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GCC [Global Climate Change] Sectors Paper

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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

CEA has the following concerns and editorial comments for Jeffrey Hunker's paper on the sectoral implications of climate change policy prepared for the Assistant Secretaries Group.

- 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 significantly 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”

will send to Hunker

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.

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White House Climate Change Task Force

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

*cc: AMW
JAF
JS
MM
JTR*

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.

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

FAX TRANSMITTAL # of pages **30**

To <i>Alicia Munnell call</i> JEFF FRANKEL	From VIRGINIA BORSEVSKA
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NGN 7540-01-317-7360 5099-101 GENERAL SERVICES ADMINISTRATION

** This fax will be transmitted in 2 parts
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

TABLE OF CONTENTS

Introduction 1

Sources of U.S. Greenhouse Gas Emissions 1

 U.S. Carbon Emissions by Fuel 1

 U.S. Carbon Emissions by End-Use Sector 2

Energy End-Use Sectors 2

The Buildings Sector 2

 Factors Shaping Industry Response 4

 Technology Options 4

 Barriers to Adoption 5

The Industrial Sector 5

 Trends in the Industrial Sector 6

 Economic Modeling Results for the Industrial Sector 7

 Factors Shaping Industry Response 8

 Aluminum 9

 Petroleum Refining 9

 Steel 10

 Chemicals 11

 Pulp and Paper 11

 Cement 12

 High-Growth Industries 12

 Non-Energy Minerals Industry 13

 Construction 13

 Motor Vehicle and Related Industries 13

 Barriers to Adoption 14

The Transportation Sector 15

 Trends in the Transportation Sector 15

 Contribution to Greenhouse Gas Emissions 15

 Factors Shaping Industry Response 15

 Technology Trends and Options 16

Agriculture 17

 Contribution to Greenhouse Gas Emissions 17

 Factors Shaping Industry Response 17

 Technology Trends and Options 18

Energy Supply Sectors 18

Electric Power Generation 18

 Contribution to Greenhouse Gas Emissions 19

 Factors Shaping Industry Response 20

 Restructuring 20

 Distributed Generation 21

 Technology Trends and Options 21

Petroleum 22

 Contribution to Greenhouse Gases 22

 Factors Shaping Industry Response 22

Coal 22

 Contribution to Greenhouse Gas Emissions 22

 Factors Shaping Industry Response 22

Nuclear Energy	23
Factors Shaping Industry Response	23
Natural Gas	24
Contribution to Greenhouse Gas Emissions	24
Factors Shaping Industry Response	24
Conclusion	25

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 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.

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.

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

	1997	Percentage of Total 1995 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

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 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.

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

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

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

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

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

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

The results 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.

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 allances” 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,” ACBEE/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. 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 N₂O 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 CO₂, CH₄, and N₂O 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 CO₂ emissions while rice and livestock production are the principle sources of CH₄ emissions.

Soil Carbon: Depletion or sequestration of soil carbon is a potentially important source of agricultural greenhouse gas emissions. Plants use photosynthesis to remove CO₂ 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 CO₂, 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 CO₂ 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 State's share of this is not addressed, the IPCC notes that the best mitigation opportunities are in areas with good agricultural land and surplus production.
- Further efforts to alter livestock management practices to reduce methane emissions: The most promising opportunities for reducing methane emissions in U.S. agriculture are in new management practices for the feeding of livestock and the handling of livestock waste (particularly cattle).

Energy Supply Sectors

Electric Power Generation

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

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

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

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

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

Renewable energy is forecast to have high growth but remain a small part of the base. Excluding hydroelectric power, whose expansion possibilities are very constrained, renewable electricity generation is expected to double over the next twenty years but will still account for less 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.

Table 6. Carbon Emissions from Electricity Generation (MMT)

	1997	Percentage of Total 1995 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 America Council for an Energy-Efficient Economy (ACEEE) show that there is a long-term potential to save about 25 percent of industrial electricity consumption at a cost that is significantly lower than the current cost of new generation units. For example, an industrial site which purchased coal-derived electricity generated at 35 percent efficiency could self-generate power in a cogeneration mode at 75-80 percent efficiency, selling power back to the grid and producing their own steam.

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

- The next generation of natural gas technologies (including gas turbines and fuel cells) are projected to achieve energy conversion efficiencies of 70 percent or more by 2005.
- High efficiency coal-fueled power plants, such as integrated gasification combined cycle, are likely to realize efficiencies exceeding 55 percent and half the 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.



White House Climate Change Task Force

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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.

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

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NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

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

*A Pre-Decisional Draft
Do Not Cite or Quote*

June 30, 1997

TABLE OF CONTENTS

Introduction	1
Sources of U.S. Greenhouse Gas Emissions	1
U.S. Carbon Emissions by Fuel	1
U.S. Carbon Emissions by End-Use Sector	2
Energy End-Use Sectors	2
The Buildings Sector	2
Factors Shaping Industry Response	4
Technology Options	4
Barriers to Adoption	5
The Industrial Sector	5
Trends in the Industrial Sector	6
Economic Modeling Results for the Industrial Sector	7
Factors Shaping Industry Response	8
Aluminum	9
Petroleum Refining	9
Steel	10
Chemicals	11
Pulp and Paper	11
Cement	12
High-Growth Industries	12
Non-Energy Minerals Industry	13
Construction	13
Motor Vehicle and Related Industries	13
Barriers to Adoption	14
The Transportation Sector	15
Trends in the Transportation Sector	15
Contribution to Greenhouse Gas Emissions	15
Factors Shaping Industry Response	15
Technology Trends and Options	16
Agriculture	17
Contribution to Greenhouse Gas Emissions	17
Factors Shaping Industry Response	17
Technology Trends and Options	18
Energy Supply Sectors	18
Electric Power Generation	18
Contribution to Greenhouse Gas Emissions	19
Factors Shaping Industry Response	20
Restructuring	20
Distributed Generation	21
Technology Trends and Options	21
Petroleum	22
Contribution to Greenhouse Gases	22
Factors Shaping Industry Response	22
Coal	22
Contribution to Greenhouse Gas Emissions	22
Factors Shaping Industry Response	22

Nuclear Energy	23
Factors Shaping Industry Response	23
Natural Gas	24
Contribution to Greenhouse Gas Emissions	24
Factors Shaping Industry Response	24
Conclusion	25

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 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.

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.

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

	1997	Percentage of Total 1995 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

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 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.

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

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

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

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

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

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

The results 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.

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. 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 N₂O 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 CO₂, CH₄, and N₂O 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 CO₂ emissions while rice and livestock production are the principle sources of CH₄ emissions.

Soil Carbon: Depletion or sequestration of soil carbon is a potentially important source of agricultural greenhouse gas emissions. Plants use photosynthesis to remove CO₂ 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 CO₂, 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 CO₂ 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 State's share of this is not addressed, the IPCC notes that the best mitigation opportunities are in areas with good agricultural land and surplus production.
- Further efforts to alter livestock management practices to reduce methane emissions: The most promising opportunities for reducing methane emissions in U.S. agriculture are in new management practices for the feeding of livestock and the handling of livestock waste (particularly cattle).

Energy Supply Sectors

Electric Power Generation

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

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

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

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

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

Renewable energy is forecast to have high growth but remain a small part of the base. Excluding hydroelectric power, whose expansion possibilities are very constrained, renewable electricity generation is expected to double over the next twenty years but will still account for less 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.

Table 6. Carbon Emissions from Electricity Generation (MMT)

	1997	Percentage of Total 1995 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 America Council for an Energy-Efficient Economy (ACEEE) show that there is a long-term potential to save about 25 percent of industrial electricity consumption at a cost that is significantly lower than the current cost of new generation units. For example, an industrial site which purchased coal-derived electricity generated at 35 percent efficiency could self-generate power in a cogeneration mode at 75-80 percent efficiency, selling power back to the grid and producing their own steam.

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

- The next generation of natural gas technologies (including gas turbines and fuel cells) are projected to achieve energy conversion efficiencies of 70 percent or more by 2005.
- High efficiency coal-fueled power plants, such as integrated gasification combined cycle, are likely to realize efficiencies exceeding 55 percent and half the 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.