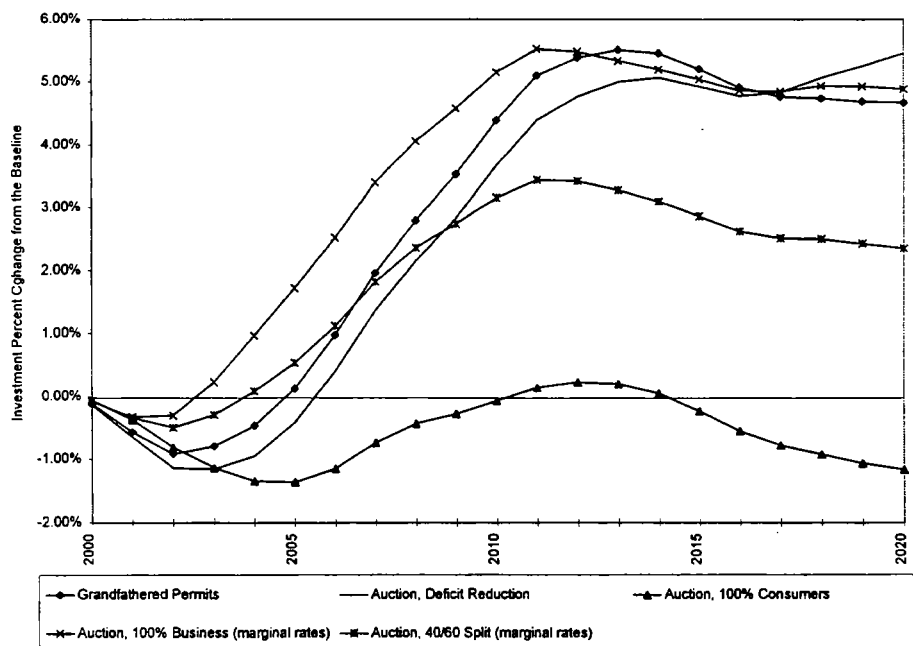
The revenue recycling options that lead to better economic outcomes are all those associated with greater investment and capital formation. Deficit reduction leads to lower interest rates, which lowers the cost of capital and facilitates investment. Recycling revenues to companies has the effect of increasing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

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

Figures 12 and 13 demonstrate the effects of revenue recycling on investment and consumption, in relation to the effect on GDP, as shown in the previous figure. As these figures show, the key to economic recovery among the revenue recycling options is to improve investment in the economy.

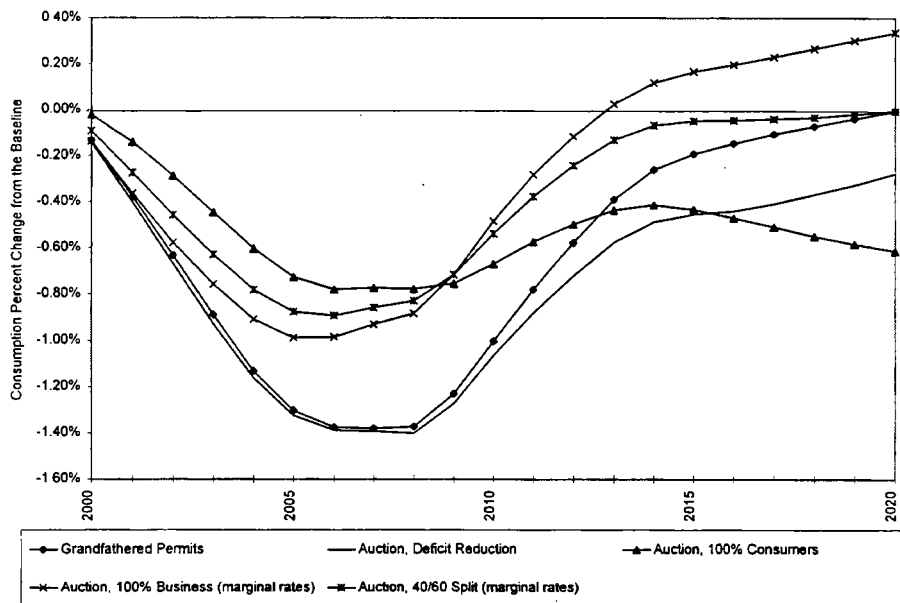
Figure 12: DRI 1990 Level Case

Investment Sensitivity to Revenue Recycling Options



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

Figure 13: DRI 1990 Level Case
Consumption Sensitivity to Revenue Recycling Options

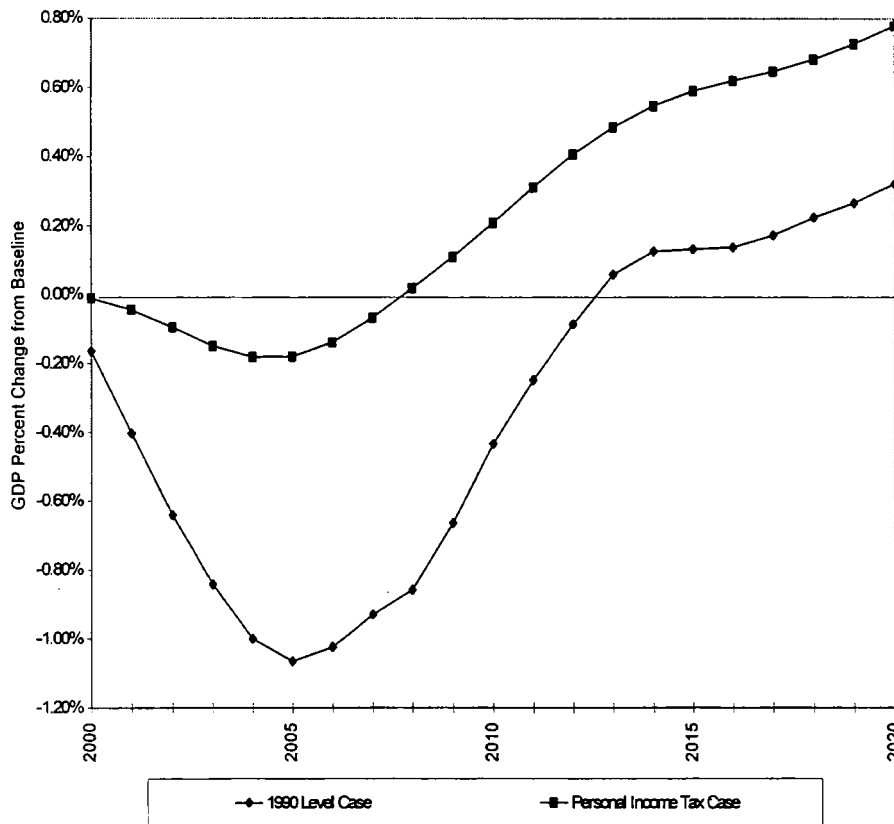


Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Assuming a 1.25 percent annual decrease in E/GDP.

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

An increase in the personal income tax results in smaller economic losses and a more prompt economic rebound than a "deficit-equivalent" carbon reduction policy, as shown in Figure 14. Thus, while revenue recycling options can affect significantly the outcome of a carbon-reduction policy, the gains they create are unrelated to carbon reduction itself.

**Figure 14: Comparison of Deficit Reduction to Personal Tax Increase:
Effects to GDP**



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

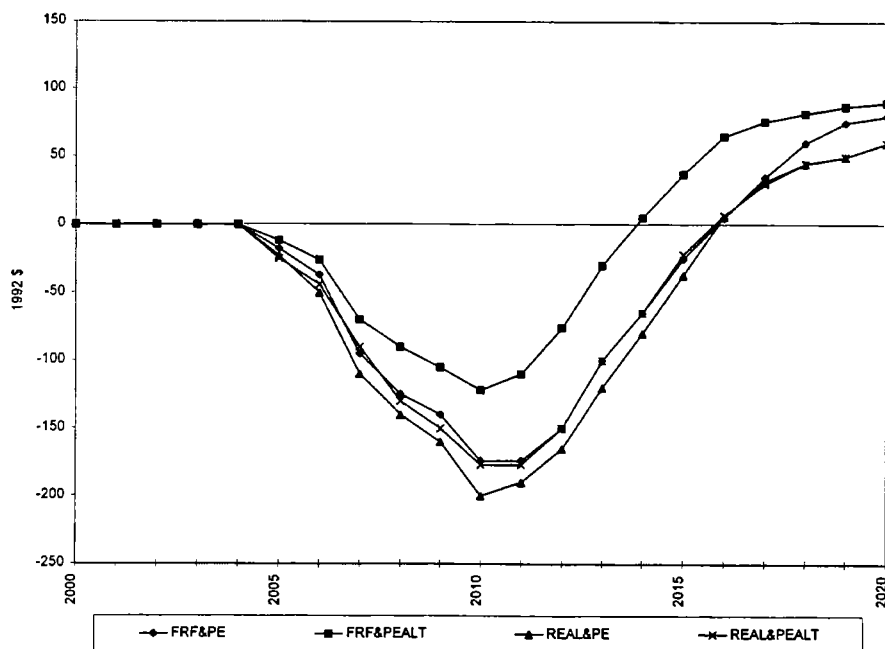
The IAT decided to maintain the DRI assumptions about the reaction of the Federal Reserve Board (Fed) to price inflation, while excluding DRI's price expectation function for consumers, business and the Fed. The Federal Reserve reaction function in the DRI model is an empirically derived estimation of likely Federal Reserve policy responses to changes in price inflation and the unemployment rate, among other variables. This reaction function was used in the analysis. The price expectation equation in the DRI model presumes that three agents in the economy-- business, consumers and the Fed -- have adaptive expectations, that is, they believe that future levels of inflation can be guessed by extrapolating current levels of inflation. This price expectations equation was *not* used in the analysis, because it seemed a poor way to model a widely-known and anticipated one-time policy event that would affect prices as would, in some sense, a sales tax. Nonetheless, the IAT ran sensitivity analyses to discover what the differences in the economic effects there would be under a carbon policy scenario if these assumptions were altered.

As can be seen from Figure 15, the effects of the DRI reaction function are very similar to those obtained when the Fed's target is assumed to be constant real non-borrowed reserves, itself a

fairly accommodating policy (depicted in Figure 15 as "REAL"). The alteration of price expectations is also important. When all three agents--business, consumers, and the Fed --view expected inflation as unchanged as a result of the imposition of a carbon permit policy, GDP losses are smaller (depicted in Figure 15 as "PEALT").

Thus, alternative views of price expectations appear to have as large an impact on the ultimate results as do alternative monetary policy reactions: when consumers, businesses, and the Fed all see a carbon-limiting policy as inseparable from an increase in underlying inflation fundamentals, and while their doing so would be myopic in the extreme, the economic results are worse. Moreover, should they do so, they force the Fed into an even more output-limiting policy posture and the combined results are far worse.

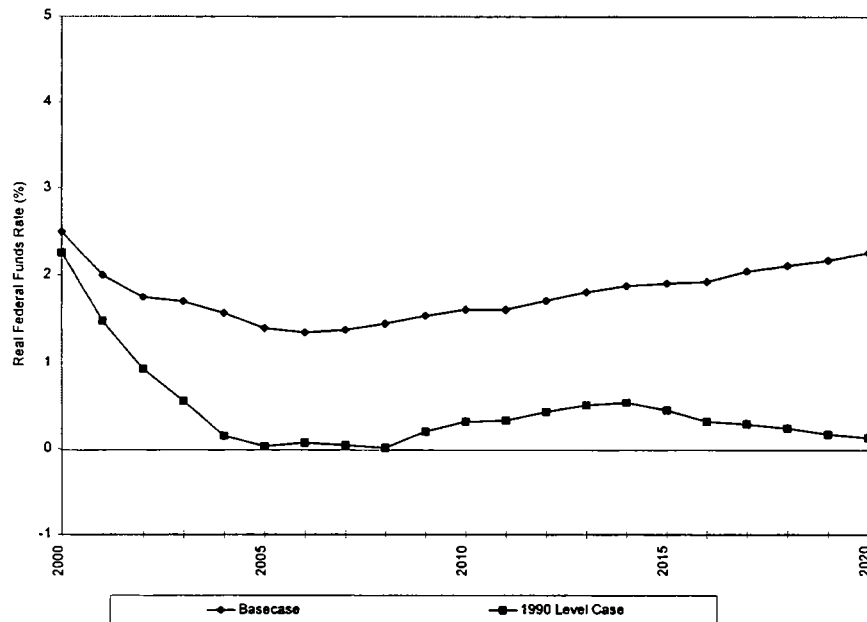
Figure 15: 1990 Level Case--Sensitivity of GDP to Assumptions about Federal Reserve Policy and Price Expectation



Note: These simulations were conducted using DRI and the NEMs Energy Model and they do not conform in detail to those conducted using DRI and the DRI Energy Model. FRF&PE means DRI's Federal Reaction Function and Price Expectation equations are both left on. FRF&PEALT means DRI's Federal Reaction Function equation is left on while the price expectation equation is switched off. REAL&PE means that the Federal Reaction Function equation is switched off and constant real non-borrowed reserves are used instead and the Price Expectation equation is left off. REAL&PEALT means that the Federal Reaction Function and the Price Expectation are switched off.

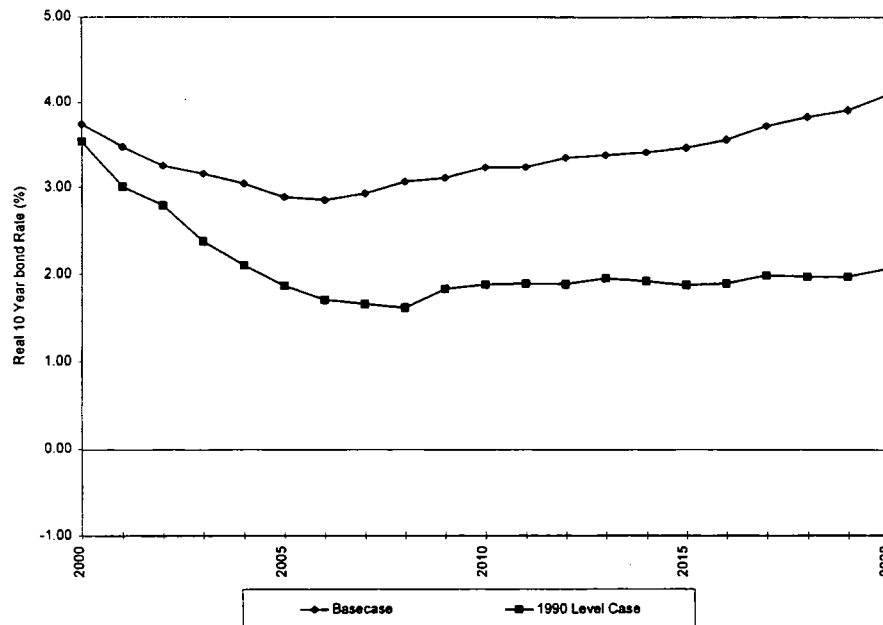
Figures 16, 17, and 18 show projections of the Federal Funds Rate, the 10-year Long Term Bond Rate, and the Federal Deficit/Surplus, respectively, from the DRI model while both the Federal Reaction Function and the Price Expectation equations are used in the analysis of the 1990 Level Case ("plain vanilla"). These results show how important the treatment of revenue flows is in the DRI model. Substantial declines in the deficit (these runs were produced before the agreement to balance the budget in 2002 was achieved in May) allow interest rates to fall, which is the key to the economy's investment response.

Figure 16: DRI 1990 Level Case--Real Federal Funds Rate



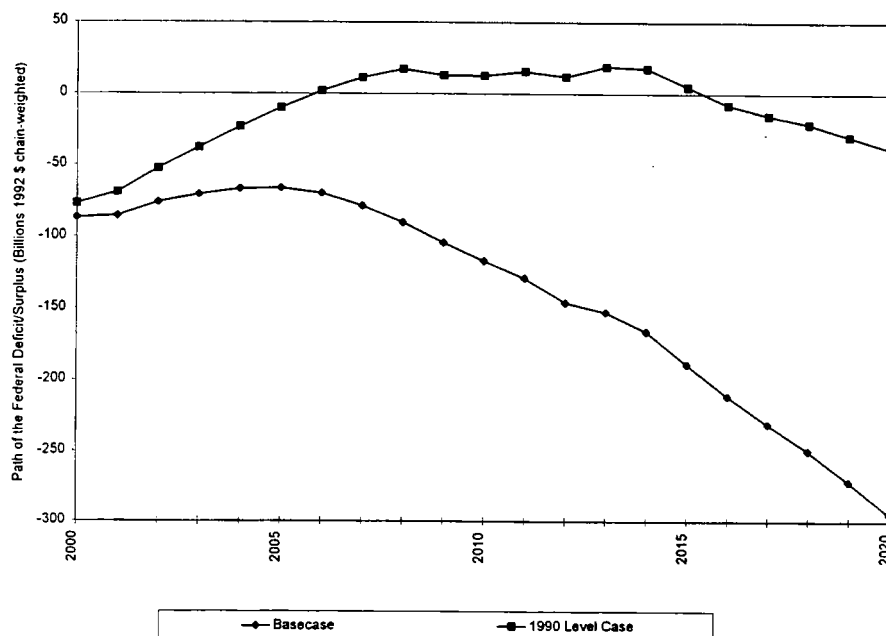
Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 17: DRI 1990 Level Case--Real 10-Year Long-Term Bond Rate



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 18: DRI 1990 Level Case--Path of the Federal Deficit/Surplus



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

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

According to results from the Markal-Macro model, an improvement in the energy intensity of 0.25 percent annually, or a total annual decline of 1.25 in energy per unit of real output, can be achieved without great difficulty. For example, such an improvement can be produced if the "hurdle rates" -- that is, the premium that households and firms appear to place in their discount rate when considering energy-efficiency investments -- declines by 21 percent. (For example, the discount rate households use when considering installing better insulation would have to fall from [FORTHCOMING] percent to [FORTHCOMING] percent). Thus, this improvement can

be achieved through diffusion practices alone, rather than requiring a higher rate of innovation and technological progress.

In fact, some analysts believe that the enactment of the Climate Change Action Plan gets us to the 1.25 annual reduction. DRI achieved a 1.25 percent annual rate of improvement in E/GDP using the latest estimates of energy savings from CCAP, as seen in Table 8. The model then takes these savings and computes carbon emission reductions based on the energy savings profile.

**Table 8: CCAP Emission Reduction Estimates by Sector
in DRI Energy Model (MMTC)**

	2000	2010	2020
Residential	-1.5	-6.1	-9.9
Commercial	0	0	0
Industrial	-11.2	-19.8	-20.8
Transportation	-4.8	-8.3	-9.1
Electricity	-15.5	-53.2	-76.3
Total	-33.0	-87.4	-116.1

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

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

For all other residential and commercial sector energy end-uses, the DRI model uses estimates of the average efficiency of all new and retrofit equipment purchases to determine fuel use requirements. These average efficiencies were increased to reflect improvements to technology

performance and higher rates of diffusion for more efficient technologies. No changes were made to the rates of capital stock turnover and replacement.

Finally, when possible, the rate of improvement in energy-efficiency that IAT assumed was applied to the economy's carbon-efficiency for purposes of modeling. That is because carbon is the appropriate target. But not all models can be managed to this parameter. Nevertheless, the differences between the two specifications is not large.

Table 9 summarizes the effects of higher technological progress (that is, the 1.75 annual rate versus the 1.25 annual rate) on the economic effects of carbon-limiting policies. As seen, higher rates of technological progress can cut dramatically the implicit price of carbon and the associated transitional GDP losses. For example, in the IAT "plain vanilla" case (assuming 1.25 percent annual efficiency improvements), the implicit price of carbon in the two models is \$82 and \$130 per ton in 2010 and \$125 and \$122 per ton in 2020, for DRI and Markal-Macro respectively. In the more advanced technology case, the implicit price of carbon is \$88 per ton and \$95 in 2010 and \$30 and 48 per ton in 2020, for DRI and Markal-Macro respectively.

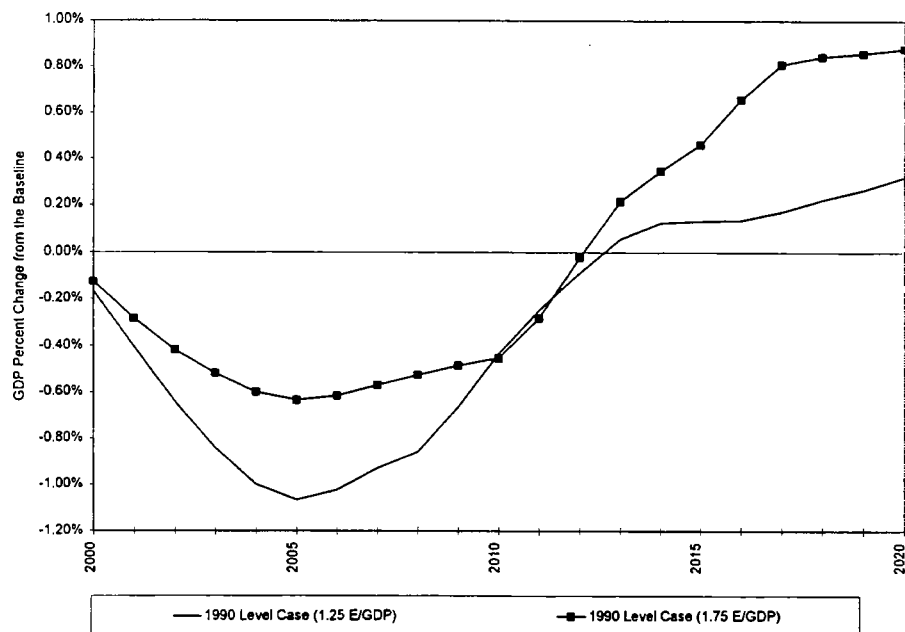
**Table 9: Sensitivity of Implicit Price of Carbon (1995 \$)
to Rate of Technological Change --1990 Level Case**

	2010		2020	
	1.25 Case	1.75 Case	1.25 Case	1.75 Case
DRI-DRI Energy	95	88	125	30
Markal-Macro	130	95	122	48

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction. DRI permit prices are generated using the annual rate of change in E/GDP. Markal-Macro permit prices are calculated using the rate of change in C/GDP.

The peak GDP losses change accordingly, as shown in Figure 19. Using the DRI model, the peak output loss of -0.6 percent occurs in 2005, and the economy reaches its pre-policy growth path by 2012. The economy's shift to a higher growth path is also more pronounced, but here the result is more believable, because it is achieved through technological progress rather than revenue recycling that raises savings and fosters investment (in fact, the level of revenue recycling falls dramatically as does the implicit price of carbon). The risk, however, is that these output gains may be somewhat overstated, because they do not account for the cost of the investments needed to reach the higher rate of technological progress. For example, firms will have to perform R&D that might distract them from other R&D tasks. If other R&D in the economy fell as energy- and carbon-related R&D was performed, overall productivity could drop and offset the economy's potential elsewhere. Alternatively, they might increase their total R&D effort, but leave the economy with fewer resources to do other things. While it is likely that these effects are second-order when compared to the effects of the improvement in carbon-related efficiency, they are still absent from the analysis.

Figure 19 : Sensitivity of GDP to the Rate of Technological Progress
DRI 1990 Level Case



Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction.

These results indicate how important technological progress is in the long term. A substantially higher rate of technological progress does not affect short-term results in a striking fashion. But it is capable of moving the analysis significantly once its effects are allowed to accumulate.

International trading of carbon permits among the Annex I countries leads to sizable reductions in costs needed to stabilize emissions. The discussion so far has centered on the how the U.S. economy reacts when the United States independently reduces emissions, however allowing an international market to trade emissions permits is an alternative to unilateral action. The purpose of such a market would be to increase the efficiency and reduce the cost of reducing global emissions by taking giving all polluters the incentive to search for least-cost solutions across national boundaries.

In brief, under a system of tradable permits, a country could either reduce emissions or purchase additional emissions "rights" (i.e., permits) from other countries. Countries with opportunities to reduce emissions that cost less than the going permit price would have an incentive to reduce emissions and sell their "right to emit" for cash. Countries that had only high cost options to reduce emissions (that is, reduction options that cost more than the permit prices) could purchase emission permits. The forces of supply and demand would set the permit price and the market incentives would push the trading group, as a whole, to institute the least cost emissions

reductions first. As a result, it costs less for the trading group, as a whole, to reach the target emissions levels, than it would for each country to unilaterally reduce its emissions to the target levels. Such a policy, of course, raises a variety of legal and institutional questions regarding how it would be implemented with certainty. These issues are not addressed here: instead, the simple assumption is made that the policy works as intended and least-cost approaches to abating carbon are identified and traded.

Using the SGM model, the IAT modeled two international trading scenarios. In the first, it examined the affects of establishing a permit market among the United States, Canada, Western Europe, Eastern Europe, Japan, the Former Soviet Union (FSU), and Australia (collectively known as Annex I countries). In the second scenario, we examined the effects of Joint Implementation, that is, establishing a wider permit market that includes the rest of the world. These scenarios are compared to a scenario in which each of the Annex I countries independently implemented our "plain vanilla" scenario for stabilizing carbon emissions ; that is, stabilizing CO2 emissions at 1990 levels in 2010 with a ten year phase in, where revenues are used to reduce the deficit, and under the assumption of moderate technological change (i.e., a .25 percent additional reduction over the baseline in the annual increase in energy or carbon efficiency).

The results obtained using the SGM model appear in Table 9. Under the "Annex I trading" scenario, the United States, Canada, Western Europe, Japan, and Australia each bear real costs for CO2 emissions reduction. The losses experienced by he different nations reflect the economic assumptions made for them (which are presented earlier in this report, in Table x) and their energy policies to date. Japan, for example, is projected to have relatively slow economic growth and already has relatively high energy prices and an extensive nuclear program. Thus, it is not projected to have strong growth in emissions over the next few decades and the implicit price of carbon in the presence of a 1990-level freeze is relatively low. Western Europe fares somewhat worse, since its economic growth is projected to be stronger, and its energy policies have been biased towards coal. Absent trading, the implicit price of carbon in the Annex I regions ranges from a low of \$82 per ton to a high of \$268 per ton in 2010.

Table 9: GDP Impacts to Annex I Countries, No Trading v. Annex I Trading**SGM 1990 Level Case**

	No Trading					Annex I Trading				
	2000	2005	2010	2015	2020	2000	2005	2010	2015	2020
Australia	0.00%	-0.17%	-0.49%	-0.37%	-0.21%	0.00%	0.00%	-0.14%	-0.15%	-0.14%
Canada	0.00%	-0.42%	-1.06%	-1.08%	-1.10%	0.00%	0.00%	-0.16%	-0.20%	-0.19%
Eastern Europe	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.72%	0.68%	0.49%
Former Soviet Union	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.39%	0.50%	0.46%
Japan	0.00%	-0.23%	-0.63%	-0.43%	-0.29%	0.00%	0.00%	-0.08%	-0.08%	-0.06%
Western Europe	0.00%	-0.19%	-0.67%	-0.43%	-0.17%	0.00%	0.00%	-0.16%	-0.15%	-0.09%
United States	0.00%	-0.06%	-0.15%	-0.17%	-0.15%	0.00%	0.00%	-0.08%	-0.10%	-0.10%

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in C/GDP.

In addition to a high permit price, near term GDP losses in Canada are the most severe in Annex I. This occurs because Canada is already less carbon intensive, but not as energy intensive as the United States. The carbon to population ratios in Canada are about 17 percent below that of the U.S. levels throughout the baseline projection period, while its energy to GDP ratio is about 46% higher. Canada relies more heavily on non-carbon sources of energy, such as hydro electrical generation.

Table 10 shows the implicit price of carbon by country without trading, trading with Annex I countries, and with Joint implementation with the developing countries.

Table 10: Implicit Price of Carbon (1995 \$) Under Annex I Trading and Joint implementation--SGM 1990 Level Case

	2010			2020		
	No Trading	Annex I Trading	Joint Implementation	No Trading	Annex I Trading	Joint Implementation
Australia	132	23	15	126	35	20
Canada	222	23	15	252	35	20
China	*	n/a	15	*	n/a	20
Former Soviet Union	0	23	15	0	35	20
Eastern Europe	0	23	15	0	35	20
India	*	n/a	15	*	n/a	20
Japan	268	23	15	257	35	20
Korea	*	n/a	15	*	n/a	20
Mexico	*	n/a	15	*	n/a	20
Western Europe	130	23	15	139	35	20
United States	82	23	15	107	35	20
Rest of World	*	n/a	15	*	n/a	20

Note: Emissions stabilized at 1990 levels in 2010 with a 10 year phase-in. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in C/GDP. * indicates the cell is blank because the country is a non-Annex I country.

The United States shows smaller output losses than Japan or Western Europe predominantly because it has more "cheap" carbon-abating opportunities. Its energy prices are lower than these regions' and it has yet to take a variety of steps to promote energy conservation and reduced fossil fuels use that are more commonplace elsewhere. Thus, it is somewhat easier for the United States to reach emission targets than other regions, which have "picked the low fruit."

Under Annex I trading, the implicit price of carbon falls dramatically -- permit prices start at \$23 in 2010 and slowly climb to \$35 in 2020. All countries gain through these lower permit prices, because as a whole they achieve stabilization at 1990 levels more cheaply. The source of these cheap emissions is the former Soviet Union and the Eastern European nations. Carbon values fall because it is cheaper for all of the industrialized nations to pay for carbon abatements in those nations (due to lax environmental standards and slow economic growth) than to pursue domestic options only. These nations gain as they become emissions permit sellers under Annex I trading.

Joint Implementation with developing countries reduce the costs of permit prices even further.

Joint implementation -- emissions trading on a global scale -- reduces the permit price further, to \$15 in 2010 and \$20 in 2020. Under this broader market for tradeable emissions permits, however, the FSU and Eastern Europe lose their monopoly on permit sales. Specifically, Joint

Implementation encourages China and India to reduce their use of coal and enter the market as emissions permit sellers.

NOTE TO READERS: IAT is still in the process of taking the lower implicit carbon prices calculated by SGM and using them as input to simulate macroeconomic conditions under DRI. Note, however, that the implicit price involved are less than those of the "110 percent case" above, and the economic losses, therefore, should be anticipated to be smaller.

Reducing carbon emissions would also lead to reductions in other pollutants of direct economic benefit.

NOTE TO READERS: The IAT is still in the process of estimating collateral environmental benefits.

The losses experienced to the U.S. by handicapping energy-intensive industries in international trade need not be large. There is widespread and legitimate concern that forcing an implicit energy price increase on U.S. producers will disadvantage them substantially through trade, particularly with those countries outside of "Annex I" that might not be subject to the same emissions limits. While the IAT is still examining these questions on an industry-by-industry basis, it used the DRI model to examine the overall trade implications of such a possible energy price differential.

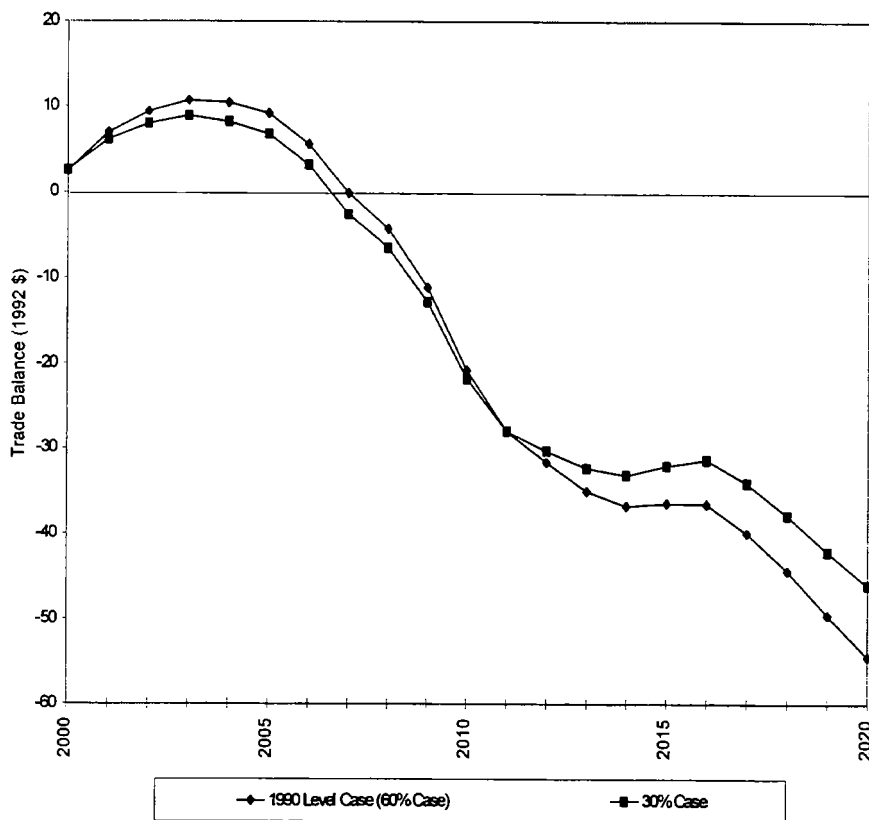
The DRI model examines overall trade effects by assuming a rate at which producers who export to the U.S. experience cost increases. In the aggregate, about 60 percent of imports of manufactured goods come from Annex I countries that will also experience higher implicit carbon prices (and, therefore,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

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

Figure 20 presents the results under these two cases. The effect of the carbon-limiting policy on trade is depicted in these runs as surprisingly small. Some of the change in trade flows is reconciled in the DRI model by allowing the exchange rate to move, but as seen in Figure 21, the anticipated changes in the exchange rate themselves are not large and do not vary between the two assumptions. The small differences are not necessarily counterintuitive. There are already

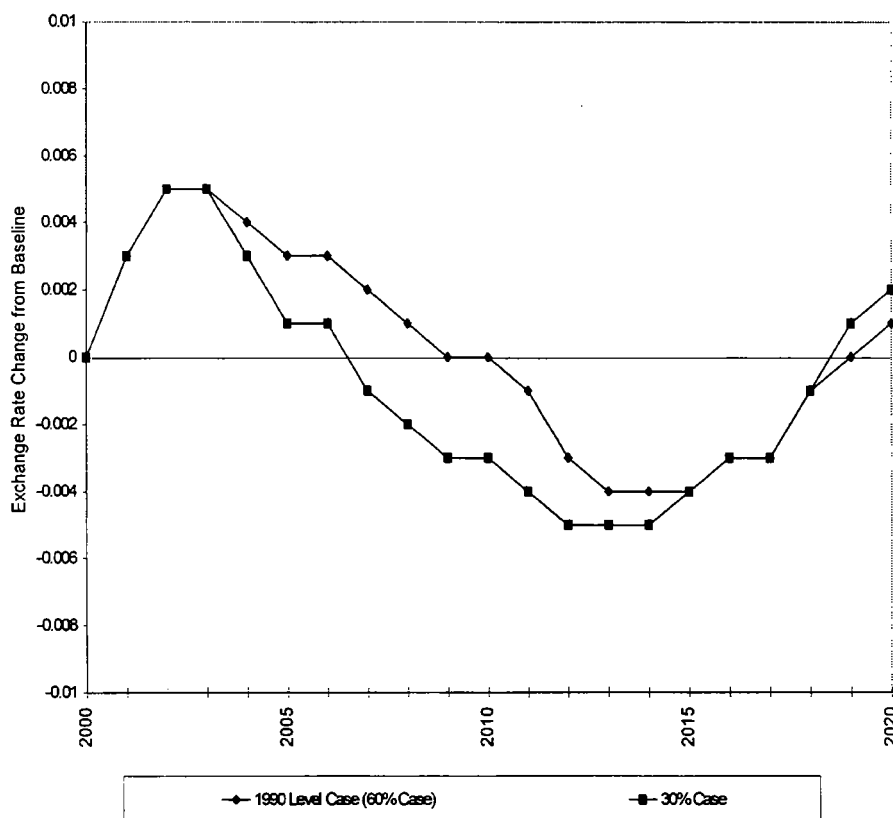
substantial energy price differences and differing environmental restrictions among trading nations that are larger than the price increase that results from the policies considered here.

Figure 20: Sensitivity of the Trade Balance to International Price Ratio Assumptions



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Figure 21: Sensitivity of the Exchange Rate to International Price Ratio Assumptions



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Regional and Sectoral Detail

Using the DRI model, the IAT examined issues regarding regional and industry detail associated with carbon-limiting policies. A summary of this detail for industry effects is given in Table 11.

Table 11: DRI 1990 Level Case--Industry Impacts
Output (Percent Change from Base case)

	2010	2020
Energy Producers		
Electric Utilities	-11.6%	-17.7%
Petroleum Refining	-8.8%	-9.3%
Coal Mining	-25.9%	-39.3%
Natural Gas	-19.9%	-18.2%
Gas Utilities	-11.4%	-10.9%
Crude Petroleum	-11.8%	-12.4%
Fuel Oil	-13.6%	-16.7%
"Pipelines, ex. Natural Gas"	-7.8%	-8.0%
Energy Intensive Industries		
Food and Kindred Products	-1.0%	-0.6%
Chemical and Allied Products	-0.8%	-0.3%
Petroleum and Coal Products	-9.2%	-10.0%
Stone Glass Clay Products	1.5%	2.9%
Paper and Allied Products	-0.4%	3.0%
Primary Metals	0.8%	1.5%

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

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

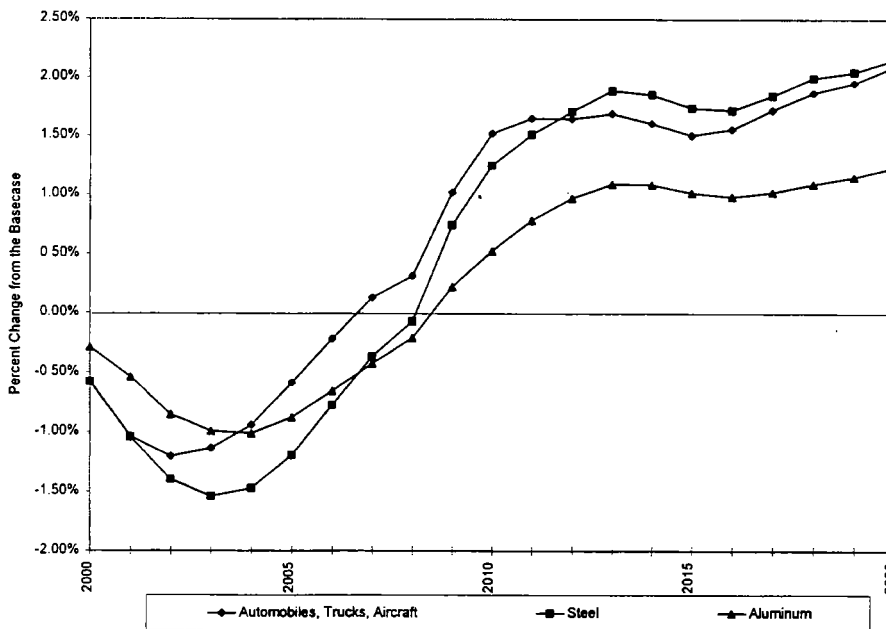
For example, a number of energy intensive manufacturing and construction sectors benefit in the long-term by the stimulus to investment created by the reduction of the deficit. For example, output of the construction, steel, aluminum, lumber and wood products, and motor vehicles are 1.0 to 4.0 percent above the baseline in 2010. Figures 22 and 23 show the transitional output losses and the long-term output gains of a number of basic energy intensive industries that produce final or intermediate products for investment.

On the other hand, industries whose production is used primarily for consumption, particularly energy products such as petroleum and coal, but also including paper, chemicals, and food and kindred products, continue to show losses in annual output, from about 0.5 to 1.0 percent, even after the economy has recovered through 2010. In the longer-term, other than the energy

producers, the consumption-oriented industries are expected to just about reach their output levels in the baseline.

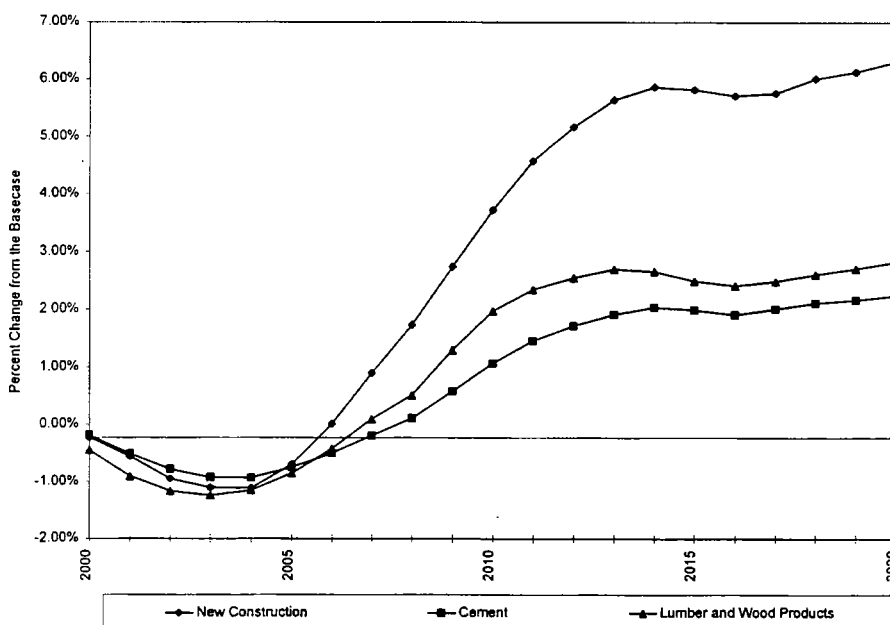
This mix effect is particularly and obviously important for energy producers. The DRI model suggests output of petroleum products will decline by 8 percent in 2010 and by 9 percent in 2020, when compared to the base case. As seen in Table 11, coal production in the U.S. will be 26 percent lower in 2010 and 39 percent lower in 2020 when compared to its projected levels in the base case.

Figure 22: DRI 1990 Level Case--Output in Key Industries--New Construction, Cement, and Lumber and Wood Products



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

**Figure 23: DRI 1990 Level Case--Output in Key Industries--
Automobiles, Trucks and Aircraft, Steel, and Aluminum**



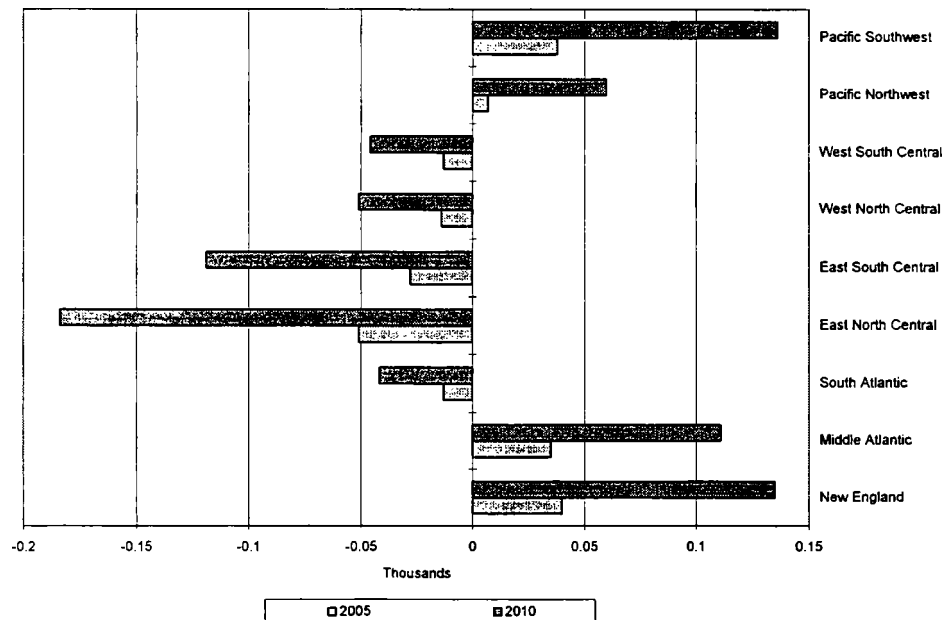
Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

Coal employment would be [FORTHCOMING] percent and [FORTHCOMING] percent lower, respectively, in those years: these declines are lower than output losses because productivity in the industry is generally anticipated to improve and the nation's coal mix is projected to shift to more productive coal reserves. These employment losses are particularly severe in the east and west south central regions. Total coal employment in the U.S. would be [FORTHCOMING] lower by 2020.

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

Regional Effects The effects of climate change policy on the various regions of the country are shown in Table 12. In general, states in the East North, East South, and West North Central regions will have proportionally greater losses in population, 150-, 125-, and 75-thousand, respectively, and employment, 210-, 165-, and 125-thousand, respectively, than the other regions of the country. See Figures 24 and 25. The New England, Middle Atlantic, and the Pacific Southwest are expected to show long-term gains in population of 125-, 110-, and 130 thousand, respectively, and in employment of 125-, 45-, and 65-thousand, respectively, because of climate change policy implementation.

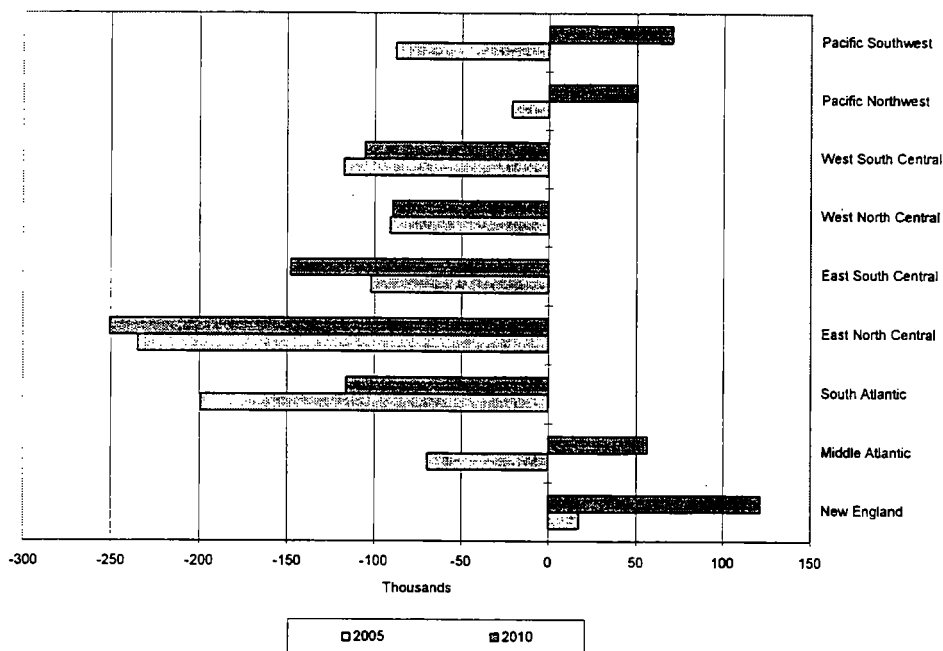
**Figure 24 : DRI 1990 Level Case--Population
(change from the base case)**



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

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

Figure 25: DRI 1990 Level Case--Total Non-Farm Employment change from the base case



Note: Emissions stabilized at 1990 levels in 2010. Revenues recycled back into the economy through deficit reduction and assuming a 1.25 percent annual decrease in E/GDP.

As shown in Table 12, although the West South Central region is expected to have the greatest losses in mining employment, about 15 thousand in 2010, this represents only about 6 percent of its total mining employment in that year. On the other hand, the East South Central Region is expected to lose about 8 thousand in 2010, but this represents about 22 percent of its total mining employment in the same year.

Table 12: DRI 1990 Level Case

Regional Impacts

Year	New England	Middle Atlantic	South Atlantic	East North Central	East South Central	West North Central	West South Central	Pacific Northwest	Pacific South*west
Disposable Income, % change from base case									
2005	0.85%	0.38%	-0.08%	-0.44%	-0.45%	-0.73%	-0.15%	0.34%	0.27%
2010	1.89%	0.74%	-0.12%	-1.07%	-1.33%	-1.24%	-0.39%	1.10%	0.60%
2020	2.85%	0.91%	0.06%	-1.37%	-1.45%	-1.89%	-0.66%	1.35%	0.70%
Total Non-farm employment, % change from base case									
2005	0.25%	-0.38%	-0.78%	-1.03%	-1.29%	-0.89%	-0.81%	-0.35%	-0.39%
2010	1.65%	0.30%	-0.42%	-1.06%	-1.80%	-0.84%	-0.68%	0.78%	0.29%
2020	2.66%	0.51%	-0.20%	-1.10%	-1.71%	-0.94%	-0.76%	1.12%	0.49%
Mining Employment, % change from base case									
2005	0.43%	-8.52%	-8.33%	-5.92%	-10.87%	-0.75%	-1.43%	-2.11%	-0.89%
2010	4.40%	-10.85%	-11.62%	-7.78%	-20.54%	1.02%	-6.44%	-1.08%	0.79%
2020	9.03%	-14.04%	-15.57%	-6.22%	-27.84%	4.25%	-4.78%	-8.34%	0.56%
Population, change from base case									
2005	0.04	0.04	-0.01	-0.05	-0.03	-0.01	-0.01	0.01	0.04
2010	0.14	0.11	-0.04	-0.18	-0.12	-0.05	-0.05	0.06	0.14
2020	0.25	0.18	-0.04	-0.30	-0.17	-0.11	-0.12	0.11	0.19
Manufacturing Employment, change from base case									
2005	9.61	1.67	-32.48	-77.07	-24.65	-19.50	-21.51	-0.95	-0.56
2010	26.48	21.72	-28.41	-116.07	-32.47	-28.33	-28.50	6.74	17.34
2020	36.92	13.90	-33.80	-142.48	-32.69	-35.25	-41.78	7.28	23.91
Transportation, Communication & Utilities, change from base case									
2005	1.74	-4.06	-12.10	-15.53	-4.90	-8.08	-8.70	-1.55	-6.49
2010	5.70	-2.94	-16.52	-25.93	-9.36	-13.46	-14.91	0.30	-5.52
2020	8.39	-4.83	-18.14	-31.18	-10.03	-16.07	-17.89	0.35	-5.35

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**Groundbreaking Energy Innovations Study Shows
Prosperous Path to Global Climate Protection**

Less Costly, Cleaner Energy Benefits the Environment and Economy

Washington, DC, June 17 — By 2010, U.S. emissions of carbon dioxide, the chief global warming pollutant, could be cut to 10 percent below 1990 levels while national energy costs are reduced by \$530 per household annually and nearly 800,000 additional jobs are created, according to a groundbreaking new report released today. These benefits can be attained through smart policies that stimulate the introduction of innovative technologies to use energy much more efficiently and to tap domestic renewable resources.

The study's findings are critical for consideration at this month's summit meetings in Denver and New York, where global warming will be a major topic as climate talks enter their pivotal final stage prior to the Kyoto climate summit December deadline.

The study, *Energy Innovations: A Prosperous Path to a Clean Environment*, paints a picture of a healthier and more secure energy future for the United States. Backed by in-depth engineering and economic analysis, the study demonstrates the benefits of choosing an *Innovation Path*, rather than remaining on the *Present Path* of inefficient, fossil-fuel dependent energy production and consumption.

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Energy Innovations was researched and written jointly by the Alliance to Save Energy, the American Council for an Energy-Efficient Economy, the Natural Resources Defense Council, the Tellus Institute and the Union of Concerned Scientists. Working together for nearly two years, independent energy policy experts from these organizations gathered data and used government analytic models to assess the effects of different policy options on the economy and environment.

The study documents our *Present Path* predicament in which energy supply and use is a burden on the economy and harmful to the environment. Alternatively, an *Innovation Path* is presented, which offers strategies that would guide the economy toward more secure, lower cost, less polluting ways of producing and using energy. New incentives, better standards and market mechanisms would be employed to promote greater energy efficiency and cleaner energy resources in cars, homes and business. These measures would generate cost savings and channel investments toward ever cleaner and more efficient technologies.

"This report serves as a roadmap on how to address the threat of global warming, while creating new jobs and lowering energy costs," said Alden Meyer, Director of Government Relations for the Union of Concerned Scientists. "Now the question is whether the Administration will have the political courage to take on the polluting special interests and protect our children's future."

Fossil fuel consumption is the primary cause of the 30 percent increase in the concentrations of carbon dioxide measured by scientists in the earth's atmosphere. This pollution buildup is causing global climate change that, left unchecked would spread the frequency and severity of heat waves, floods, droughts and storms; disrupt crops, forests and ecosystems; spread disease and undermine economies and communities.

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"President Clinton has recognized that a greenhouse world is no place to nurture our children," said Dan Lashof, Natural Resources Defense Council Senior Scientist. "Now he must lead the United States and the world onto an innovation path that will cut greenhouse pollution even as it grows the economy."

Once incorporated into the country's energy policies, the benefits of the *Innovation Path* are significant. Analyzed against the continuation of current U.S. energy trends, the dividends in 2010 include:

- Reduction in fossil fuel dependence
- Renewable energy delivering 14 percent of energy needs
- Carbon dioxide pollution reduced by 10 percent below 1990 levels
- National energy costs reduced by \$530 per household annually
- Creation of 770,000 new jobs

"Three concerns — our environment, our economy and our security — compel us to rethink the current U.S. energy strategy," said John DeCicco, Senior Associate, Governmental Relations for the American Council for an Energy-Efficient Economy.

"With oil imports rising, America is at risk from economic disruption or military conflicts due to our dependence on imported oil," he said. "The *Energy Innovations* study points the way to a more secure economy while protecting the environment."

The key energy technologies that would become the cornerstones of the *Innovation Path* include fuel cells, advanced gas turbines, integrated green building designs, membrane technology, biomass fuels, advanced wind turbines, and thin film photovoltaic modules. The final mix of technologies will ultimately yield more usable energy and less pollution from each ton of coal, barrel of oil or cubic foot of natural gas. The shift from the dependence on fossil fuels will be orderly as the country moves to an increasing percentage of renewables.

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The study takes special note of the opportunities presented by the emerging regulatory changes taking place in the electricity industry. The treatment of environmental and energy efficiency policies in the context of utility restructuring is critical to the nation's chances of curtailing global warming and spurring economic growth.

"In the race to greater competition in the electric utility industry, it is crucial that restructuring be handled so that environmental gains are not lost," said David M. Nemtzw, President of the Alliance to Save Energy. "If restructuring of this industry is not handled right, environmental, economic, national security, and other benefits of clean energy would be at peril. Energy efficiency and renewable energy must play a leading role in restructuring legislation and upcoming climate change talks."

"The policies analyzed here, will provide impetus for the kinds of technological innovation, learning and diffusion, needed to ensure sustainable development of our economy and society in a sustainable world," says Steve Bernow, Director of the Energy and Environment Program at Tellus Institute. "This will reflect both continuity, in our traditions of creativity, inventiveness and practical ingenuity, and change in our transition to a more modern and cleaner technological basis for our economy."

###



CHOOSING OUR ENERGY FUTURE

The Present Path

National energy consumption rises from 85 Quads in 1990 to 105 Quads in 2010 and 119 Quads in 2030.

Economic growth averages 2.2% per year under *Present Path* assumptions.

In spite of economic growth, many job opportunities are lost due to energy waste and rising oil imports.

National energy bill rises to \$650 billion in 2010 from \$540 billion in 1990.

Fossil fuels, which account for 85% of U.S. energy use today, still account for 85% in 2010.

The United States remains fossil-fuel dependent for the foreseeable future, with renewable resources meeting only 11% of our energy needs in 2030.

Petroleum use rises from 17 Mbd (million barrels of oil per day) to 21 Mbd in 2010 and 25 Mbd by 2030.

U.S. oil import bill rises to \$104 billion annually by 2010, continuing to add to our trade deficit and drain the economy.

Energy intensity of the U.S. economy declines at 1.1% per year.

Air pollution from nitrogen oxide (NOx) emissions persists with little change from present level of 20 million tons per year.

Sulfur dioxide (SO₂) emissions decline only slowly, from 19 million tons annually today to 13 million tons by 2010.

Global warming emissions of carbon dioxide (CO₂) rise steadily from 1338 MTc (million metric tons of carbon per year) in 1990 to 1621 MTc in 2010 and 1892 MTc in 2030.

The Innovation Path

National energy consumption held to 89 Quads in 2010 and is cut to 69 Quads in 2030.

Economic growth averages 2.2% per year under the *Innovation Path*.

Energy savings result in job creation, with a net employment boost of nearly 800,000 jobs nationwide by 2010.

National energy bill held to \$560 billion in 2010. Net savings amount to \$530 per household per year in 2010.

Fossil fuel dependence drops to 79% by 2010 and down to 68% by 2030.

The country starts a clear transition toward renewable resources, which meet 14% of U.S. energy use needs by 2010 and 32% by 2030.

U.S. petroleum use trimmed to 16 Mbd by 2010 and then drops to 12 Mbd by 2030.

Oil import bill cut to \$83 billion by 2010, saving \$21 billion per year that would be otherwise largely lost to the economy.

U.S. energy intensity declines at 1.9% per year, falling 32% by 2010.

NOx air pollution is reduced 24% below the 1990 level by 2010, falling to 15 million tons per year.

SO₂ pollution is reduced 64% below the 1990 level by 2010, dropping to 7 million tons per year.

U.S. CO₂ emissions are cut to 1207 MTc, 10% below the 1990 level, by 2010 and reductions continue, pushing emissions down to 728 MTc, or 45% below the 1990 level, by 2030.

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THE CHAIRMAN

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

Statement before the House Commerce Subcommittee on Energy and Power

Dr. Janet Yellen

Chair, Council of Economic Advisers

Tuesday, July 15, 1997

Good afternoon, Mr. Chairman and members of the Subcommittee. I appreciate the opportunity to discuss with you today the economics of global climate change.

Introduction

In his speech to the United Nations Special Session on Environment and Development in June, President Clinton emphasized that the risks posed by global climate change are real and that sensible preventive steps are justified. This assessment accords with the views of the more than 2300 economists, including 8 Nobel laureates, who signed a statement supporting measures to reduce the threat of climate change. The economists endorsed the conclusions from last year's report by the Intergovernmental Panel on Climate Change (IPCC), which said that governments should take steps to reduce the threat of damage from global warming, and went on to argue that market-based policies can slow climate change without harming the American economy.

At this time the Administration has not settled on a particular set of new policies to reduce greenhouse gas emissions. Instead, the President indicated in his U.N. speech that he intends to engage in a discussion with all interested parties about the problems posed by

greenhouse gas accumulations and the costs and benefits of corrective action. To this end, the President will hold a White House conference on climate change later this year, and Members of his Cabinet and other senior Administration officials will meet with Members of Congress, scientific and economic experts, environmentalists, local government officials, and business and labor leaders on a regular basis over the next several months to discuss issues related to climate change. This process is intended to inform the Administration's decision-making process, which will culminate in a U.S. policy position in the international negotiations in Kyoto in December of this year.

An important step in this -- and any -- policy process is determining the impact it will have on the American economy. President Clinton's top priority, since his first days in office, has been revitalizing the U.S. economy, creating jobs and investing in people and technology to enhance long-term growth. And, we have made tremendous progress. The President is not going to jeopardize that progress. Any policy he ultimately endorses on climate change will be informed by his commitment to sustaining a healthy and robust economy.

In my testimony today, I would like to describe some of the principal lessons that emerge from the voluminous literature, much of it relatively recent, on the economic impacts of policies to address global climate change.

Underlying Uncertainties

Before I begin my discussion of the economic literature, I would like first to acknowledge the uncertainties associated with estimating both the costs and benefits of reducing greenhouse gas emissions. To provide some perspective: as you all know, it is difficult to gauge exactly what impact the balanced budget agreement will have on the U.S. economy's growth rate, levels of employment, interest rates and consumption over the next five years. But with global climate change, it is orders of magnitude more difficult to gauge the effects on the economy: we are concerned with not just the next five years and not just the American economy, but, rather, we are dealing with economic and physical processes that operate globally and over decades, if not centuries.

Although a great many scientists believe that global climate change is already underway, the more serious potential damages associated with increasing concentrations of greenhouse gases are not predicted to occur for decades. This means that the benefits of climate protection are very difficult to quantify. And, while the potential costs of reducing greenhouse gas emissions may be more immediate, they too, as I will discuss below, are difficult to predict with any certainty. Many unanswered questions exist about the biophysical systems, potential thresholds, and economic impacts. In short, if anybody tells you that he or she has the definitive answer as to the costs and benefits of particular climate change policies, I would suggest that you raise your collective eyebrows.

Lessons from the Economic Literature

Let me now turn to the economic literature and try to summarize what I think we know so far about this difficult topic. Most economists have not addressed the benefits of climate protection, but rather have focused on the costs associated with alternative paths for reducing greenhouse gas emissions. The economic literature includes estimates using many different models to evaluate numerous alternative emission reduction strategies. In fact, because there are so many different models, economists initially faced difficulties in comparing results: they could not sort out the extent to which differences in results stemmed from differences in models and assumptions versus differences in baseline emission paths and policies. To solve this problem, thereby enabling meaningful comparisons, many economists have calibrated the various models by performing a standardized simulation. Specifically, they have assessed the consequences of stabilizing greenhouse gas emissions at 1990 levels by 2010 or 2020.

Within the Administration, a staff level working group -- the Interagency Analysis Team (IAT) -- has attempted to estimate some of the economic implications of climate change policies. They took the emissions scenario most often used in academic literature -- that is, stabilizing emissions at 1990 levels by 2010 -- as the starting point for their own analysis. I would emphasize that this scenario is not Administration policy; instead, it was picked to make comparisons with other models easier. The staff group employed 3 different models -- the DRI model, the Second Generation Model (SGM) and Markal-Macro model, all commonly available in the public sphere. In running these models, the staff adopted a common baseline and, to the maximum extent possible, similar economic assumptions. This modeling effort produced some

useful lessons, but as we found from the peer reviewers' comments, it also suffered from some serious shortcomings. Both the lessons and the shortcomings point to one clear conclusion: the effort to develop a model or set of models that can give us a definitive answer as to the economic impacts of a given climate change policy is futile. Rather, we are left with a set of parameters and relationships that influence estimates of the impacts. In my view, it is more productive to employ a broad set of economic tools to analyze policy options than to seek to develop a single definitive model.

I understand that a draft of the staff analysis was given to the Subcommittee this morning, along with the reviewers' comments. I would be happy to answer any questions you may have about this modeling effort.

The Lessons. Modeling efforts both inside and outside the Administration clearly indicate that economic analysis can do no more than estimate a range of potential impacts from particular policies and highlight how outcomes depend on underlying assumptions about how the economy works and the ways in which policy is implemented. However, the economics literature on climate change does point to several important lessons:

How the economy works. First, the magnitude of the costs of reducing greenhouse gas emissions in the various models depends crucially on a number of key assumptions about how the economy works. For instance:

- If firms in the economy can shift from high-carbon to low-carbon energy sources quickly, the costs of climate protection will be lower.
- If the economy has significant opportunities, even now, to employ energy-saving technology at low costs, the costs of climate protection will be lower.
- If technological change occurs at a rapid rate, or is highly responsive to increases in the price of carbon emissions, the costs of climate protection will be reduced.
- If the Federal Reserve pursues a monetary policy oriented toward keeping the economy at full employment, transitional output costs will be lower.

In short, the greater the substitution possibilities and the faster the economy can adapt, the lower the costs.

How the plan is implemented. Second, costs depend critically on how emission reduction policies are implemented. It boils down to this: if we do it dumb, it could cost a lot, but if we do it smart, it will cost much less and indeed could produce net benefits in the long run. The over 2300 signatories of the economists' statement argued that any global climate change policy should be rely on market-based mechanisms. Such mechanisms allow for flexibility in both the timing and location of emission reductions, thereby minimizing the costs to the U.S. economy. The economists concluded that "there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run."

- The speed at which emissions reductions are required can have large effects on the estimated costs. It is important to allow sufficient lead-time for orderly investment in new equipment and technology. Alternatively, if emission reduction requirements are too far off in the future, the incentives to adopt energy efficient technologies are weakened because people may not view the policy as credible.
- A “cap and trade” system in which emission permits are issued and then traded among firms can substantially reduce the cost of meeting an emissions target by creating incentives for emissions to be reduced by those firms and in those activities where costs are lowest.
- International emission permit trading substantially lowers costs by applying the same cost-minimizing principle globally.
- So-called “banking” and “borrowing” of permits increases flexibility and lowers costs by allowing firms to change the timing of their emission reductions.
- Joint implementation, whereby US firms would receive credit for undertaking emission reductions in countries with low abatement costs, would also lower the domestic burden.

An additional aspect of implementation that profoundly affects the costs of reducing emissions concerns “revenue recycling.” In many model simulations, emissions are reduced by using various market mechanisms. For many of these scenarios, the Federal government realizes an increase in revenues. Economic growth can receive a

long-term boost if these revenues are used to reduce distortionary taxes that diminish the incentives to invest, save or work, or if the revenues are channeled into deficit reduction, thereby lowering interest rates and boosting investment. In fact, in some models and scenarios, emissions reduction generates a net economic benefit when the revenues are recycled in a growth-promoting fashion.

Which countries participate. The third lesson that emerges from a study of the economics of climate protection is that developing, as well as developed, countries must be part of the process. While developed countries are responsible for most of the greenhouse gas currently in the atmosphere, developing countries are starting to catch up. By 2040, the largest fraction of emissions is estimated to come from developing countries. Thus, any comprehensive plan to deal with this global problem must include a mechanism to bring developing countries into the process.

The timetable for the inclusion of developing countries is also important. The sooner that developing countries face incentives to move away from carbon intensive energy sources, the less likely it is that they will become dependent on those types of fuels to spur their economic growth. In short, global problems require global solutions. We must find the technologies and solutions to lead the way.

Conclusion

Let me conclude. Policies to promote economic growth, create jobs, and improve the living standards and opportunities of all Americans have been and always will remain the top priority of the President and his Administration. In his remarks to the Business Roundtable on global climate change, the President said “[l]et’s find a way to preserve the environment, to meet our international responsibilities, to meet our responsibilities to our children, and grow the economy at the same time.”

Some of the key economic lessons we have learned that will help us achieve the President’s goal include:

- Inherent uncertainty dictates that models should be expected to generate only a range of economic impacts, not definitive answers.
- Key assumptions about how the economy works directly influence the estimated costs of climate protection.
- Implementation of any policy needs to be market-based and flexible over time and space to achieve the lowest cost reductions.
- All nations, both developed and developing, need to participate.

Thank you. I would be happy to answer any questions you may have.

The Subcommittee on Energy & Power

(Ratio: 16-13)

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The Committee on Commerce
2125 Rayburn House Office Building
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The economic and environmental impact of the proposed int. global C.C. agreement
Tuesday 7/15 1pm 2123 RHOB

Tuesday, July 15, 1997

Hearing 1:00 PM 2123 Rayburn House Office Building
Subcommittee on Energy and Power hearing on The Economic and Environmental
Impact of the Proposed International Global Climate Change Agreement.

Questions

What will be the regional impact on jobs, production costs, industries, etc.?

- Michigan (automobiles)
- Kentucky (coal mining)
- Texas (oil)

What will be the national impact on jobs, production costs, industries, etc.?

What should the role of developing countries be?

- How will negotiations proceed if developing countries do not participate but we insist they do?

How will climate change policy affect the consumer?

What is the Administration position on climate change?

What policy tools does the Administration plan on using? What would be a cost-effective approach to lowering emissions in the US?

What benefits will the US see from a climate change treaty? The world?

IAT was working on determining the economic impacts of an Administration policy.
What are these results?

Is global warming a problem?

Will any climate change treaty hurt the international competitiveness of US firms?

What role does CCAP play in achieving the needed emissions reductions?

Some might argue that R&D funds for the energy-producing industries should be cut to put us on the right path to cut emissions. What would be the impact on this down the road?

Questions for Climate Change Hearings

Under-Secretary of State Wirth stated at the June 19 hearing before the Senate Foreign Relations Committee: "These are the same models [IAT models] that were very wrong about what happened with the energy bump up in pricing after the Arab Oil Boycott of 1972. They were the same models that, for the most part, were very wrong about the cost of the Clean Air Act." Why should we base our policy models that have a track record of being "very wrong"?

Where are the models? I understand that the Administration's analysis has undergone peer review? How long did the reviewers have to assess the analysis? How long have you had their comments? If you have had more time to integrate their comments then the reviewers had to assess the models, then why haven't we seen a publicly distributed analysis yet?

What are the benefits of preventing climate change estimated by the IAT models? If there are no estimates of benefits, how do we know what we are getting with these expensive policies? If the state of the science and the economics is insufficient to generate estimates on benefits, doesn't that imply that we don't know enough about the problem to enact costly policy measures?

Some of the studies on this issue indicate that climate change policy might actually increase U.S. GDP. How can this be? If there are great win-win technologies already in existence, why hasn't the private sector already adopted them? Isn't the Administration's Climate Change Action Plan supposed to encourage voluntary adoption of these energy efficiency technologies? Do some of these gains in GDP reflect revenue recycling? Is the argument for revenue recycling unique to climate change? Isn't it just a reflection of the more basic idea that the economy would improve if government removed more distorting taxes and replaced them with less distorting taxes?

If the Administration intends to implement a climate change accord through a "market-based" strategy, what are the details going to be? Most of the discussion has focused on an emissions cap and a trading program. How will you allocate the rights to emissions? Will you auction them off, or give them to carbon dioxide emitters? Wouldn't an auction serve as a de facto tax on carbon?

If China, India, and other non-annex I countries continue to emit carbon dioxide and other greenhouse gases after the U.S. implements a costly emissions reduction policy, what do you expect the benefits of our actions to be?

If non-annex I countries do not have to reduce their emissions, how many jobs do they expect to lose as a result of an international climate agreement? None? Or would they actually have a net gain? Emission reductions similar to ones being discussed in the U.N. have been estimated to result in a loss of between about 1 million and 1.7 million U.S. jobs. Wouldn't U.S. jobs go overseas?

leakage

Non-compliance

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20502

MEMORANDUM

TO: Skip Laitner
FROM: Jay Shogren and Joe Aldy *JS*
DATE: July 11, 1997
RE: Comments on Industrial Emissions and Economic Impacts Paper

Below we have provided several comments on your paper. If you have any questions, please feel free to contact Joe at 395-1455.

1) Win-win claim: The author argues that "since these new technologies tend to lower the overall cost of doing business, investments in energy efficient technologies may actually improve the competitive position of many industries." Then why haven't private firms already adopted these technologies? If a private benefit-cost analysis on an energy efficient technology is positive, then there is no need for policy to stimulate the adoption of the technology. Perhaps the slow rate of adoption reflects unaccounted costs in this analysis, such as high costs of capital or high costs of private information.

2) Rates of return: Heat recovery and cogeneration systems can "save 10% of energy use with an internal rate of return of 30-60%." This may be the case, but the omission in this discussion highlights what is probably the case: high capital costs, even with good returns, can serve as a barrier to action.

3) Understated benefits: The author notes that efficiency technologies "often" yield reduced labor and other material costs that are not captured in a discussion of the benefits. On the other hand, assessments of these technologies may not account for firms' opportunity costs for investing capital. If a firm has a fixed pool of investment capital in any period, even if an efficiency technology has a positive benefit-cost analysis relative to doing nothing, it may not be positive relative to the option of improving the quality of the product manufactured.

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20502

MEMORANDUM

TO: Eric Petersen
FROM: Jay Shogren and Joe Aldy *JS*
DATE: July 11, 1997
RE: Comments on Buildings Sector Paper

Below we have provided several comments on your paper. If you have any questions, please feel free to contact Joe at 395-1455.

1) Barriers to adoption: The author notes that there "is clear evidence that many of the potential reductions are not being realized in the current market system because of a number of institutional, organizational, and other barriers that work against the diffusion of energy-efficient technologies." The list of barriers include: insufficient information, lack of expertise for design, lack of low cost sources of capital, and inability for efficiency purchasers to fully capture rents. Barriers are not an indication of market failure. Market barriers reflect the real costs of adopting a technology that may not be included in the explicit price for the technology. For example, this could include the transaction costs of determining how well a new technology works with the building's existing technology. This inadequate information is a private good, not a public good, problem. Therefore, it represents a market barrier, not a market failure. While it is an explanation for why a technology has not been adopted, it is not rationale for policy intervention. Further, without an analysis of these barriers, it is impossible to determine how adoption rates will change under different carbon prices. We shouldn't just assume away the barriers.

2) Cost savings of technologies: The author notes that an array of technologies can have an annualized cost of \$14-\$24 billion/year with an annual energy bill savings of \$33 billion. We would like to see this broken down by each technology, or technology class (some may be big winners and others could be losers). Also, we would like to know the cost assumptions in estimating energy bills (since the modeling efforts presume significant increases in electricity prices). Have there been sensitivity analyses done to estimate if there is some floor price on carbon that would make the technology adoption more costly than the energy bill savings?

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20502

MEMORANDUM

TO: Eric Petersen and Jim Turner
FROM: Jay Shogren and Joe Aldy
DATE: July 11, 1997
RE: Comments on Electric Power and Renewable Energy Papers

Below we have provided several comments on your papers. If you have any questions, please feel free to contact Joe at 395-1455.

Given that these two papers address many similar issues, we provide one set of comments. It could be beneficial to coordinate these papers, and consider integrating them into one paper. For example, coordinating the presentation of data is of paramount importance. On our first read through of these papers, it appears that the Markal-Macro and DRI models forecast either a 35% increase in non-hydro renewables in 2010 under GHG stabilization (electric power paper) or a more than threefold increase in renewables in 2010 under GHG stabilization (for M-M only in renewables paper). Given the potential uses of these papers, the same set of analytical results should be employed in all discussions.

Electric Power Sector

1) Changing the rate of retirement: Coal plants are, for the most part, fully depreciated. Therefore, the costs of coal-based electricity result from variable cost factors only. Switching to new forms of power requires significant capital investments. This situation puts renewables at a competitive disadvantage with coal, but this situation reflects a market barrier, not a market failure. Since effective policy should focus on failures and not barriers, policy should only affect the rate of retirement by getting the "price right" for carbon emissions.

2) Comparing renewable energy sources to coal-based energy: The modeling efforts anticipate significant decreases in the costs of renewable sources of energy with more R&D investment in the near future. How does the increase in carbon prices affect the investment in cost-reducing technologies for coal power? Do the higher prices stimulate investment in technologies that improve the efficiency of coal-fired power plants? Is there the possibility that utilities could adopt post-combustion carbon sequestration technologies, possibly analogous, in function if not in form, to SO₂ scrubbers?

Renewable Energy Sector

1) Note on biomass fuels: While they may not emit any net carbon, chemical intensive crops for ethanol still have a net positive effect on atmospheric loadings of greenhouse gases through fertilizer applications and escape of nitrous oxides. In addition, growing crops does require the consumption of fossil fuel energy. Further, there is the issue of transporting the biomass. For biomass fuels in cogeneration, which I understand could be scrub grown on marginal agricultural lands, this may not be as serious of an issue. This isn't to say that relative to coal, biomass is a loser, but just to point out that calling biomass a net zero contributor ignores several effects.

Also, the debate on biomass fuels tends to neglect the fact that it reallocates environmental bads from carbon dioxide emissions to chemical runoff and habitat modification.

2) Wind and solar power vary spatially: It would be interesting to know where wind power and solar power are most cost-effective. Some regions can definitely support one or the other better than other regions. However, is this an issue with deregulation of the utility industry? How could state rules on the use of renewable sources of energy by utilities affect allocation of wind- and solar-based electricity from regions with significant wind- and solar-generation to regions with less generation?

3) Factors that accelerate use of renewable energy: The author identifies four factors. Actually, the first two factors are the same: consumer choice and the opportunity to pay a price premium for "green" energy. The third factor is that states may require utilities to pass some renewable energy portfolio standards -- such standards eliminate the likelihood of a green energy premium, since consumers could not differentiate between utilities if they all provide green energy. The fourth factor is that lower renewable energy costs will spur more investments, especially relative to rising fossil fuel costs. Note that firms might invest in renewables even more under deregulation if the price premium effect becomes apparent.

268-2724
J. L. ~~Smith~~ Gorte

Freight, Aircraft and Rail Emissions Projections and Potential for Reduction

Key Points

- Total carbon emissions from the transportation sector in 1995 were nearly 470 MMT. The freight, aircraft and rail sectors accounted for nearly 200 MMT of carbon emissions, or 42 percent of all transport emissions.
- All modes of freight transport, including trucks, rail, pipeline, shipping, and air, have improved their energy efficiency. However, intermodal shifts to more energy-intensive trucking and air transport has meant very little change in the amount of energy used to haul a ton of freight from 1972 to 1995.
- Energy use and carbon emissions from non-personal vehicles is likely to surpass energy use and emissions from automobiles shortly after the millenium.
- Opportunities to reduce carbon emissions or energy use in commercial vehicle transport before 2010 will likely come mainly from trucking and air transport. Analysis of possibilities in a study by 5 DOE laboratories estimated that roughly 20-45MMT could be saved by new technolgies, increased use of cellulosic ethanol fuel, and improved traffic flows. About 10 MMT in reduced emissions come from trucking, 10-15 come from air transport, and 7-10 from rail. Beyond 2010, further significant reductions are possible through improved aerodynamics (laminar flow) and more efficient propulsion in aircraft, and in rail and trucking, major improvements could be made if hybrid/fuel cell powertrain technology can begin to capture more than a trivial share of the market.
- To achieve the savings in emissions by 2010 will require a more aggressive program of research and development in conventional powertrains and propulsion, as well as policies to encourage the use of new technologies and/or capital turnover. The same is true, but at significantly greater scales, of very low emission or zero emission technologies like fuel cell/fuel cell hybrid powertrains in rail and truck, and advanced laminar flow technologies in aircraft.

Background

The transportation sector, which includes both personal transportation (cars and light trucks, rail and air) and freight (heavy trucks, rail, aircraft, pipeline, and ships) accounts for almost 11 percent of U.S. GDP. The freight sector accounts for about a third of that.

Total emissions from freight and aircraft were just over 200 MMT, with heavy trucks and aircraft each accounting for about one-third of the total. Aircraft emissions account for all aviation, including freight, passengers, and military, with the lion's share of aviation carbon

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emissions coming from passenger travel. Air freight was estimated at 1% of all air transport in 1989, and while it is the fastest-growing mode of non-local freight transport, it probably only accounts for a few percent of all freight transport in 1997. The share of emissions due to freight alone is unavailable, as many commercial flights carry both passengers and freight.

The U.S. economy moves more ton-miles of freight every year, on every mode. All modes of non-local freight transportation increased between 1970 and 1994. Air freight increased the most (434%), followed by trucks (210%), rail (57%), pipeline (41%), and water (37%). Water, rail, and trucks are each responsible for about 25% of freight movement, measured in ton-miles.

Truck use for freight has increased dramatically in the last 15 years. Historically, rail has had an advantage in hauling heavier freight. In recent years, however, trucking loads have grown heavier; between 1982 and 1992, mileage traveled by trucks with operating weights above 80,000 lbs. increased 193%, and 120% for trucks below 33,000 lbs. The average length of haul increased from 224 miles in 1974 to 317 miles in 1994.

All modes have consistently improved their energy efficiency. Improvements have come from both technology and operational efficiencies. Between 1984 and 1994, heavy truck energy use per vehicle mile decreased 0.4% per year, and 1.6% annually per ton-mile. In rail, energy use per car-mile dropped 0.9% per year, and 2.7% annually per ton-mile.

Between increasing efficiency and the shift to more energy-intensive modes (trucks and air), the net energy effect is about a wash: if energy intensities of 1972 still prevailed, 1994 freight movements would have required about as much energy as was actually used in 1994 to haul more than three times the amount of freight.

Trends

According to Argonne National Laboratory, total energy use by non-personal vehicles is expected to surpass that of personal vehicles before 2005. Improvements in fuel efficiency improvement have slowed in personal vehicles, but continue in other modes of transport. In freight, the weight and cost of fuel carried has a direct effect on the amount of freight that can be carried, so there are incentives to improve fuel efficiency even when fossil fuel prices are low.

Trucks and aircraft are expected to continue as the fastest-growing forms of non personal transport, and will account for the greatest increases in emissions. The airline industry, since deregulation, operates close to maximum efficiency, and opportunities to use alternative fuels in aircraft are limited. Therefore most of the opportunities to reduce emissions from aircraft are in development and deployment of more fuel-efficient engine and airframe technology.

Reducing emissions from surface freight, on the other hand, is possible through both technological improvement and progress in reducing inefficient use of trucks (e.g. continued reduction in empty backhauls, more efficient routing, intrastate warehousing) and shifting from trucks to rail.

Results and Potential for Reducing Emissions

Neither DRI nor SGM include technological advances that affect emissions, or energy consumption, in the freight sector. DRI, in fact, assumes constant MPG for all heavy trucks through 2010, at just over 5 mpg, less than the average for heavy trucks now (approximately 6.8 mpg on-road).

Markal Macro includes several advanced technologies to improve the energy and carbon efficiency of freight. All three cases (base, stabilization with a rate of improvement in the use of energy as a share of GDP of 1.25%/year, and stabilization with an annual rate of improvement of 1.75 percent) bring in more fuel-efficient diesels, with faster rates of introduction in the 1.25 and 1.75 cases. In addition, both advanced technology cases phase out existing gasoline trucks, and penetration of trucks LPGfuel. The 1.75 case shows very rapid penetration of diesel trucks that are 20% more efficient than current diesel trucks, starting in 2010 and accounting for well over 95% of vehicle miles traveled by 2020. Fuel efficiency of heavy trucks increases to 6.9 mpg in the 1.25 case and 7.3 mpg in the 1.75 case of Markal Macro. Carbon emissions in 2010 are forecast to be nearly 98 MMT in the base case, 88 MMT in the 1.25 case and 18 MMT in the 1.75 case (see figure above).

Emissions from rail, freight, air freight and pipelines were specified exogenously for the IAT, since none has more than a marginal impact on energy use and carbon emissions as a whole. The forecast shows emissions from rail freight at 10.5 MMT in the base case, and 9.7 and 9.8 MMT, respectively, in the 1.25 and 1.75 cases. Emissions from shipping are reduced from 8.5 MMT currently to about 7.6-7 for all cases in 2010.

Technology Options: Trucks. There are many opportunities to improve energy efficiency and carbon dioxide emissions in freight. Improved aerodynamic design, advanced diesel engines, vehicle weight reduction through materials substitution, improved tires, and electronic engine and transmission controls can achieve fuel economy improvements ranging from 2 to over 20 percent in heavy trucks, as can advances in computational methods (hardware and software) aimed at understanding turbulence both for aerodynamics and within fuel chambers. More revolutionary technological advances, including the use of fuel cells in powertrains, are possible with an aggressive program to develop fuel cells for motor vehicles, along with the storage devices (batteries and ultracapacitors), fuel storage, and infrastructures supporting increased use of hydrogen fuel. With such a program, it might be possible to introduce hybrid fuel cell/electric powertrains into trucks before 2010, though significant market penetration is very unlikely by then.

Rail. Fuel cell/electric powertrains may be somewhat more likely to happen in locomotives than trucks, though significant market penetration of fuel cells in rail before 2010 is doubtful. The cost of fuel cell power is still prohibitive in rail, but with further development and expansion in the use of fuel cells for other applications (light duty motor vehicles and terrestrial power generation, e.g.) the economics may become more favorable. While widespread use of fuel cells for any kind of transport poses some significant infrastructural, maintenance, and technical problems, there has been significant progress in fuel cell and other hybrid powertrain technology over the past several years, with significant contributions from PNGV and NASA and DOD programs. With increased spending on hybrid powertrain development and the appropriate incentives to develop infrastructure and support for operation and maintenance, fuel cell applications may be possible, though at no significant scale, by 2010.

Technology Options: Aircraft. In aircraft, energy efficiency is a perennial concern primarily because reducing the weight of fuel is one way of reducing aerodynamic drag, a central and constant concern of aircraft and engine designers. NASA programs aimed at achieving greater fuel efficiency in engines were both technically and economically successful in the 1980s, improving the efficiency of existing engines as well as producing new, more efficient jet engine cores and components. NASA and industry (principally GE and Pratt and Whitney) also

produced advanced turbofan and unducted fan engines that achieve significant gains in energy efficiency, but have not been commercialized primarily because falling fossil fuel prices reduced the payoff to greater efficiency in the late 1980s; these engines, however, are still available and could be incorporated into aircraft designs with less expense and development expense than clean-sheet designs would entail should they become more attractive options in the future. Ongoing NASA/DOD/industry work on energy efficiency continues, under the Integrated High Performance Turbine Engine Technology program, aimed at achieving a 40 percent improvement in energy efficiency by 2003. NASA research on computational fluid dynamics and numerical simulation is also showing promise for modifying the skins of aircraft to include tiny, micron-thin riblets that could decrease turbulence, and thereby, drag, by 5 or 6 percent, increasing fuel efficiency and airlines' profit margins. It is quite likely that some of these improvements could show up on commercial aircraft before 2010, although full market penetration will take decades due to lengthy capital life.

Intermodal Switching. Intermodal shifting, or switching from truck to rail haul or air transport, has been underway for some time. Intermodal transportation of freight, or using both trucks and rail or aircraft, cuts emissions by relying on more energy-efficient modes (rail and air) rather than trucks for part of the trip. The Department of Transportation estimates in its 1996 annual transportation statistics report that intermodal freight hauls meant 1.5 million fewer large trucks on the highways. A simulation done in Markal Macro shows that diverting 10 percent of truck ton-miles of freight to rail could save 4.3 to 4.7 MMT of carbon. Whether such a shift would be operationally feasible is unknown. Markal Macro includes no cross-elasticities to optimize intermodal shifts, and while DRI docs, no shifts occurred in IAT runs of DRI's energy model.

Action

Overall, the IAT model runs could be described as technologically conservative in the freight area. Foreseeable technologies could make more significant reductions in emissions, particularly with more aggressive efforts to develop and diffuse the technologies. Programs to develop transportation technologies such as PNGV and NASA programs on energy efficiency and aerodynamics could probably bring these new technologies to proof of concept or demonstration before 2010, and several, particularly in truck componentry and efficiency, could be well established in the market. Energy experts at DOE's multiprogram laboratories point out, however, that current levels of funding for PNGV are probably inadequate to achieve the program's technical goals.

Technical success in research and development does not assure adoption or diffusion of new technology. Successful completion of the technical program of PNGV and NASA's engine and laminar flow programs must also be followed by investment in commercial development and marketing by industry in order to achieve market penetration. Moreover, capital in the freight sector tends to be turned over quite slowly; with maintenance and overhauls, trucks can last a couple of decades and locomotives and aircraft even longer. Incentives to hasten capital turnover, such as accelerated depreciation programs or investment tax credits, would also help to achieve stabilization. Finally, improving energy and carbon efficiency can also pay off in terms of improved competitiveness of efficient engines and powertrains on international markets.

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Market mechanisms can also reduce emissions while improving economic efficiency when prices are brought in line with true costs. Better pricing truck use of highways is justified considering that trucks probably do not pay their fair share for use of federally-funded highways, according to the Department of Transportation. Obliging trucks to pay a greater share of the cost of highway construction and maintenance would also be likely to increase incentives for intermodal switching, as would subsidizing rail transport or operating freight railroads.

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Industrial Emissions and Economic Impacts

Key Findings

- ◆ Based upon data from AEO97, the industrial sector now uses 37 percent of the nation's energy. It is responsible for 32 percent of the overall U.S. greenhouse gas emissions.
- ◆ The industrial sector has the potential to reduce energy use and carbon emissions by 10-15 percent over 2010 baseline forecasts through cost-effective investments in energy efficient technologies, and in some cases, low-carbon technologies.
- ◆ The annual investment necessary to achieve this level of carbon reduction is on the order of \$2.3 to \$3.8 billion per year through 2010. This is about 2-3 percent of the investments made by the manufacturing sector in 1995. Such investments should have only a small impact on the rate of capital stock turnover compared to a base case — accelerating the depreciation rate, for example, from a 30-year to a 29-year average life of equipment and structures.
- ◆ Many of the most successful technologies have multiple benefits, including environmental- or productivity-enhancing features. Since these new technologies tend to lower the overall cost of doing business, investments in energy efficient technologies may actually improve the competitive position of many industries.
- ◆ These energy savings and reduction in carbon emissions are unlikely to happen without policy measures driving the improvement in the industrial capital stock.

why haven't
they been
implemented
then?

Background

The industrial sector has made important strides in reducing overall energy intensity over the past 25 years. However, there are still readily-available but underutilized technologies with two and three-year paybacks that can reduce industrial energy use by 10 percent or more. The use of heat recovery and combined heat and power (i.e., cogeneration) systems, for example, can save 10 percent of energy use with an internal rate of return of 30-60 percent. Better maintenance of compressed air systems can save 40 percent of the energy used in such systems. And more energy-efficient motor systems can also provide a significant source of electricity savings.

Broadly speaking the industrial sector includes farming and ranching, agricultural services, fisheries, forestry, mining, construction and manufacturing. While many policy analysts think of "industry" as a homogenous set of economic activities, it embraces an incredibly diverse set of processes ranging from the growing and processing of food products to the production of paper, plastic resins, cars and computers. The process and energy requirements of each of the individual industries that are within the industrial sector are as different as the products that they produce. While many products have similar uses, the processes involved in making them may be vastly different. For example, plastic drink bottles, glass drink bottles, and aluminum cans all are similar products; however, they share almost no processes in common. For this reason, it is important to develop climate policies which reflect these important differences among the industrial sectors.

Based upon data from the Energy Information Administration, the industrial sector now uses 37 percent of the nation's energy, or 34.4 out of a total 93.6 quads. Carbon emissions are now at about 32 percent or total emissions in the United States, or 471 of 1467 MMT. With normal rates of capital stock turnover, the industrial energy intensity is expected to decline at a rate of 1.2 percent in base case forecast for the period 1997-2015 (*Annual Energy Outlook 1997*).

Key Industrial Indicators for 2010 and 2020														
Indicator	Market-Macro							DRI						
	1995	2010			2020			1995	2010			2020		
		Base Case	Case 2	Case 3	Base Case	Case 2	Case 3		Base Case	Case 2	Case 3	Base Case	Case 2	Case 3
Output (1995=1.000)	1.000	1.408	1.400	1.412	1.544	1.531	1.551	1.000						
Energy (Quads)	19.6	22.8	19.3	20.2	24.3	19	20.1	22.8	25	21.9	22.3	26.4	21.9	22.4
Emissions (MMT)	466	563	421	465	592	407	456	472	521	436	445	542	419	422
10-Year Rate of Annual Efficiency Improvement	n/a	1.1%	2.6%	1.7%	0.8%	1.5%	1.4%	n/a	1.5%	2.6%	2.7%	0.9%	1.5%	1.4%

John Thomas

US EPA

Energy and Transportation Sectors Division, OPPE

401 M St. SW Mailcode 2126

Washington, DC 20460

Fax Cover SheetDATE: July 7, 1997

TIME: 12:52 PM

TO: Tom Rhoads

PHONE: (202) 395-3114

FAX: (202) 395-6853

FROM: John Thomas

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RE: Current and Projected Import and Exports Shares

Number of pages including cover sheet: [12]

Message

Judi Greenwald requested that I send along the work I've done on industry impacts under a stabilization policy. I will also send these documents as attachments. The text is a narrative summary of the work I've done as part of the Inter-Agency Analysis group formerly headed by Ev Ehrlich. The charts are related to work I've been doing to analyze "potential vulnerability" in terms of trade. The charts summarize, (for energy producers and energy intensive industries), the current and projected percentage of US consumption that is filled by imports and the share of US output that is exported. I've also summarized these numbers for all industries at the two-digit SIC code level. Additionally, I've ranked all industries by the share of imports from non-annex I countries as a share of US consumption and US exports to non-annex I countries as a share of Total Output. This is probably the best number to consider as an indicator of "potential vulnerability" to changes in terms of trade with non-annex I countries. I've included a table summarizing the 25 industries for which trade with non-annex I countries are a large share of the industry's activity. I will work on some summary charts for the energy intensive industries showing these shares, and summarize the 2010 forecast. Please contact me if you have any questions or further requests.

Sincerely,

John Thomas

technologists claim this may be too conservative

ECONOMIC MODELING RESULTS FOR INDUSTRIES

The IAT used the DRI/McGraw-Hill Inter-Industry Model to analyze the impacts of climate policies on specific industries. The model calculates production, detailed inter-industry transactions and trade for 246 industries, using production and trade data from the DRI Macroeconomic Model and detailed projections of changes in efficiency and productivity over time.

Under the central stabilization case, direct emissions reductions in the industrial sector account for about one-fifth of total emission reductions – 19% (48 MMTC) in 2010 and 21% (70 MMTC) in 2020. Reductions in overall energy demand as well as improvements in industrial energy efficiency account for the reductions. Energy intensity across all industries initially declines at a rate of 3.25% per year vs. 1.5% in the base case and later slows to about 1.5 % per year vs. 1% in the base case.

One major area of concern is the effect of carbon constraints on the most highly energy-intensive industries – cement, aluminum, steel, pulp and paper mills, and the energy-intensive sectors of the chemicals industry¹ – who account for a relatively small portion of total output (2% to 3% of GDP)² but a relatively large portion (38%) of total industrial energy use. For these industries, whose products mainly serve as intermediate inputs to other manufacturing industries, energy accounts for as much as 30% to 40% of total production costs.³ As higher energy prices raise their costs, domestic energy-intensive producers might lose market share to competitors from non-Annex I countries under a climate treaty that affects Annex I but not Annex II countries.

The impact of climate stabilization policies on the energy-intensive industries may be very sensitive to how the policy is implemented.

- If emission permits are auctioned off and the revenues are used to reduce the budget deficit, the reduction in government borrowing will reduce real interest rates and, in turn, stimulate demand for consumer durables, new construction and business investment. Higher construction, investment, and durables demand, in turn, raises the demand for such energy-intensive goods as cement, aluminum, and steel. Pulp and paper products, energy-intensive chemicals and other energy intensive products more closely tied to non-durable consumer good consumption do not fair as well under this scenario.

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

The results from this analysis stand in contrast to other studies, (Sutherland, 1997) which tend to predict that carbon stabilization policies would severely impact U.S. energy-intensive industries

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and perhaps drive large portions of these industries overseas, with little net effect on global emissions. While a stabilization policy would certainly have an effect on energy-intensive industries, the most dire of these predictions almost certainly overstate the impacts of climate policies. Geographic and regional shifts in global energy-intensive production are inevitable even in the absence of climate policy. For instance, even in the baseline, emerging Asian countries' share of basic metals exports is expected to increase from 11% to 17% by the year 2010,⁴ and chemicals and plastics exports are forecast to increase from 13% to 19%.⁵

The *carbon emissions leakage* that would occur with a stabilization policy are quite small. *Carbon emissions leakage* is created by manufacturing or other emitting operations relocating to non-annex I countries and avoiding inclusion under the emissions cap. Even with higher permit values projected without international emissions trading, (\$95/ton C in 2010), the projected emissions from all increases in imports and decreases in exports amount to less than .7% of total industrial emissions, (3.4 MMTC).

The IAT analysis did account for changes in terms of trade for U.S. industries. non-Annex I producers (including China Mexico, Korea and Brazil), which currently account for about 40% of U.S. imports, would not be faced with energy price increases from a stabilization.⁶ Under such conditions, there would be an increase in imports from non-Annex-I countries and decreases of US exports to the world market. To reflect such changes in U.S. import and export shares the analysis took the following steps: **(these steps might also be referred to in texts and then footnoted)**

- 1) Based on the share of energy as an input to each sector, the percentage increase in cost of production was calculated
- 2) The production cost increases were then adjusted on the basis of the changes in wages, interest rates, and exchange rates occurring under the policy
- 3) The share of imports coming from and exports going to Annex I countries in each sector was adjusted to account for significant changes that would immediately occur under the policy (i.e. the share of cement imports to the U.S. from annex I countries, currently at 74.50% is reduced to 37.25%)
- 4) The non-annex I import and export shares for each sector from step 3) were then used with product specific elasticities to determine the relative shifts in imports and exports that would result from the price increases

Such an analysis could be a more conservative estimate of the actual changes that would occur under the policy. Cutting the Annex-I shares of US imports and exports by half immediately might overstate the shifts resulting from the policy. Additionally, the relatively rigid

⁴ Global Industry Review: A Semi-Annual Review of World Trade and Industry Trends for Major Countries and Regions, WEFA Group and ICF Kaiser International, First Quarter, 1997, v. 1 n. 1.

⁵ Ibid.

⁶ That is, since only 60% of U.S. imports are from Annex I countries, import prices were assumed to rise by 60% of the U.S. price increase across all sectors.

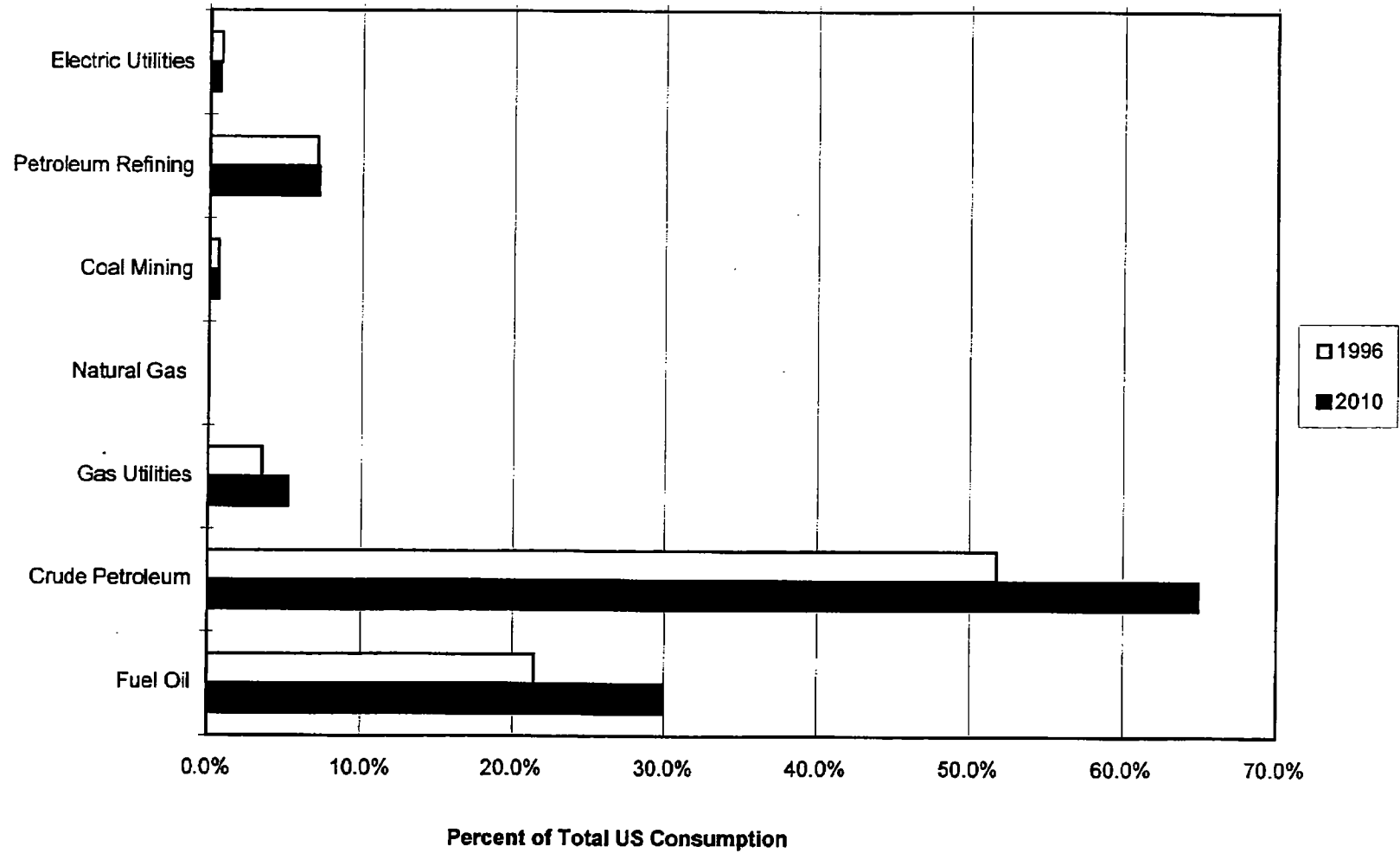
representation of substitution possibilities in production that characterizes the model may overstate the effect of energy price increases on production costs. In contrast to the DRI model, models that have a more detailed and flexible representation of production technologies (such as general equilibrium models) or that represent technological shifts (i.e. from integrated steel mills to electrometallurgical mini-mills or from primary aluminum to secondary aluminum) would yield lower estimates of production cost increases.

The potential for new, technologically advanced productive capacity in developing countries will also depend on the returns to new capital investment in these countries. Although foreign direct investment in non-Annex I nations has been increasing, it has done so slowly over time. Differences in returns to investments attributed to differences in capital market imperfections and differences in worker productivity would likely limit the rate at which new capacity is added and production is shifted from Annex I to non-Annex I countries.

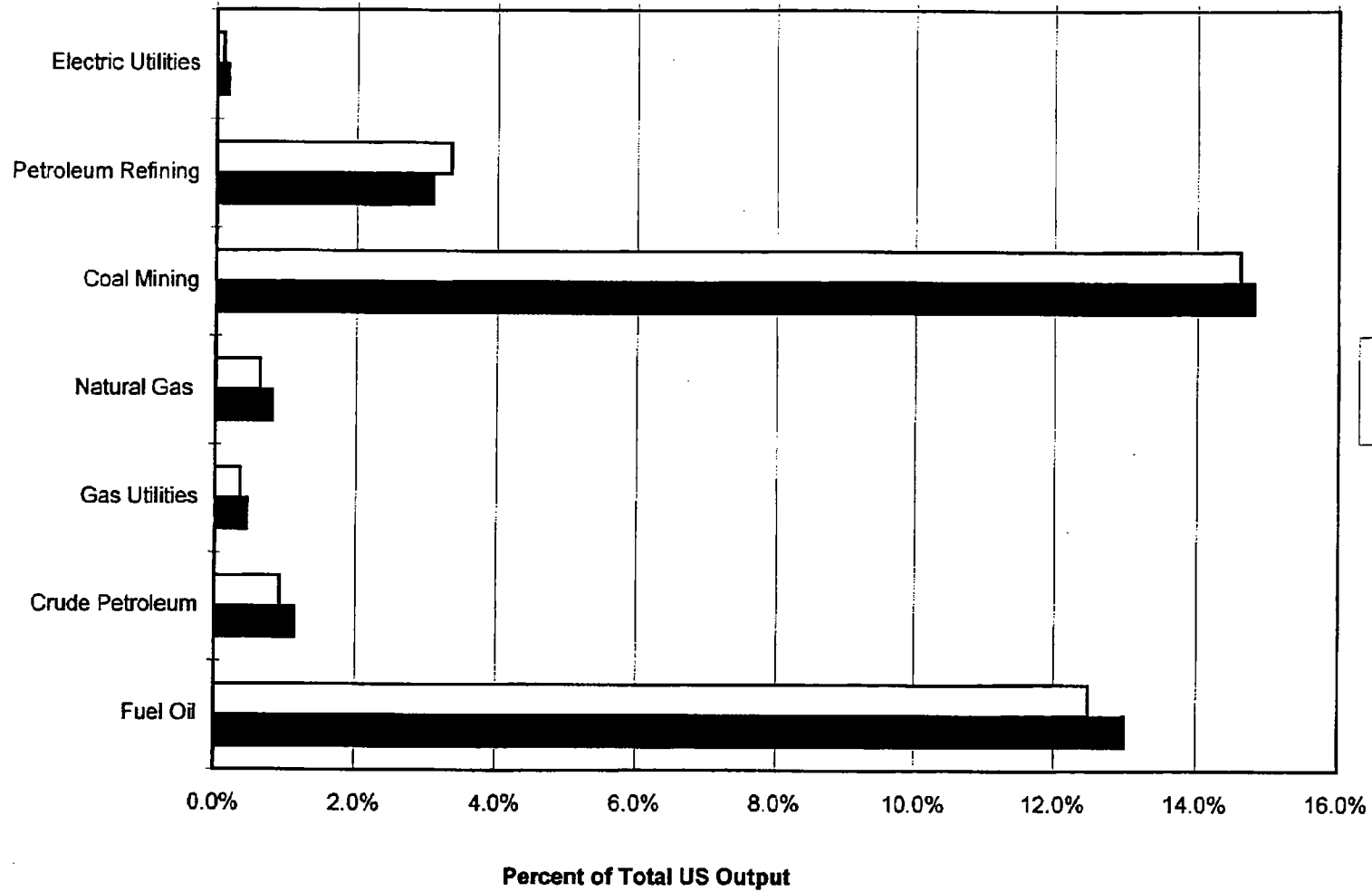
Industries with Significant Non-Annex I Trade Shares (1996)

Rank	SECTOR	Non-Annex I Imports		Non-Annex I Exports	
		as a % of		as a % of	
		Total Consumption	SECTOR	Total US Output	
1	RUBBER & PLASTICS FOOTWEAR	86.5%	MINING & OIL FIELD MACHINERY	56.1%	
2	OTHER LEATHER GOODS	63.0%	TANKS & TANK COMPONENT	43.8%	
3	LEATHER FOOTWEAR	62.6%	ELECTRON TUBES	43.2%	
4	HOUSEHOLD AUDIO & VIDEO EQUIP.	57.1%	TURBINES & TURB. GENERATING SETS	33.3%	
5	APPAREL FROM PURCHASED MATL	47.7%	SEMICONDUCTORS	30.3%	
6	KITCHEN POTTERY PRODUCTS	42.0%	AIRCRAFT & MISSILE PARTS & EQUIP,NE	28.0%	
7	JEWELRY & SILVERWARE	39.0%	MACHINE TOOLS, METAL FORMING	27.0%	
8	TOYS & SPORTING GOODS	38.3%	COTTON	26.9%	
9	CRUDE PETROLEUM	37.0%	MISC. ELECTRONIC COMPONENTS	25.4%	
10	WATCHES & CLOCKS	33.7%	RADIO & TV BROADCASTING & COMM EQ	25.0%	
11	SEMICONDUCTORS	33.1%	MISC GENERAL INDUS MACHINERY	23.2%	
12	COMPUTER PERIPHERAL EQUIPMENT	31.9%	AIRCRAFT	22.7%	
13	ELECTRONIC COMPUTERS	30.2%	CONSTRUCTION MACHINERY	21.4%	
14	COMMERCIAL FISHING	27.3%	MAGNETIC & OPTICAL RECORDING MEDI	21.2%	
15	MUSICAL INSTRS & PARTS	26.3%	MACHINE TOOLS, METAL CUTTING	21.1%	
16	BLOWERS & FANS	23.5%	ELECTRICITY MEASURING INSTR	19.6%	
17	MAGNETIC & OPTICAL RECORDING ME	22.6%	PUMPS & COMPRESSORS	17.7%	
18	FRESH, FROZEN & CANNED SEAFOOD	22.0%	PRINTING TRADES MACHINERY	17.6%	
19	CALCULATING & OTHER OFFICE MACH	21.8%	NONFER ROLLING & DRAWING,NEC	17.2%	
20	MOTORCYCLES, BICYCLES & PTS	20.8%	HOUSEHOLD AUDIO & VIDEO EQUIP.	16.8%	
21	ELECTRICAL EQUIP & SUPPLIES	20.1%	WATCHES & CLOCKS	16.3%	
22	SMALL HOUSEHOLD APPLIANCES	20.1%	ELECTRONIC COMPUTERS	16.2%	
23	MISC DURABLES & SEMIDURABLES	19.1%	KITCHEN POTTERY PRODUCTS	16.0%	
24	OPHTHALMIC GOODS	17.4%	MOTORS & GENERATORS	15.9%	
25	MISC. ELECTRONIC COMPONENTS	17.1%	OTHER SPECIAL INDUSTRY MACH. *	15.8%	

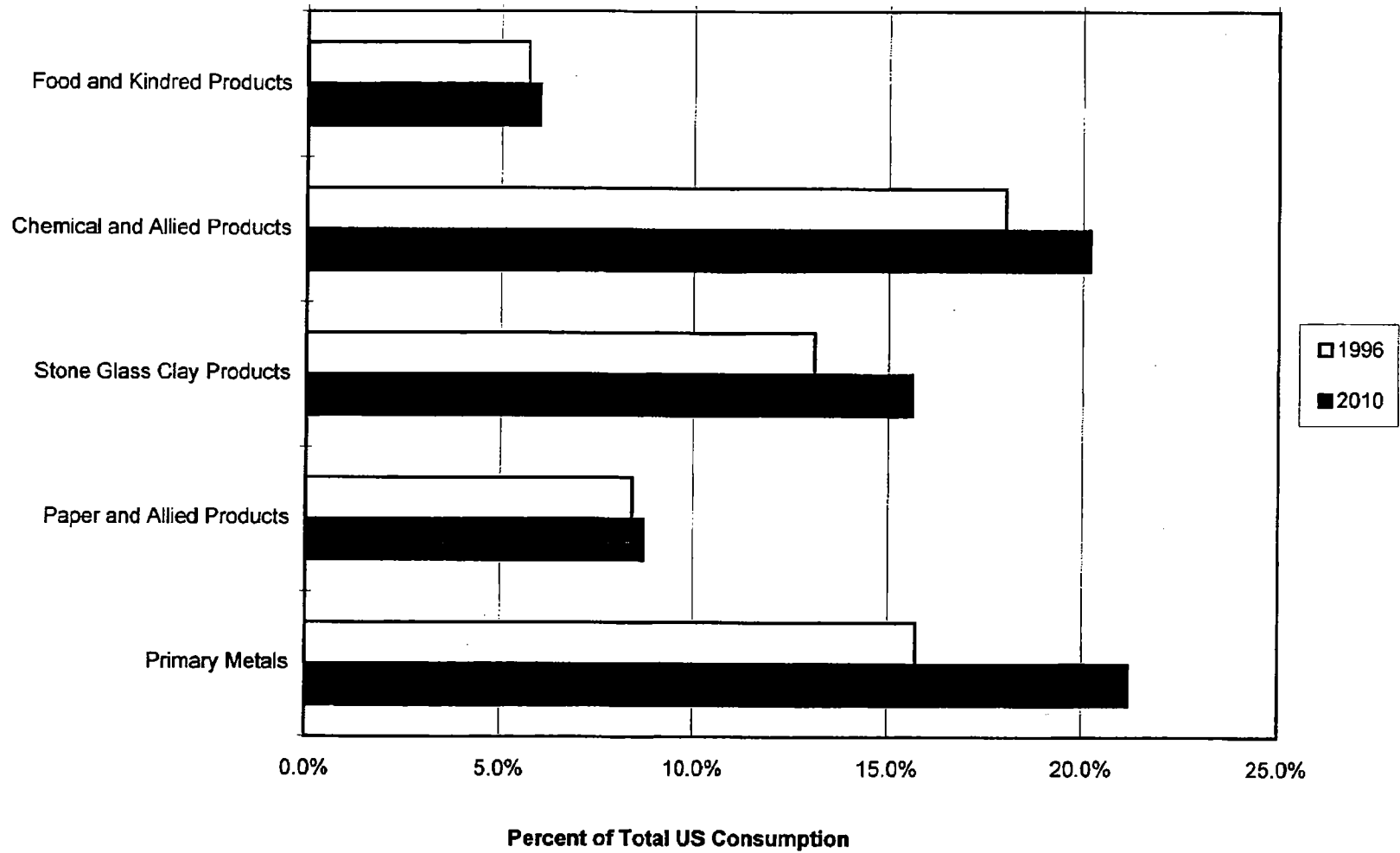
Energy Producer Imports



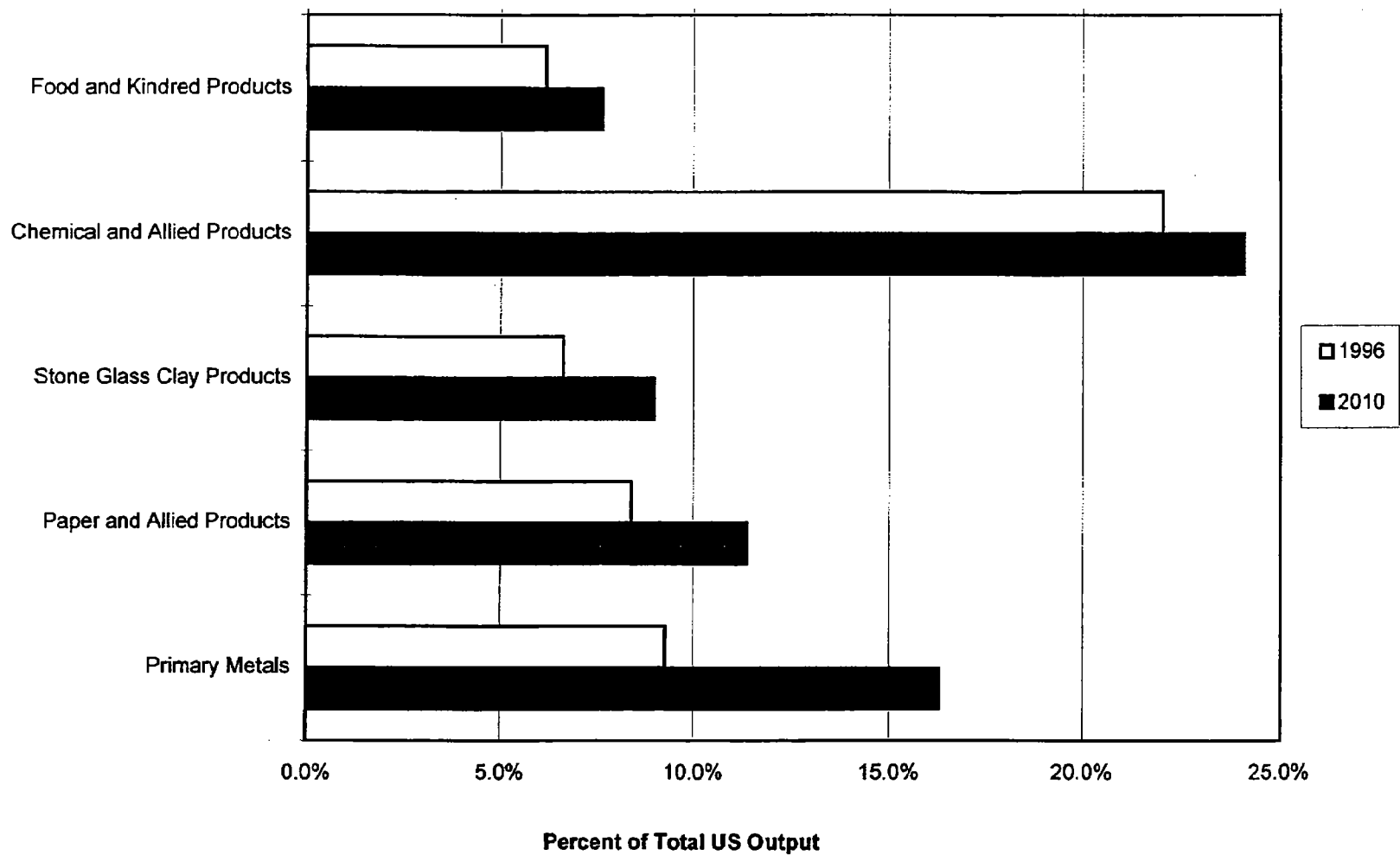
Energy Producer Exports



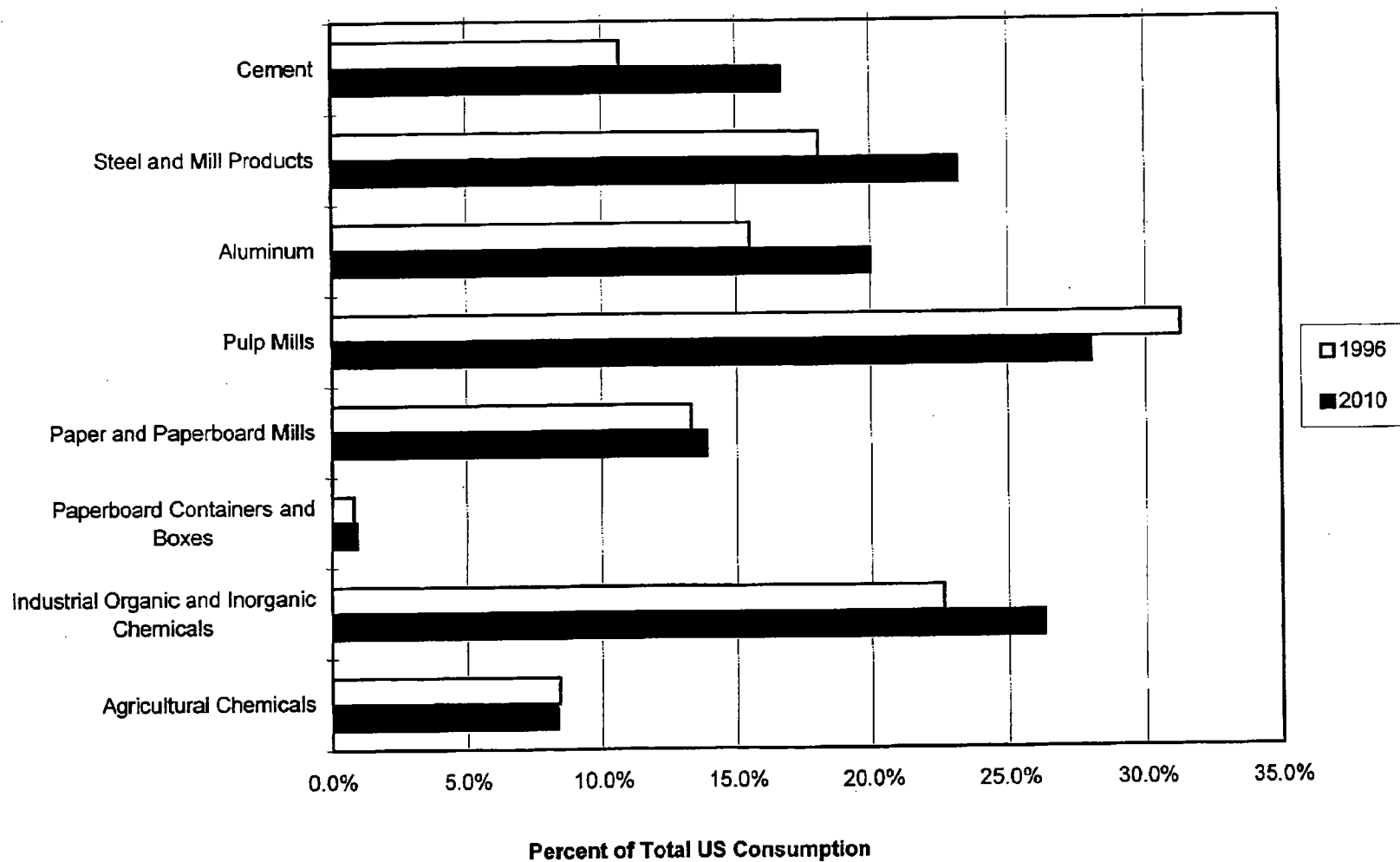
Energy Intensive Industry Imports



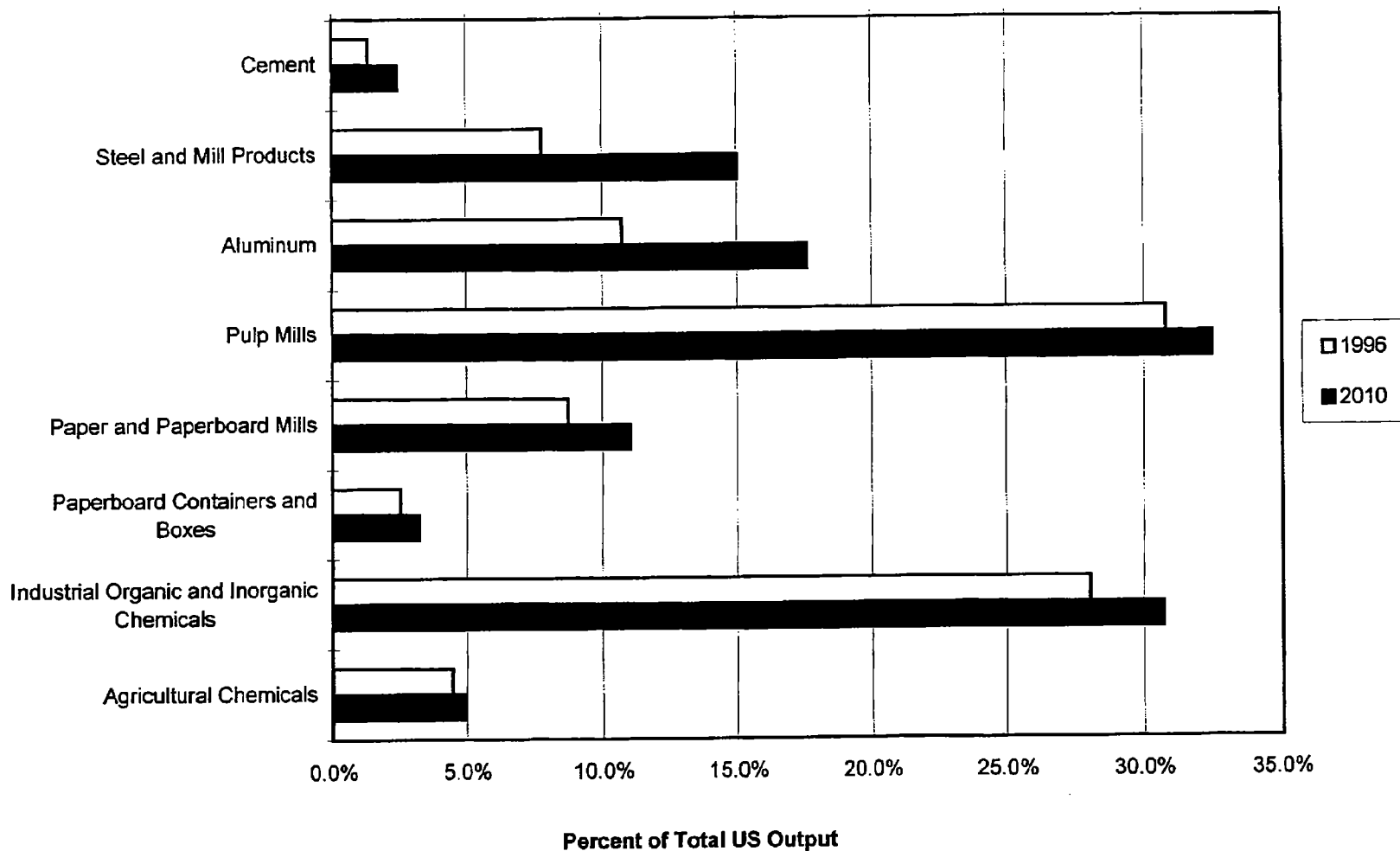
Energy Intensive Industry Exports



Detailed Energy Intensive Industry Imports



Detailed Energy Intensive Industry Exports



Summary of Import and Export Shares: 2 Digit SIC

	Imports as a % of Total US Consumption 1996	Exports as a % of Total US Output 1996	Imports as a % of Total US Consumption 2010	Exports as a % of Total US Output 2010
Agriculture Forestry and Fishing	4.8%	8.0%	5.0%	8.2%
Mining (excl. Fossil Fuel Extraction)	10.4%	11.2%	9.6%	13.0%
Mining (incl. Fossil Fuel Extraction)	27.4%	5.7%	33.0%	6.8%
Food and Kindred Products	5.7%	6.2%	6.0%	7.6%
Textile and Apparel	29.3%	9.0%	39.0%	16.0%
Lumber and Wood Products	11.2%	6.1%	11.5%	7.9%
Furniture and Fixtures	19.6%	5.8%	30.9%	11.7%
Paper and Allied Products	8.4%	8.4%	8.7%	11.4%
Printing and Publishing	1.5%	2.5%	2.0%	3.6%
Chemical and Allied Products	18.0%	22.0%	20.2%	24.1%
Plastics Materials and Resins	8.9%	18.4%	9.6%	22.9%
Petroleum and Coal Products	9.5%	5.6%	11.2%	5.7%
Rubber and Misc. Plastics Products	13.8%	7.0%	9.9%	7.0%
Leather and Leather Products	67.9%	17.5%	76.1%	28.4%
Stone Glass Clay Products	13.1%	6.6%	15.6%	9.0%
Primary Metals	15.7%	9.2%	21.2%	16.3%
Fabricated Metal Products	9.3%	7.3%	10.3%	11.1%
Industrial Machinery and Equipment	35.4%	31.3%	57.7%	47.6%
Electronic and Other Electrical Equipment	40.8%	33.6%	61.8%	52.4%
Transportation Equipment	25.6%	22.4%	26.4%	27.8%
Insturments and Related Equipment	24.0%	21.0%	28.8%	25.6%
Misc. Manufacturing Industries	41.6%	16.0%	52.5%	29.5%
Transportation Services	0.8%	13.6%	1.7%	20.1%

Transportation: Light Duty Vehicles and Carbon Emissions

Key Findings

- ❖ Based upon data from AEO97, the transportation sector will use about 25.4 quads of energy in 1997, about 27 percent of the nation's total energy requirements. Because of its almost total dependence on petroleum fuels (accounting for 97 percent of total energy use), the transportation sector is responsible for 34 percent of the overall U.S. greenhouse gas emissions.
- ❖ Light duty vehicles, including automobiles and light trucks, will account for about 58 percent of the nation's total transportation energy requirements in 1997. In contrast, freight trucks will use only 16 percent of the transportation energy in 1997. The remaining 25 percent of the transportation share will be used by air, rail and marine travel, pipeline fuels and lubricants.
- ❖ The transportation sector has the potential to reduce energy use and carbon emissions by 15-20 percent over 2010 baseline forecasts through cost-effective investments in energy efficient technologies, and in some cases, low-carbon technologies. The savings can be achieved without significantly affecting either comfort, safety or travel.
- ❖ The anticipated 2010 energy and carbon savings could be achieved in the case of automobiles, for example, if new car sales in that year achieve one-third of the fuel economy represented by the PNGV goal of 80 MPG.
- ❖ Assuming that PNGV cost goals are not met, and that the price of new vehicles in 2010 reflect current estimates of new technology costs, a 45 MPG car will cost between \$800 and \$1,200 more than a 28 MPG car (in 1995 dollars). Assuming 13,600 vehicle miles traveled for new vehicles and a gasoline price of \$1.23 in 2010 (also in 1995 dollars), this implies a roughly 3.5 to 5.3 year simple payback for a car that has an expected 14-year lifetime.

Background

After a roughly 15-year period (1975-1990) of energy efficiency improvements in the nation's vehicle fleet, energy use in the transportation sector now appears to be growing at nearly the same rate as the gross domestic product (GDP). In the case of light duty vehicles, the growth in energy consumption is driven by increases in the vehicle miles traveled (VMT), and the significant growth of light trucks (including vans, sport cars and recreational vehicles) which have a substantially smaller fuel economy. The sales of light trucks have grown from a 20 percent market share in 1975 to a 40-percent market share in 1994. Whereas new cars are rated at 28 MPG, light trucks enter the market with a rating of only 20.5 MPG.

Savings Potential

Despite the significant growth in energy use by light duty vehicles, the technology exists to increase the average fuel economy of the nation's transportation fleet by 40 percent or more in the year 2010 — without the need for reduced travel or increases in the cost of travel. This is true in both the movement of people and freight. This success would be achieved in the case of automobiles, for

example, if new car sales achieve one-third of the fuel economy represented by the Partnership for a New Generation Vehicle (PNGV) goal of 80 MPG.

Major technologies for near-term light duty vehicle improvements include, for example, material substitution, reduced aerodynamic drag, improved automatic transmissions, reduced engine friction, variable valve timing, and advanced tire designs. Many of these technologies have already emerged in the market, lacking only appropriate policy signals to accelerate their diffusion, or to redirect their use toward fuel economy instead of improving other vehicle attributes. Honda, as one example, employs a system of variable valve timing that is used to boost power and improve fuel economy. General Motors has one vehicle that has already achieved a low aerodynamic drag. On the other hand, lean-burn engines which increase engine thermal efficiency are a low-risk technology that should be readily available by 2010.

argues for
policy to
eliminate
barriers

Work developed for the "Car Talk" advisory committee¹ resulted in estimated reductions of both energy use and carbon emissions (measured in million metric tons of carbon, or mmMTc) through a variety of both technology and policy options. Summarized in the table below, and generally covering the period 2005 through 2025, the options include improved land-use planning, higher fuel prices, fuel economy standards and feebates, the PNGV vehicle, and the use of low life-cycle carbon fuels.

Modeling a different set of technology assumptions showed a significantly different set of results. DRI focused on largely behavioral response to reduce transportation energy consumption, while Markal-Macro had a larger technology bent. The table on the following page highlights these differences. (Note: the reference to CCAP is the so-called Case Two scenario which moved toward but did not necessarily hit a rate of decline in E/GDP of 1.25 percent. This compares to an assumed 1.00 percent decline in the base case. The Case two scenario includes both the full set of CCAP programs as well as "announcement effect." Case three, the Technology Case formerly described as the 1.75 Case, assumes a higher level of investment potential for cost-effective energy efficient/low-carbon technologies.)

In case two (with stabilization), DRI forecasts a 9 percent reduction in VMT with an 8 percent increase in MPG for new automobiles. DRI's case three (with stabilization) forecasts a 5 percent VMT reduction with a 10 percent increase in new car MPG. MM shows a seven percent drop in VMT for the CCAP scenario. This rebounds, however, to nearly base case levels with better assumptions about improved levels of technology. Although new cars in MM enter the market in 2010 with a high EPA-rated fuel economy (again, with about one-third of the improvements of the PNGV goal), the entire fleet of automobiles show an on-road MPG of only 30 MPG because of the time needed for fleet turnover. Hence, it is the on-road change in fleet fuel economy — moving from 24.2 to 30 MPG — that drives much of the transportation energy and carbon savings.

In the Markal-Macro assumptions, a new vehicle at 45 MPG would cost an estimated \$1,200 above new cars in the base case. The newly released *Energy Innovations* study suggests an added cost of about \$800 dollars (in 1995 dollars). However, owners of the new vehicles would save about \$225 per year in avoided gasoline costs (also in 1995 dollars, assuming an average driving range of

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

13,600 miles per vehicle and a cost of gasoline of \$1.23 per gallon). Simple payback for this technology improvement would range, therefore, from 3.5 to 5.3 years. In comparison, the average life of a new car would be about 14 years.

Car-Talk Summary Table of Policy Options²
(mmMTCe)

Policy Measure	Policy Type	2025 Annual Emission Reduction
Land Use and Transit Policy Package	Less VMT	25
Fuel Price Increases (\$0.50/gal.)	Less VMT	120
Parking Tax (\$2.00 nationwide)	Less VMT	25
Road Pricing	Less VMT	25
Fuel Economy Standards, "Feebates"	More Fuel Efficiency	90
PNGV	More Fuel Efficiency	60-200
Bio-Ethanol Subsidy	Low Emission Fuels	100
GHG Savings Needed to Return Personal Transport Emissions to 1990 Levels by 2020-2025		200-260

Key Automobile Indicators in 2010

	DRI			Markal-Macro		
	Base	CCAP	Technology	Base	CCAP	Technology
VMT	1526	1403	1450	1619	1509	1597
MPG New Car (EPA)	29.2	31.4	32	30.7	43.4	44.7
MPG Car Fleet (EPA)	24.7	26.5	30.6	29.3	32.7	35.7
MPG Car Fleet (On-Road)	23.3	24.5	26.9	24.4	27.3	30

2. Emission reductions may not be added since the impact of implementing multiple policies may be significantly less than is implied by adding up the individual estimates. However, the motor vehicle GHG model used to develop most of these estimates can be used to forecast the effect of multiple policies.

Electric Power

Key Findings:

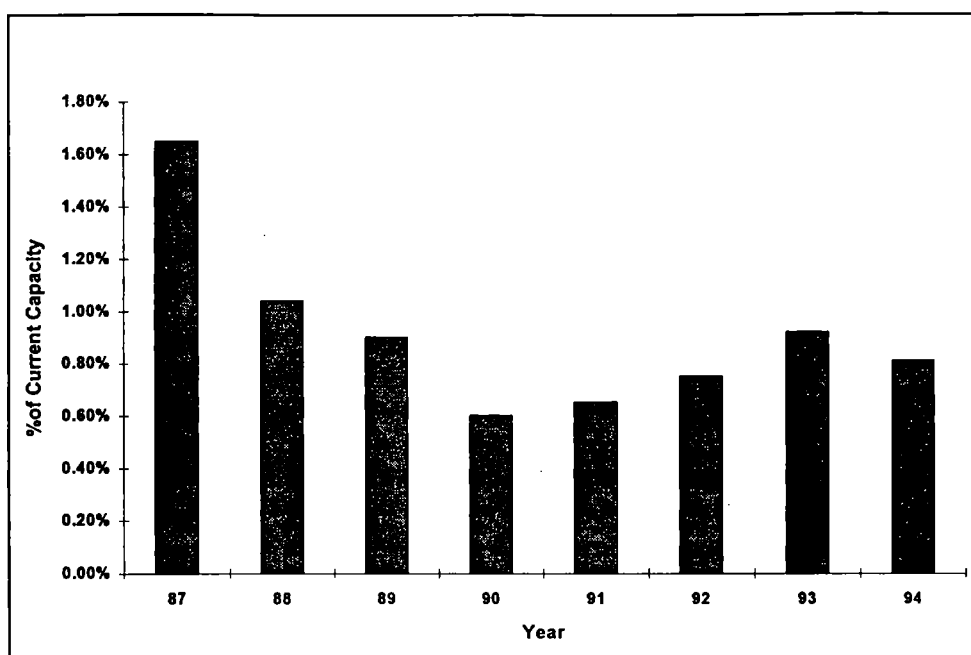
- Potential reductions from this sector are very large (250MT+) and will make up a substantial portion (25-50% or more) of the total needed to stabilize national emissions.
- If the capital stock of this industry continues to turn over at the rates seen in the last decade, it will take 1000 years to retire the existing stock of power plants. Changing the rate of retirement of existing plant would facilitate the transition to a lower carbon intensive power sector.
- Coal use will certainly decline and delivered power prices will increase if carbon use is constrained. The decline in coal use (both in the electric sector and nationally) will be from 25-60% under stabilization. According to the IAT, prices will rise by about 25%.
- Natural gas, demand-side efficiency and renewable power are the main means of reducing emissions. These options would compete with each other in a carbon-constrained economy. The outcome of this competition is uncertain: gas use could increase in this sector by 15- 50% depending on the relative economics of these options.
- Non-hydro renewables currently account for about 2.7% of the US power supply; even at fairly rapid rates of growth, these technologies will not constitute a large share of generation for some time. To be commercially viable, costs of renewable technologies need to decline from current levels of around \$0.05/kWh to perhaps \$0.03-0.035/kWh (in the absence of high fossil fuel prices).
- Competitive trends and air pollutant regulation will need to be integrated with climate policy.

Background

Electric power meets just over 30% of US energy demand. Electric power generation continues to grow in tandem with economic growth, unlike most other forms of energy consumption. Electric power sales of roughly \$200 billion represented 3% of US GDP in 1995. Despite advances in the efficiency of fuel use, US electric power supply maintains an historic reliance on coal and (increasingly) natural gas, leading to an upward GHG emissions trend that is expected to continue in the absence of climate policies.

The critical role of capital turnover is demonstrated by the near-absence of power plant retirements in the 1990s (See Figure 1 below). Access to new markets, regulatory uncertainty and regional conditions have all contributed to the slowdown of plant replacement, with planned 10-year retirement rates falling below 1% in 1989 and holding at low levels through the 1990s. This implies a 1,000-year period to turn the entire stock over once, an extraordinary (and presumably temporary) situation. Changing this trend is a key job for climate policy.

Fig. 1: 10-Year Plant Retirement Forecasts, 1989-1994



Coal will continue supplying more than half of the Nation's electric power through 2010. Coal consumption, of which 90% is in the electric sector, will reach 1 trillion tons in 1997, and by 2010 is expected to reach 1.1 trillion tons. Natural gas supplies 15% of US power, near its historic peak share, and is growing most rapidly today. Nuclear power, currently 20% of the US power supply -- an historic high -- will decline as plants age and face increased competition.

Most renewable power is currently hydroelectric, supplying 9% of US electricity. The potential for hydro expansion is limited. Non-hydro renewables currently account for about 2.7% of the US power supply. Even at fairly rapid rates of growth, these technologies will not constitute a large share of generation for some time. To be commercially viable, costs of renewable technologies need to decline from current levels of around \$0.05/kWh to perhaps \$0.03-0.035/kWh (in the absence of high fossil fuel prices).

Model Results and Potential for Reducing Emissions

This sector will be a key contributor to any GHG emissions reduction strategy. The IAT results show this sector reducing emissions by 20-33%. Because there are no direct emissions control technologies, achieving reductions relies on reducing demand or changing fuels. The rate of turnover in the capital stock becomes an important factor in determining both the means and the cost of GHG emissions control in the electric power sector.

The dominant emission reduction option is to use natural gas in place of coal, either through co-firing or repowering in existing coal units, or through increased use of new high-efficiency gas plants. Baseline (AEO97) coal capacity is forecast to increase from 315 GW in 1995 to about 330 GW in 2015 (including 40 GW of new plant and 25 GW of retirements) with virtually no coal-gas switching in existing plants. GHG policy will lead to less new coal capacity, more retirements, and some fuel switching at existing units. By 2015, coal *capacity* will fall to 275 GW, a drop of 55 GW or 15%. About 10-20 GW of coal-gas conversions are forecast, consistent with the Interlab study. Coal *use* (both in the electric sector and nationally) will decline by 25-60% if a stabilization target is met. Fuel use is affected more than installed capacity, because of resulting changes in dispatch.

Stabilization will result in very large additions of gas combined-cycle capacity -- up to 150 GW. Natural gas use is affected by several sectors and competing fuels and is very sensitive to assumptions. IAT

models project increased gas demand in the electric power sector of 15-50%, but this could be offset by declines in other sectors (some models indicate net declines in US natural gas demand under a GHG stabilization policy). Most models show a small increase (about 5%) for a limited period. If electricity demand is reduced through efficiency, however, all of these fuel impacts could be considerably lessened.

As part of a GHG emissions reduction strategy, generation from non-hydro renewables will increase. Some models indicate that wind and biomass may become cost-effective options as more emissions reductions are called for. For example, MARKAL-MACRO and DRI both indicate a 35% increase in non-hydro renewable use in 2010 under GHG stabilization. Models may understate the potential of renewables because they do not consider 'green power' demand from consumers, niche markets or dispersed power (small scale production scattered throughout the system).

Further electricity supply options include increasing the efficiency of existing fossil plants, and improving other parts of the power system (mainly the transmission grid) to minimize losses. Impacts on the industry are sensitive to demand responses. When end-use demand is lowered, fewer new high-efficiency natural gas power plants are built and less gas and renewable power is used. Coal use is relatively less affected. Overall costs in the utility sector are lower. Combining end-use efficiencies with new supply technologies yields the lowest cost estimates for achieving substantial emissions reductions in the power sector.

Physical responses are generally similar between models, but the estimated costs of reducing emissions vary. The cost of replacing power from an existing coal plant with a new natural gas plant may appear quite similar between models (see box), given assumptions for fuel and equipment costs in 2010. However, the modeled costs of reducing emissions are quite different. These differences mainly result from assumptions about capital replacement decisions and cost allocation. Other factors include some early coal-gas switching, and the potential natural gas price response. As a result, estimates of delivered (weighted average) electricity price impacts vary: +25% in DRI, +40% in NEMS.

Relationship to other trends

A carbon constraint will be introduced at the same time as a competitive restructuring of the industry and the implementation of the NAAQS. The combination of open power markets and market-based air regulation (i.e. a set of cap-and-trade systems for SO₂, NO_x and CO₂) will likely make climate-related policy incentives work faster and more effectively. At a minimum, there will be interactions between these changes which will alter the emissions profile of the sector.

For air regulations, early analysis using IPM and NEMS indicates that although new ozone and particulate matter rules will have a limited effect on CO₂ emissions (a reduction of approximately 5% from 2010 baselines), GHG limits could induce significant reductions in the criteria pollutants, on the order of 5-10% for SO₂ and 25-35% for NO_x.

Initial work on competitive power markets indicates that the ongoing restructuring of the power industry may have important effects. GHG emissions may increase in the near term (by perhaps 5-7% in the first ten years), due to increased sales by the cheapest coal units and higher demand. But competition may

Fuel switching cost analysis, costs in cents per kWh			
Assumes baseloaded units at 70% capacity factor,			
capital recovered over 30 years			
(levelized)			
Year=2010			
Non-fuel costs (capital plus O+M)			
	DRI	NEMS	IPM
Old coal	0.55	0.76	0.55
New gas	0.5	0.74	0.5
Fuel costs—without C tax (2010 baseline)			
	DRI	NEMS	IPM
Coal	0.89	1.14	0.72
Nat. gas	1.61	1.62	1.39
Total production costs—without C tax			
	DRI	NEMS	IPM
Old coal	1.44	1.9	1.27
New gas	2.11	2.36	1.89
Split	0.67	0.46	0.62
\$/ton C	54	31	50

prove helpful in the long run if new technologies can readily enter markets, and if market-based incentives are a part of climate policy. One great unknown is the potential demand for cleaner power on the part of consumers, who will have new information and choices.

Combining market-based environmental policy, consumer choice, and new technologies may offer greater efficiency and enable the power sector to provide electricity that is both cleaner and higher-value. The technologies and physical changes needed for large-scale GHG emissions reductions appear to be reasonably achievable, although the costs of reductions are less certain. Industry restructuring, air regulations, and climate policy can work together, if closely integrated to achieve the best fit.

The Carbon Reduction Potential in the U.S. Buildings Sector

July 8, 1997 Draft

Summary

Substantial reductions in greenhouse gas emissions are possible in residential and commercial buildings through greater use of cost-effective energy efficiency technologies that not only cut energy use, but also save consumers and businesses money. Estimated potential carbon emissions savings in the residential sector are 13-40 million metric tonnes (MMT) in 2010 and 30-70 in 2020. In the commercial sector, potential emissions savings are 13-40 million metric tonnes (MMT) in 2010 and 30-70 in 2020.

Background

Energy is used in buildings to provide a variety of services such as space heating and cooling, lighting and refrigeration and to power a broad array of appliances and equipment. U.S. buildings energy consumption accounts for nearly one third of total primary energy consumption and related greenhouse gas emissions. The 1996 bill for these energy services was over \$200 billion.

Energy intensity in buildings has declined substantially over the past twenty years. Energy use per square foot of commercial space declined by about 30% between 1979 and 1992, while residential energy use per square foot has dropped by 18% since 1978. Despite these past gains, the latest EIA business-as-usual forecasts project that commercial energy use in the future will decline by only 0.2% per year, and residential energy use by 0.5% per year. However, numerous studies (National Academy of Sciences, 1991 and Office of Technology Assessment, 1991, EMF-12, 1994) have indicated that a substantial potential remains for cost-effectively reducing U.S. energy consumption and greenhouse gas emissions - particularly in buildings.

Despite the large opportunity, there is clear evidence that many of the potential reductions are not being realized in the current market system because of a number of institutional, organizational, and other barriers that work against the diffusion of energy-efficient technologies. These barriers include lack of appropriate and reliable product information; split incentives between efficiency purchasers and those receiving benefits; lack of expertise for design, installation and operations; and low cost sources of capital.

Potential

Analysis results indicate that large reductions in future greenhouse gas emissions could be realized through the use of more energy-efficient technologies at a net reduction in the total cost of energy services in residential and commercial buildings. The table below shows the baseline EIA projections of primary energy consumption in a future without a global climate treaty, any market signals to reduce carbon emissions or substantial technological advances in these areas.

	1995	2010	2020 ¹
Residential total (quads)	10.5	11.9	13.8
Commercial total (quads)	7.1	8.1	8.9
Buildings total (quads)	17.6	20.0	22.7

¹ Market/Macro Base Case

The potential energy use reductions indicated by the IAT analysis are shown below. These results assume a binding international climate treaty leading to increased emphasis on U.S. carbon emissions reduction as well as federal and State policies to accelerate the use of existing cost-effective energy efficient buildings technologies.

	Market		DRI		Labs Study
	2010	2020	2010	2020	2010
Residential total (quads)	1.2-2.5	3.4	1.4-1.5	1.6-2.1	0.5-1.1
Commercial total (quads)	1.1-1.2	1.4	1.0-1.2	1.6-1.7	0.6-1.1
Buildings total (quads)	2.3-3.7	4.8	2.4-2.7	3.2-3.8	1.1-2.2

The IAT number translate into carbon savings of 26-33 MMT in 2010 and 35-44 MMT in 2020. A complementary bottom-up analysis is contained in the forthcoming study by five national laboratories, U.S. Carbon Reductions by 2010 and Beyond: The Potential of Energy Efficient and Low-Carbon Technologies. This study, which is a much more detailed sectoral analysis, indicates a lower overall energy savings potential, but a significantly higher electricity savings potential. As a result, estimated potential carbon emissions savings are 25-50 MMT. The major sources of reductions include residential miscellaneous uses, commercial other uses (such as office equipment), lighting and space conditioning. These investments are estimated to have a annualized cost of \$14-\$24 billion, but result in annual energy bill savings of \$33 billion.

While the IAT and the national laboratories study differ on the precise size of the potential for these three markets, they do agree that they are substantial. This suggests a need for additional technology development and deployment in these areas as part of a national climate strategy.

Implications

The IAT analysis results are rather difficult to place in context because of the top-down method of analysis. The National Laboratories study, however, is quite clear on what is required, as it is based on a technology-by-technology and end-use by end-use analysis. In order to achieve the lower end of the range, about 35% of buildings in 2010 need to be using existing cost-effective buildings technologies. The high end of the range requires 65% of buildings in 2010 to use such technologies. Efficiency gains could be higher, but would require lower technology capital costs than those assumed in the analysis. This range does not require premature retirement of capital stocks - only normal retirements of various equipment and currently expected renovation timing.

The key opportunities for efficiency gains in the residential sector include miscellaneous electrical appliances such as electronic equipment and small appliances, lighting, water heating, space heating, air conditioning and refrigeration. End-use energy savings in the top three areas are estimated to be 0.7, 0.2 and 0.3 quads, respectively. Overall, these results require the average energy efficiency of residential equipment in the affected buildings to improve by 12% over the next 13 years. The specific rates of improvement vary substantially among end uses - from 50% in lighting to 30% for miscellaneous electrical appliances to 12% for air conditioning to 10% for electric space heating. Building shells are assumed to become 4-14% more efficient. All these improvements are based on currently available technologies.

The opportunities for efficiency improvements in the commercial sector include miscellaneous electrical and natural gas uses (such as telecommunications equipment, medical equipment, pumps, light product assembly and many other activities not easily categorized), lighting, space heating and air conditioning. End-use energy savings in the top three areas are estimated to be 0.4, 0.4 and 0.3 quads, respectively. These results require the overall energy efficiency of commercial equipment in the affected buildings to improve by 18% over the next 13 years. The specific rates of improvement vary substantially among end uses - from 30% for miscellaneous electrical appliances to 25% for air conditioning to 20% for lighting to 20% for gas space heating. As in residential, all these improvements are based on currently available technologies. Thus these estimates appear plausible relative to the performance improvements, stock turnover and infrastructural

investments they imply.

The potential for energy efficiency gains in residential and commercial buildings is not limited by technology but rather by market barriers that impede the rapid market penetration of these cost-effective measures. The probability of realizing the potential savings estimated thus is largely dependent upon the effectiveness of policies in removing the barriers to these investments.

Actions

Realizing the potential savings above will require a proactive set of federal, state and local policies that accelerate technology deployment, energy efficient building design and construction and energy efficient building operations. This is critical because most of the carbon savings estimated above will result not from new technologies, but rather from increased market uptake of existing and near-term technologies. Maintaining carbon emissions stabilization or cutting emissions further will also require continued technology improvement. Federal agencies, State governments and many local organizations already conduct programs to move the buildings sector toward a lower carbon future. However, the challenge in implementing such policies is considerable since the industry is so fragmented - there are hundreds of thousands of builders, designers, suppliers and others. Some of the federal actions that will need to continue or begin include:

- working with state and local partnerships to improve efficiency of existing buildings through information, demonstrations, technical assistance (e.g., Rebuild America, Energy Star);
- facilitating the manufacture and purchase of high-efficiency equipment and appliances;
- working with the insurance companies, financial industries, utilities and other market intermediaries to remove barriers to investments in energy efficiency;
- Accelerated development of a portfolio of advanced buildings technologies - such as fuel cells in buildings, reflective surfaces and materials, and advanced windows.

The Role of Renewable Energy in a U.S. Climate Change Strategy

July 8, 1997 Draft

Summary

Renewable energy has substantial potential to reduce U.S. carbon emissions in the mid and long term. These technologies are significant options because they emit little or no carbon. While renewable energy technologies have typically been viewed by some as both costly and futuristic, rapid and steady declines in costs and improvements in performance have resulted in several of these technologies being competitive in selected markets today and the expectation that others will be competitive in broader markets in the near future. Estimated potential carbon savings from increased use of renewable electricity generation are 22-26 million metric tons (MMT) in 2010 and 50-85 in 2020.

Background

Renewable sources of energy are either continuously resupplied by the sun or they tap inexhaustible resources, such as geothermal energy. The use of modern renewable energy technologies to generate electricity either does not pollute or emits far less pollution than burning any fossil fuel. Most renewable energy technologies produce no greenhouse gas emissions at all during operation, and are responsible for only very small emissions during manufacture. Biomass fuels emit no net carbon on a life cycle basis--the amount of carbon released by biomass combustion is equal to the amount absorbed from the atmosphere during growth. Today, roughly 12% of the country's electricity generating capacity is based on renewable power systems. Over 85% of this generation is from hydropower - which has little potential for expansion. However, the remaining renewable technologies - including wind, biomass, photovoltaics, solar thermal and geothermal - are becoming increasingly economic and have large potential to expand and reduce greenhouse gas emissions in the mid to long term. Both wind and photovoltaics are experiencing a 20% cost reduction for every doubling of cumulative production. Photovoltaic cells, which convert sunlight into electricity, have dropped from 90 cents per kilowatt-hour in 1980 to under 20 cents today, while wind power has dropped from 25 cents per kWh to 5 cents. Cost reductions will continue to occur because of R&D advances such as thin film photovoltaics as well as manufacturing factors such as economies of scale and improvements in manufacturing processes that come with increased production. Several major international companies, most notably Royal/Dutch Shell, expect these technologies to be the dominant global source of energy by the middle of the next century and are beginning to make substantial investments in their development.

Two of these technologies - wind and biomass - could also play important roles by 2010. Wind is projected to have a levelized cost of energy of 2.6-3.2 cents per kilowatt-hour by 2005 - quite competitive even in a world without a climate treaty. Biomass has a large potential in two key markets: co-firing with coal and cogeneration of power and steam in industry. Incremental costs for co-firing for many sites are less than \$200/kW - making it a low cost low-carbon option. Industrial biomass gasification and high efficiency cogeneration have a large potential for emissions reductions - especially in the forest products industry, which has abundant biomass feedstocks. Geothermal energy also could play a significant role by 2010. Geothermal energy has a large potential in two markets - building space conditioning through geothermal heat pumps and electricity generation.

Potential

Analysis results indicate that renewable electric technologies have a large potential for reducing carbon emissions. The table below shows the baseline EIA projections for renewable electricity generation capacity as well as the results of the Markal Macro and DRI models. The EIA baseline assumes a future without a global climate treaty, any market signals to reduce carbon emissions or substantial technological advances in renewables. The IAT results assume increased focus on U.S. carbon reduction and a continuation of the current trend of improvements in the performance and costs of renewable electric technologies.

Does this include hydro

Renewable Energy Generation Capacity (GW)	1995	2010	2020
EIA AEO97 Base Case	9	14	26
Markal Macro	9	31-33	70-120
DRI	9	?	?

Note: 2020 EIA baseline estimates are extrapolated from 2015 projections.

These numbers translate into carbon savings of 15-16 MMT in 2010 and 35-60 MMT in 2020 - assuming that renewable energy technologies displace efficient gas generation. However, the IAT models have limited representation of utility and industrial cogeneration markets, so biomass capacity is likely underestimated. The forthcoming study by five national laboratories, U.S. Carbon Reductions by 2010 and Beyond: The Potential of Energy Efficient and Low-Carbon Technologies, offers a more detailed analysis of biomass. That study suggests a substantially higher potential for biomass co-firing with coal and greater potential for biomass gasification and cogeneration in industry. These numbers translate into additional carbon savings beyond the IAT Markal results of 7-10 MMT in 2010 and 15-25 MMT in 2020.

Implications

The analysis suggests that the contribution of renewable electric technologies in 2010 could be substantially higher than projected in the base case. However, the contribution of these technologies in 2010 (excluding hydroelectricity) is still expected to be less than 5% of U.S. generation capacity. However, in considering renewables, it is important to realize that they are in the midst of a major, long term transition from "advanced technologies" with only a peripheral market role to mainstream technologies that will be technologies of choice in the energy marketplace early in the next century. This is critically important, because in the long term, zero-carbon energy supply technologies will likely be the most important component in a national greenhouse gas emissions reduction strategy. The use of these technologies is also rapidly expanding in developing countries - particularly those without national utility systems. Development of the U.S. renewable industries is vital to any U.S. desire to be a major exporter of environmental technologies in the 21st century.

The pace and timing of the transition of renewable energy is difficult to project because of uncertainties in the rate of R&D progress, the evolution of restructuring and energy policies and consumer interest in "green energy". Four factors will tend to accelerate the use of renewable energy. First, restructuring of the electricity industry will make available more choices to consumers allowing consumers to choose electricity based not only on cost, but a variety of other factors including environmental impact. Second, it has been demonstrated in many areas that consumers are willing to pay a premium for "green power" - indicating that environmental choices presented by industry could be quite popular with consumers. Third, some energy policies at the State level are evolving in a direction that directly support renewable energy. For example, several States have already passed renewable energy portfolio standards and several more are considering similar actions. Finally, continued decreases in renewable energy costs - especially in the face of potentially rising costs of fossil fuels - will motivate additional investments in these technologies.

① + ② are the same. if ③ → ↑ pr then it will be the premium stated in (

The renewable energy projections imply a substantially higher growth rate in investments in renewable electric technologies than projected in the business as usual base case. In the base case, the overall growth rate is 3.5% per year through 2010 and over 6% per year between 2010 and 2020. In the IAT technology investment case, renewable electricity capacity grows 10% per year through 2010 and 8-14% per year between 2010 and 2020. The Markal model suggests that wind and biomass co-firing with coal will account for most of the renewable energy increase. The 2020 wind power projections are consistent with use of about 10% of total U.S. wind resource, so the only potential major constraint is one of wind turbine manufacturing capacity. The growth rates would require a major expansion of a small U.S. industry -

although wind turbines could be imported as well. For biomass co-firing, a net of 2.5-3.5% of coal electricity production is co-fired with biomass in 2010 and 4-8% is co-fired in 2020. That would require a maximum of 2-3 million acres of woody and herbaceous energy crops in 2010 and 5-10 million acres in 2020 - largely on marginal farmland - although substantial use of agricultural and forestry wastes could reduce these requirements

In reality, It is more likely that a portfolio of technologies would account for the projected increases in renewable energy. Wind and co-firing of biomass with coal are the likely lowest cost options by 2010, but geothermal power could also make a sizable contribution. By 2020, it is expected that a diversified portfolio of technologies would be used - including wind, biomass, geothermal, photovoltaics and solar thermal. These technologies would all be cost competitive in many areas - allowing power generation companies to select technologies that make best use of local resources and best match their power demands.

Actions

While electricity from fossil fuels continue to become cleaner and cheaper, expanded R&D and deployment could make a number of renewable technologies beyond wind competitive on purely economic grounds in the next 10 to 20 years: photovoltaics, biomass gasification, solar thermal, and geothermal. In a greenhouse-gas constrained world, these zero-carbon emitting sources of power would be even more competitive. The following actions could accelerate the use of these technologies by 2010 and make a large difference beyond 2010.

- expanded technology research and development to continue to lower costs and increase performance;
- expanded cost-shared technology deployment efforts with industry to increase utility system experience and increase U.S. production renewable energy production capacity - lowering costs still further; and
- promotion of U.S. renewable energy technologies abroad to tap the huge market for renewables in the developing world - enabling U.S. producers to further lower costs.

Testimony of the Honorable John D. Dingell
Senate Foreign Relations Committee
Subcommittee on International Economic Policy, Export and Trade Promotion

June 19, 1997

Mr. Chairman, I appreciate your holding this hearing. I consider it a great honor to testify beside my good friend and highly respected colleague from West Virginia, Senator Byrd.

I do not appear before this Subcommittee as a critic of the idea that we are engaged in climate change negotiations and that we are moving forward. I'm critical of the idea that we are negotiating without the full and proper information that we need.

With respect to the climate change negotiations, I have several questions to which I have yet to receive satisfactory answers.

JD One: Have we overreached on the science?

The State Department has concluded that current science proves that global warming is "dangerous" and requires immediate emissions reductions. But the official U.N. scientific body has gone only so far as to identify a link between human activity and warming, but their own document on the science states, and I quote, "our ability to quantify the human influence on global climate is currently limited." In other words, we don't know with any degree of precision how big the problem is, we don't know how fast it's moving, or how it can be mitigated.

My friend and former colleague Tim Wirth, who will testify later this morning, agrees on this point. At a public forum this February he said there is "no doubt about the *theory*" of climate change and that "we don't know where, how much or how fast."

JD Two: Is what we're seeing here a classic example of mission creep?

i.e.) CCAP
We've seen a shift from voluntary to mandatory policies. Initially, the Administration's policy was based on voluntary agreements with industry and reliance on "joint implementation" of mutually beneficial partnerships between U.S. industry and developing countries. For instance, U.S. companies would get credit for helping developing countries build clean power plants. But sometime early in 1996, the tone changed. Mandatory emissions reduction became the goal.

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3 Three: Who is representing America's interests? Are we setting ourselves up for an economic fiasco?

In a letter to me in 1995, President Clinton promised not to agree to anything which would adversely affect U.S. competitiveness. But the State Department has signed onto agreements that are procedurally and substantively disadvantageous. The outcome may be an agreement late in 1997 in Kyoto imposing mandatory emissions reductions on developed countries, and at best only voluntary steps for developing nations.

We've already committed ourselves to steps to control emissions and potentially harm our competitiveness. The developing countries are scot-free. We've gotten not a single, solid, binding commitment from them.

My friends in the Administration argue that they are being hard-nosed because they have rejected the more extreme proposals advanced by groups such as the Association of Small Island States, or AOSIS. But I find scant reason to congratulate our negotiators for refusing the chance to submit our unconditional surrender.

4 Four: Even if you agree that climate change is a problem, is the Administration really doing anything to protect the environment?

The theory of global warming holds that greenhouse gases have an effect no matter where in the world they are emitted. This is not like the debate over acid rain or ozone, where emissions from one part of the country were thought to cause problems in another, identifiable region. China will surpass us in terms of emissions early in the next century. If you accept the theory of global warming, those emissions will cause as much harm to the climate as emissions from the developed countries today.

5 Five: How is all this going to work?

I've yet to see a proposed negotiating text that includes specific dates and numbers. Those are important matters, but there are some other fundamental issues at hand: Who will have to do what? Who will enforce the agreement, and how timely would enforcement be? If we establish a trading system, is China or any other developing country going to be allowed to keep credits for themselves as a country? Or will companies be allowed to use them to offset operations elsewhere in the world? Does anyone seriously believe China, or any other country for that matter, will act on altruistic motives?

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* This leads me to my sixth and final question. Why are we doing this before we have the most basic information about how climate change policies will affect our economy? In short, has the Administration bothered to do its homework?

⇒ We were supposed to have the vaunted analysis and assessment of the impact of climate change policies on the U.S. economy by the end of last year. It has not been completed yet, despite repeated promises to Congress and industry that it would be available before important policy decisions are made. But the State Department formally proposed a cap-and-trade negotiating position in January. In short, the analysis is self-evidently too late to inform the process, and likely will be used to justify what the Administration has already decided to do. Just as clearly, public participation and comment on the analysis and assessment is irrelevant. And the Department of Commerce official in charge of the analysis and assessment has moved on to pursue other career opportunities.

I have asked the Administration whether, when they go to Kyoto next December, they will *refuse to sign* any agreement that binds the U.S. to new emissions obligations unless it holds our economic competitors in the developing world to equivalent obligations. I cannot in all truth say that I have received a reassuring answer.

My concerns very closely parallel those of American labor, and I am delighted that you will be hearing from Secretary-Treasurer Trumka of the AFL-CIO. I commend to you the resolution on climate change adopted by the AFL-CIO Executive Council, as well as the Senate resolution offered by Senator Byrd.

Let me close by noting again that I am not opposed to our being part of international negotiations on climate change. But I would approach those negotiations the way I would approach a high-stakes poker game: with an open mind, but not with a blank check.