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[Comments on Heinz Center's "Limiting Greenhouse Gas Emissions Through Emissions Trading: Interim Report"] [loose]

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To: Rosina Bierbaum

From: Jeffrey Frankel

Subject: Comments on the Heinz Center's "Limiting Greenhouse Gas Emissions Through Emissions Trading: Interim Report"

Thank you for the opportunity to review this draft report.

I am afraid we have some reservations. As you know, the Council of Economic Advisers has said from the beginning that we could implement the Kyoto agreement smart, or do it dumb. We and others have spelled out, for example in Janet Yellen's testimony, what precisely we mean by 'doing it smart.' The Heinz Center study, while well-intentioned, overlooks problems with options that -- to be blunt -- represent what we mean by 'doing it dumb.' Much of the report should not be seen as suggestive of actual policies we should adopt, but merely illustrative policy examples.

For a general discussion of international trading and other important elements of climate change policy, we might refer the writers to Chapter 5 of our recent Economic Report of the President, available electronically through GPO Access at <http://thorplus.lib.purdue.edu:8100/gpo/>. We have no comment on the report's extensive discussion of political factors in the design of the policies, but confine ourselves to the economic questions they present.

The Executive Summary states that the report presents four alternative control programs that can achieve the Kyoto targets reasonably cost effectively; yet no quantitative analysis of costs and benefits appears in the report. Neither does the report qualitatively compare the costs and benefits of different approaches, except by noting selective advantages and disadvantages of various approaches. Our expectation is that these options would have very different measures of cost effectiveness.

The report points out that the Kyoto Protocol requires international trading to be "supplemental" to domestic emissions reductions, and then arbitrarily estimates that the US will purchase 50 MMTCE abroad. We suggest that the amount of permits purchased international be treated parametrically. At the least, the report should examine alternative assumptions of the number of permits purchased abroad.

This paper relies on the results of analyses conducted in three studies: EPA/DRI, NEMS/DRI, and the 5-Labs report. We question whether the application of these analyses to the task of designing a domestic trading program is entirely appropriate. Relying on short-term macroeconomic forecasting models like DRI to project sector-specific required emissions reductions more than a decade in the future can be problematic. In review of the IAT report, Drs. Nordhaus and Jorgenson stated the following:

"This model [DRI] is especially appropriate for projecting the impacts of monetary and fiscal policy over a time horizon of

approximately two or three years. For longer term projections, however, it is highly inappropriate and has some important limitations that are well-known to the community of economic forecasters. For example, the DRI long term projections are extremely sensitive to assumptions about energy prices. This feature is totally at odds with most empirical work and with the practice of government agencies that produce such projections” (page 2 of April 24, 1997 letter to IAT).

The third study, the 5-Labs report, is an engineering study premised on unspecified hypothetical policies. Our view is that the estimates of a sector’s emissions reductions, based on unknown policies, should not be used as guidance in developing policies.

Further, this study’s omissions on several important issues (trading across gases and trading across time) and seemingly arbitrary assumptions on other important issues (emissions reductions through sinks, emissions reductions through international trading, emissions reductions through the Clean Development Mechanism), results in findings that would have relatively little value to policy makers, even if the methodology of applying macroeconomic and engineering modeling results were appropriate.

Box 2-2 compares tax and cap-and-trade approaches with regulations that would enforce efficiency standards. This analysis appears to misunderstand the cost-minimizing role of tradable permit systems, and to misunderstand economic costs associated with regulation. For example, the report incorrectly suggests that regulatory measures are less costly than price policies when price elasticities of demand for energy are low. The author inaccurately characterizes current literature on the adoption of energy conserving technology.

In perhaps its most important analytic omission, the report fails to mention the potentially very large economic costs associated with maintaining different marginal abatement costs across and within sectors and, similarly, the costs of efficiency standards relative to price signals. If the predictions of the models are used to try to set efficiently a sector-by-sector cap, two problems come up. First, the models could be wrong, and second, regulatory standards will not result in efficient emissions reductions within each sector. Only through trading across sectors will the marginal abatement costs be equalized and costs of meeting the target minimized. The claims that efficiency standards can lower costs are not well-supported.

The H. John Heinz III Center
for Science, Economics
and the Environment



**Limiting Greenhouse Gas Emissions
Through Emissions Trading:**

Interim Report

*A multi-sector, collaborative research project
convened by the H. John Heinz III Center for Science, Economics and the Environment*

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Research Collaborators:

Pat Atkins, Alcoa
Alex Cristofaro, Environmental Protection Agency
Dan Dudek, Environmental Defense Fund
Jae Edmonds, Battelle Laboratories
Joe Goffman, Environmental Defense Fund
Eric Haites, Margaree Consultants
David Hawkins, Natural Resources Defense Council
Gordon Hester, Electric Power Research Insititue
Peter Karpoff, Department of Energy
Nancy Kete, World Resources Institute
Daniel Lashof, Natural Resources Defense Council
Lester Lave, Carnegie-Mellon University
John Palmisano, Enron Corporation
Cliff Russell, Vanderbilt University
Paul Stolpman, Environmental Protection Agency

Heinz Center Staff and Consultants:

Alan Crane, Consultant
K. John Holmes, Fellow
Robert M. Friedman, Senior Fellow and Vice President for Research

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EXECUTIVE SUMMARY

Most of the world's industrial powers have agreed that the risks of global climate change are sufficiently great that significant actions to forestall it are warranted. If the United States ratifies the Kyoto Protocol to the Framework Convention on Climate Change, it will be committed to reducing emissions of greenhouse gases as part of this effort.

The United States also faces a set of *domestic* decisions that will have as great an impact on our people and the economy as the international decisions now being made. The Senate, which must ratify the Protocol, the U.S. business community, and many other groups are vitally interested in the details—and ramifications—of the domestic program that must be put in place to implement the emission limits set in Kyoto.

This report presents four alternative control programs, all of which can achieve the Kyoto targets reasonably cost effectively, but with very different characteristics and distributive effects. Emissions trading is a key component of all the alternatives that we present, but the details of implementation, and how trading will be combined with other policies to help lower emissions, differ. It is these differences that are central to the decisions that Congress must make, and which this report explores in detail.

Carbon dioxide is by far the most important of the greenhouse gases. Carbon dioxide is an inherent product of the combustion of fossil fuel (coal, petroleum, and natural gas.) Accounting for credits in the Kyoto Protocol for carbon storage in trees, the United States will have to reduce its emissions of carbon dioxide to a few percentage points below the level of 1990, or about 1300 million metric tons of carbon (MtC) on average within the period 2008 to 2012. Estimates of carbon emissions by 2010 without controls are typically in the range of 1690 to 1760 MtC. The target requires reducing projected emissions by about 25 percent unless substantial credits can be purchased from other countries at low cost. This report assumes that 50 MtC can be purchased, raising the U.S. domestic target to 1350 MtC, which is close to the 1990 emissions.

Reducing emissions will require reducing the use of fossil fuel, which now supplies over 70 percent of the nation's energy. Table 1 shows the emissions by sector in 1996. Total emissions must be reduced by about 8 percent below 1996 levels to comply with the Kyoto Protocol, even with 50 MtC purchased from abroad. The only means for reducing this high dependence on fossil fuel without causing great economic damage are:

- using fossil fuel more efficiently;
- replacing coal, which has a high carbon content, with natural gas, which releases less carbon dioxide for the same energy; and
- replacing fossil fuel with non-carbon fuels.

Table 1 - Carbon dioxide emissions by end use from direct combustion and electricity generation. Values are for 1996 and from *Emissions of Greenhouse Gases in the United States 1996* (U.S. Department of Energy, 1997).

	Direct emissions	Electricity emissions	Total	Percentage of total
Residential carbon dioxide emissions (MtC)	97 (6.6%)	190 (13%)	287	19.6%
Commercial carbon dioxide emissions (MtC)	74 (5.1%)	156 (10.7%)	230	15.7%
Industrial carbon dioxide emissions (MtC)	307 (21.0%)	170 (11.6%)	477	33.6%
Transportation carbon dioxide emissions (MtC)	468 (32.0%)	1 (0.1%)	469	32.1%
Total (MtC)	946 (64.7%)	(517) (35.3%)	1463	100%

Policies to instigate these changes must be based on an understanding of how energy is used and what factors will get users to change. Table 2 shows the reductions that are expected from each end-use sector according to three scenarios for emissions in 2010, as accounted for by each of the three means.

Improved energy efficiency is responsible for most of the reduction in Table 2. The economy is expected to grow substantially, but energy use drop, as happened after the energy crisis of 1973. Many technologies for improved efficiency are available that would be in the economic interests of the user, and many more are close. Energy efficiency improvements can significantly reduce the use of fossil fuel, but it is not clear by how much before the economic penalty becomes unacceptable, or what policies will be required to get energy consumers to make the appropriate decisions.

efficiency improvements
are uneconomic at
the prevailing prices

Table 2 - Carbon emissions reductions expressed as percent of *total* reductions, by sector and method, for year 2010. These reductions are the average of reductions derived from the High-efficiency, Low-carbon projection of the Interlaboratory Working Group and the EPA/DRI and NEMS models from the Interagency Analytical Team's analysis.

		low-C	non-C	efficiency	total
small sources	Residential <i>range</i>			8.0% 4-11%	8.0% 4-11%
	Commercial <i>range</i>			8.3% 8-9%	8.3% 8-9%
	Transportation <i>range</i>		1.1% 0-3%	19.5% 14-25%	20.5% 14-28%
large sources	Industry <i>range</i>		0.5% 0-2%	20.8% 14-32%	21.3% 14-32%
	Electricity <i>range</i>	22.4% 11-43%	19.2% 5-35%		41.9% 18-62%
All sources	Total <i>range</i>	22.4% 11-43%	20.8% 5-35%	56.5% 45-77%	100%

There is currently no mechanism in place for controlling emissions of carbon. Users are free to buy and burn as much fossil fuel as desired. Three types of policies to reduce GHGs are explored in this report. One is to restrict the entry of fossil fuels into the economy to levels that result in meeting the emissions goal. Fuel prices would rise, and users would find ways to use less. The second is to limit the amount of carbon emissions that large users—electric utilities and heavy industry—can produce. This method is similar to current controls for air pollutants such as sulfur dioxide. The third type is to impose strict efficiency standards on energy using equipment, such as automobiles and appliances. Such regulations could be used in conjunction with either of the first two types.

Trading of permits—whether for the sale of fuel, the emissions of carbon or even for regulatory standards—is an effective way of introducing flexibility into the control system. Under this approach, a company that can easily reduce emissions does so, then sells the rights to those emissions. A company that finds reductions expensive can buy permits instead. The emissions goal is met at lower cost than if both companies had to meet a fixed reduction under command-and-control regulation.

This report describes four alternative control systems, each of which includes trading:

- Option I is a hybrid system that “caps” (that is, limits) emissions from large combustors and controls smaller sources through emissions standards. The right to emit is allocated (directly given) to utilities and large industrial facilities who may use these rights themselves or sell them to others. Controls on vehicles would be tradable, with vehicle manufacturers bettering their standard able to generate permits to sell or bank and those unable to meet the standards required to obtain permits.
- Option II caps the amount of carbon in fossil fuel that can enter the economy by imposing limits^c on sales from energy producers and distributors. Coal producers, oil refineries, and natural gas pipelines are required to purchase and hold permits for the^{total}

carbon that they produce or transport. Permits are purchased either directly at an auction by the federal government or through resale. *grandfathering precluded?*

- Option III, like Option II, caps carbon on the supply or fuel side. However, unlike Option II, emissions permits would be allocated to both producers and *some* consumers of fossil fuels (i.e., large coal combustors.) Giving permits away to both coal extractors and combustors recognizes that these may be two groups most negatively affected by carbon controls. In addition, this option includes standards on manufacturers of energy consuming equipment. *Standards?*
- Option IV is a hybrid system similar to Option I. It expands the sources under the cap to include vehicles by including *total* future emissions from vehicles. Option IV also spreads the permit allocation among producers and combustors.

Each of the four proposed systems has its own particular advantages, having to do with its:

Cost minimization?

- compatibility with the current regulatory structure (Option I), *debatable no stat authority*
- ability to send carbon price signals through the economy (Options II and III), or *market trading?*
- recognition of political compromises needed to enact controls (Options III and IV). *why is this in here?*

Capping emissions from utilities and large industrial sources, as proposed in Option I, is similar to acid rain controls. The standards that apply to other CO₂ sources under this option are similar to efficiency standards currently in existence for light duty vehicles and some appliances. This compatibility with the current regulatory structure will ease implementation. *would*

Many consider market-based approaches to be the most economically efficient approach to pollution control. Option II is the only alternative that relies *solely* on price signals to induce emissions reductions.

Any emissions reduction program will have relative “winners and losers.” Options III and IV attempt to use the allocation of permits to partially compensate those hurt most by the change in policy.

Table 3 displays the basic design differences among the options. One difference among them is whether they cap carbon sold by fuel producers (Options II and III) or they cap CO₂ emissions from large combustors and control more diffuse emissions sources with standards (Options I and IV). A second difference is whether they are relatively simple designs (Options I and II) or whether they reflect the types of compromises that typically could emerge from the political process (Options III and IV).

Table 3 - Overview of control options comparing them in terms of their primary control mechanism and level of complexity.		
	Economy-wide fuel carbon cap and trade <i>Reliance on price signals (fuel and electricity)</i>	Partial emissions cap; Product standards for small sources (some tradable) <i>Electricity price signals, standards</i>
Relatively simple designs	<i>Option II</i>	<i>Option I</i>
Political compromise designs	<i>Option III</i>	<i>Option IV</i>

Table 4 shows the largest categories of emissions and how the emitters are affected by the control designs. Under Option I, over 50% of current emissions would be covered under the cap, with most of the remainder of emissions captured under standards on manufacturers of energy-consuming equipment (manufacturers of vehicles, furnaces, air conditioners, and hot water heaters). Option II is an economy-wide cap on carbon, creating a price signal to all emissions sources, inducing them to either reduce

consumption of fossil fuels or switch to fuels with a lower carbon content. Under Option III, most emissions sources see both a price signal from energy suppliers as well as emissions standards on manufacturers of energy-consuming equipment. Option IV differs from Option I mainly in the more rigorous cap on the transportation sector.

This interim report includes three chapters. The first presents background information on the Kyoto Protocol and the general paths the United States could follow to comply with it. Chapter 2 discusses the U.S. energy system, what has to be done to reduce emissions to the specified levels, and who has to take action to do so. Chapter 3 presents descriptions and preliminary analyses of the four control policy approaches sketched briefly above. The final report will analyze these control policies in greater detail.

Table 4 - Comparison of control strategies on emissions sources for the alternative emissions trading designs. The term *cap* indicates emissions are directly capped; the term *price* indicates price increases due to a cap on either fuel carbon or carbon emissions. Efficiency standards are not tradable, unless marked otherwise. "*Cap*" (in quotes) indicates a tradable standard that caps emissions potential.

		Option I		Option II		Option III		Option IV	
	% of emissions	Cap and trade	Efficiency standards	Cap and trade	Efficiency standards	Cap and trade	Efficiency standards	Cap and trade	Efficiency standards
utility	40.4%	cap	indirect effect	price		price	indirect effect	cap	indirect effect
large manufacturing combustion	11.7%	cap	minor	price		price	minor	cap	minor
small manufacturing combustion	1.2%		minor	price		price	minor		minor
manufacturing electricity use	16.1%	price	minor	price		price	minor	price	minor
non-manufacturing industrial	6.6%	price (partial)	transport. Standards	price		price	transport. Standards	price (partial)	transport. standards
space heat and cooling (fuel and electricity)	13.1%	price (partial)	most	price		price	most	price (partial)	most
lighting	6.5%	price	partial	price		price	partial	price	partial
appliances	15.0%	price	partial	price		price	partial	price	partial
cars and trucks	24.9%		tradable standards	price		price	fixed	"cap"	"cap"
other transport	7.4%		partial	price		price	partial		partial

CHAPTER 1

INTRODUCTION

There is a growing scientific consensus that global climate change, induced by emissions of carbon dioxide and other greenhouse gases, poses significant risks. Changes in rainfall patterns, rising temperatures, inundation of coastal areas from rising oceans, and other phenomena could have major impact on people and the economy. While uncertainties still exist over the rate and exact nature of global climate change, many world leaders have concluded that the risks are too high to ignore.

These views led 159 nations to send representatives to a meeting in Kyoto, Japan in December 1997 to determine the Protocol to the Framework Convention on Climate Change, established in 1992. If ratified by the U.S. Congress and at least 54 other nations, the Kyoto Protocol will commit the United States to reducing its emissions of greenhouse gases to a level 7 percent below those of 1990. The key terms are summarized in Box 1-1. It is essential for Congress and others to understand in detail how the Nation could reduce emissions and how much it will cost prior to consideration of the treaty.

If the United States is to reduce emissions of greenhouse gases, the main focus will be on carbon dioxide (CO₂) from fossil fuel combustion. CO₂ is the major anthropogenic greenhouse gas, accounting for about 85 percent of all such current emissions. U.S. emissions have increased from 1374 million metric tons of carbon (MtC) in 1990 to an estimated 1496 MtC in 1996. Over 98 percent of these emissions come from the combustion of fossil fuel.

CO₂ is an inherent product of the combustion of fossil fuel, specifically coal, petroleum, and natural gas. There is, as of now, no practical way to directly trap and sequester emissions of CO₂ or to modify their nature to render them harmless. Thus the means now typically practiced to reduce the environmental impact of conventional air pollutants will not work with CO₂.

be available for in the 1st commitment period.

Box 1-1
The Kyoto Protocol

The Kyoto Conference resulted in a Protocol, adopted by 39 nations, including all the major industrial economies. The Protocol established many of the conditions under which emissions of greenhouse gases are to be reduced. The key points affecting the United States are in Articles 3 (establishing the targets), 6 (joint implementation among Annex I nations), 12 (joint implementation with non-Annex I nations), and 17 (initially 16 bis, on trading among Annex I countries).

Article 3 sets limits for the aggregate emissions of 6 greenhouse gases specific for each party (7 percent below 1990 emissions for the United States on average in the 5 years 2008 through 2012); requires demonstrable progress by 2005; accounts for carbon storage (positive or negative) in forests and land; allows for trading among parties to the Protocol; and allows for banking of credits if emissions goals are exceeded during a commitment period.

Article 6 elaborates on the emission reduction units that can be acquired from other Annex I parties, specifies that these reductions are to be **supplemental** to domestic actions, and defers full guidelines to a later conference.

Article 12 establishes a "clean development mechanism" for transferring credits from emission reductions in non-Annex I nations.

Article 17 states that the Conference of the Parties shall implement rules for trading among Annex I countries, and that such trading will be supplemental to domestic actions.

However, the Conference also left many uncertainties. In particular, the Kyoto Protocol is unclear on the meaning of "supplemental". That term could be interpreted as almost any fraction of the total reduction required, though the authors probably meant a fairly low level. Total carbon equivalent emissions of the six greenhouse gases in 1990 were 1618 million metric tons (MtC), so the target is 1537 MtC. Emissions in 2000 probably will be about 1850 MtC, requiring actual reduction of over 300 MtC. If supplemental is defined in terms of a fraction of the total cap, every percentage point amounts to about 15 MtC, which is 5 percent of the reduction required. Thus if 10 percent of the cap could be obtained from abroad, the United States would have to reduce its own emissions by half the assigned reduction. Hence the definition will be very important.

In addition, because the Protocol does not explicitly allow domestic reductions prior to 2008 to offset post-2008 emissions, the use of early credits to initiate action will be politically difficult. ~~Nevertheless, early credits may be essential for a smooth and affordable transition to the emission target.~~

to be determined

misleading
Departures from baseline
reduce future reg's.

Fossil fuel currently supplies over 70 percent of all the energy used in the United States. For every American, the economy annually uses almost 4 tons of coal (mostly to generate electricity), 1000 gallons of oil, and 90,000 cubic feet of natural gas. Supplies now for all three fuels are plentiful and inexpensive, and that is likely to continue to be the case for the next two decades, with the possible exception of temporary disruptions of petroleum imports. Consumption is rising steadily. Reducing the amount of fossil fuel consumed in this country means reversing a century-long trend that was interrupted only during the energy crises of the 1970's.

The energy crises caused extensive damage to the economy. Replicating that damage deliberately to reduce carbon emissions is not a plausible option. The problem now is how to reduce carbon emissions from fossil fuel use with little or no damage to the economy. There are three general technical options:

- use fossil fuel more efficiently;
- replace coal, which has a very high carbon content, with natural gas, which releases much less CO₂ per unit energy; and
- replace fossil fuels with energy sources with no net emissions of CO₂;

Carbon emissions will continue to increase with economic growth unless government policies are enacted to implement these three general technical options. It is relatively straightforward to specify what physically must happen to reduce emissions to any given target such as the one agreed to at Kyoto. The problem, as noted above, is to motivate energy users to make the decisions that will move the country along an economical trajectory. Furthermore, estimates of the costs involved in meeting such a target range from net positive benefits (because of reduced energy purchases) to a reduction of several percent of the gross national product (because of energy constraints and disruptions).

← reduce other
GHG's
sinks

There is currently no mechanism in place for controlling emissions of carbon. Any user is free to buy and burn as much fossil fuel as desired. Meeting a target will require price increases, restrictions on emissions, regulations, incentives, or--quite likely--some combination of approaches. However controls are applied, energy patterns will change for users and producers. Energy is a vital part of the economy, and it will be critical to minimize costs and disruption. Policies aimed at electric utilities or manufacturers may be entirely inappropriate for individual consumers. Policies for improving the efficiency of automobiles may be very different from those for improving the efficiency of buildings. Different policies will also encounter varying levels of opposition.

Various strategies have been proposed. The simplest one conceptually would be a tax on fossil fuel based on the carbon content. Make the cost high enough and people will use less energy, as shown in the 1970s. However, as appealing as this proposal may be from an economist's perspective, it could be painful for many people, especially those least capable of absorbing the additional cost. It also could hurt the country's international competitiveness. The level of tax required to meet a given target is uncertain, and *any* new tax probably would be unpopular. For these reasons, the political acceptability of high energy taxes is dubious.

relative to what?
costs of standards?

An approach to control that gets around some of these problems is to limit the amount of fossil fuel that can be introduced into the economy. Producers and importers could be allowed to market fossil fuels only up to the point where carbon emissions would meet the target. Alternatively, large consumers such as utilities and industry might be required to have permits to burn fuel, while energy efficiency standards could be applied to vehicles, appliances, and other large end-uses of energy. Permits could be traded among users for economic optimization, as discussed later in this report.

The energy system is complex, and whatever form of regulation is applied, economic efficiency will be best served if maximum flexibility is built into the system. Permit trading is an effective way of introducing flexibility. Under this approach, companies

that can easily reduce emissions do so, then sell the rights to those emissions to others that find it cheaper to buy permits than to make the necessary reductions themselves. Total emissions are the same as if each company made the same reduction, but both sets of companies are better off financially. Trading schemes can also reward early actions if the implementer can receive credit for such actions either for sale or use in later years. Meeting a target such as that agreed to at Kyoto will require starting almost immediately. The existing infrastructure to produce and consume energy is massive. Changes of any significance take many years to implement. Encouraging actions to reduce emissions before the control system is implemented is essential.

*Such as through
price signals & expectations.*

Emissions trading systems have been used for other pollutants with generally good results, including sulfur dioxide, lead in gasoline, and chlorofluorocarbons (CFCs). However, experience with such trading is quite limited, and none of the other programs approaches the magnitude and complexity of controlling emissions of CO₂.

Control and trading for carbon emission rights could vastly exceed the complexity of trading for these other pollutants, and the consequences of setting up the system poorly could be great. Furthermore, these other pollutants have been generally produced by companies, whereas CO₂ is in large part produced by individual people. While there is a general consensus that trading would be beneficial, there are many uncertainties as to how it can be implemented as part of an effective control system, and what the results would be. Where in the energy system should control points be established for permitting? How should the permits be distributed: allocated to companies according to historical patterns or auctioned to the highest bidder? How can the buildings and transportation sectors be included? How will companies and individuals alter their energy-related decision-making as a result of control and trading? How are the costs and benefits distributed throughout the economy?

This report is an interim result of a study of the major options for control and trading systems. It describes where CO₂ emissions come from and how they may be reduced.

Then it describes four options to effect these changes. The four systems involve different combinations of fuel supply restrictions, emission limitations, and regulation.

The final report will analyze these options in much greater depth.

What was the 1st?

more costly to reduce

The second factor is the degree to which emissions of other GHGs can be reduced. Several, such as methane, can be controlled more easily than CO₂. Others will be harder. The five gases listed in the Kyoto Protocol collectively were equivalent to 244 MtC of carbon in 1990. The level to which each can be reduced for the same cost per ton carbon equivalent is uncertain, and the effect on CO₂ could be positive or negative. This analysis assumes that the net effect is zero.

Finally, while the Protocol allows members to take credit for reductions they arrange in other developed (Annex I) countries, these credits must be "supplemental to domestic actions." The Protocol is not clear what this means. Supplemental could be interpreted as almost any fraction of the total reduction required, though the authors probably meant a fairly low level overall. In fact, the term "reduction" is unclear because it could mean reduction from the level of 1990, or from actual peak emissions (say around 2005) before reductions take place, or from projections of what emissions would have been in 2010 without control. The simplest approach would be to define the limit as a fraction of the QELRC as calculated for all GHGs, but that might take a revision of the Protocol. Large credits could be available from the countries of the former Soviet Union because the collapse of those economies after 1990 led to major reductions in emissions of carbon. As their economies recover, many opportunities will become available to build efficiency into new investments there. In addition, many attractive opportunities exist for reductions from low-cost efficiency improvements in developing countries. Many of these international opportunities will be quite inexpensive relative to those in the United States, so the limit could be very important. For the purposes of this report, it is assumed arbitrarily that about 50 MtC of credits will be imported. Therefore carbon emissions can be as much as 1350 MtC (1300 + 50).

big weakness

However, it should be noted that the cost-effective level of international purchases might be much higher. One of the Interagency Analytical Team models calculated that 72 million tons of permits (for real improvements, not credits for reduced economic activity) could be purchased from the former East Bloc at low cost, and that joint implementation with developing countries could add considerably more.

CDM

A higher cap would, of course, be easier and less expensive to meet. While that is not addressed directly in this report, each sector can be considered largely independently, and two levels of reductions are presented for each. The lower level of emissions correspond to policies that emphasize cuts from each of the sectors. The higher ones could either represent a lower emphasis for reduction on that sector or a higher domestic target (e.g., because of increased international trading.)

skip to next page 1st

SOURCES OF CO₂

Fossil fuels, the source of almost all anthropogenic carbon emissions in the United States, are used in four sectors: buildings (residential plus commercial), industry, transportation, and electric generation⁴. Energy is used in buildings for heating, cooling, hot water, lighting and appliances. Industry uses energy for a variety of functions in the manufacture of products. The transportation sector uses it to move cars, trucks, and other vehicles. Fossil fuels also are used to generate electricity, another form of energy which in turn is used in buildings and by industry. Energy consumption for 1990 (the target base year) is shown in Table 2-1. This table also shows energy data for 1994 (the latest year for comprehensive data on energy used in manufacturing,) and 1996 (the most recent broad data.) Table 2-1 depicts the trajectory the nation has been following, which provides a basis for understanding the changes that must happen to get back to 1990 levels.

Total energy use in 1990 was 84.1 quadrillion BTUs (quads), of which 72 quads were from fossil fuel. The remainder was nuclear power and various renewable energy sources, none of which produce CO₂. The largest sector was electricity, with about 35 percent of the total. Transportation was second with 27 percent. However, when the energy required to produce electricity is counted in the sector where it is used, industry becomes the largest sector with 32.1 quads, followed by buildings with 29.5 quads. Almost 40 percent of 1990's energy was provided by petroleum. Natural gas and coal each accounted for about 22 percent.

Total emissions of carbon from fossil fuel consumption in 1990 were 1346 million metric tons (MtC). Carbon emissions by sector and fuel are shown in Table 2-1. The electric sector was the largest producer because of its high use of coal, even though

⁴ Electric generation is frequently not considered to be a separate sector, because it is an intermediate use of fuel. Essentially all electricity is consumed by the buildings and industry sectors. It is separated in this report because the decision making on reducing the use of electricity is different from that on increasing the carbon efficiency of electricity generation and transmission. Such decision making is the major focus of this study. However, the tables with energy use and carbon emissions show both the 4 sectors and with the electric sector subsumed in the buildings and industry sectors.

CHAPTER 2

REDUCING CARBON DIOXIDE EMISSIONS

Meeting the commitment of the Kyoto Protocol will require significant reductions in emissions of carbon dioxide (CO₂) and other greenhouse gases (GHGs), as discussed in Chapter 1. The specific level of CO₂ emissions from domestic fossil fuel combustion cannot be precisely defined at this time because it will depend on: 1) how much credit can be taken for carbon stored in trees; 2) purchases of reductions made in other countries, and; 3) how much the other GHGs are reduced. These factors are discussed in Box 2-1.

Based on a preliminary assessment of these three factors, we estimate that carbon emissions from U.S. fossil fuel combustion might be limited to about 1350 million metric tons (MtC). That target would be essentially equal to the emissions of 1990, not to the 7 percent below 1990 that one might expect from the Kyoto Protocol.

Furthermore, the level could be significantly higher, as discussed in Box 2-1.

Emissions limitations could be raised if large amounts of reductions are purchased from other countries, or if more credit could be given for reforestation than is assumed here.

Although 1350 MtC is certainly an easier target to meet than 7 percent below the emissions of 1990, it still will be a significant decrease from current emissions, and an even greater decrease from estimated 2010 emissions absent controls. In order to understand what will have to be done to meet this target, this chapter reviews where CO₂ emissions come from. It then describes by sector what changes can be made to reduce emissions to the level required. It also discusses major trends, such as competitiveness in the electric power industry, that could have a significant effect on efforts to meet the target, and expected improvements in technology. Then it reviews the significant decision makers influencing activities in each sector, and how they might react to policies designed to reduce emissions of carbon.

Box 2-1

Kyoto Carbon Target for the United States

The goal (referred to as quantified emission limitation or reduction commitment--QELRC) of the Kyoto Protocol for the United States is reduce emissions of the six greenhouse gases to 7 percent below the levels of 1990 as specified in Annex B. Total emissions of carbon (in the form of CO₂) in 1990 were 1374 million metric tons (MtC)¹. Of this, 1344 MtC were from the combustion of fossil fuel. If all greenhouse gas (GHG) emissions were to be held to the same goal, the target for carbon would be 7 percent below the 1990 level, or 1278 MtC.

Essentially all of the reduction would have to come from combustion of fossil fuel since the release of CO₂ from sources such as cement manufacturing is an inherent part of the process. Therefore the limitation for fossil fuel combustion would be 1248 MtC, or slightly lower if concrete manufacturing increases significantly.

However, other factors may change the need for CO₂ emission reductions. First, sequestration of carbon in forests and land from direct human-induced land uses changes and practices must be taken into account in calculating net emissions to meet the QELRC (according to the Protocol the QELRC is based on emissions only, and does not include carbon flow into or out of carbon sinks). Vast areas of former farm land in the United States have reforested since 1920. According to one estimate, a net 281 MtC of carbon per year was sequestered in U.S. forests from 1952 to 1992 from land newly turned to trees and the growth of older forests². This represents an offset of about 25 percent of U.S. emissions of carbon over this period. Future sequestration is expected to slow to 178 MtC per year as forests mature and reforestation of croplands decreases.

If the full value of this sequestration is allowed, carbon emissions from fossil fuel combustion could be raised to 1426 MtC (1248 + 178). This is only slightly lower than the 1463 MtC estimated for emissions from fossil fuel combustion in 1996. Thus little reduction in fossil fuel use from current levels would be required. However, under the terms of the Protocol, credit for sequestration is limited to carbon stored by trees planted after 1990, which would disqualify about half the 178 MtC³. Further limiting credit to larger tracts of land substantially reforested since 1990 might reduce the allowable sequestration to about 50 MtC/year. Therefore sequestration is assumed here to raise allowable emissions to about 1300 MtC (1248 + 50).

¹ *Emissions of Greenhouse Gases in the United States*; 1996, DOE/EIA-0573(96), October 1997, p x

² R.A. Birdsey and L.S. Heath, "Carbon Changes in U.S. Forests," in L.A. Joyce (ed.), *Productivity of America's Forests and Climate Change*, General Technical Report RM-GTR-271 (Fort Collins, CO: USDA Forest Service, 1995, as reported in *EIA Emissions of Greenhouse Gases in the United States, 1996*.

³ Forests reach carbon equilibrium in 30-50 years, so those started before 1990 account for about half the sequestration.

TABLE 2-1
Historical Energy Use and Carbon Emissions by Fuel and Sector

1990	Energy Use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Buildings	0.2	7.2	2.2	0.6	19.3	29.5	150	460
Industry	2.8	8.5	8.3	2.2	10.3	32.1	288	454
Transport	0.0	0.7	21.8	0.1	0.0	22.5	431	432
Electric	16.2	2.9	1.3	9.3	[29.6]		477	
Energy	19.1	19.3	33.6	12.3		84.1		
Carbon	481	273	591	0			1346	1346

1994	Energy Use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Buildings	0.1	8.0	2.1	0.7	20.5	31.4	158	482
Industry	2.5	9.6	8.9	2.5	10.7	34.2	297	467
Transport	0.0	0.7	22.8	0.1	0.0	23.6	452	452
Electric	17.3	3.1	1.0	9.8	[31.2]		494	
Energy	20.0	21.3	34.7	13.1		89.2		
Carbon	496	302	604	0			1401	1401

1996	Energy use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Buildings	0.1	8.7	2.2	0.7	22.2	33.9	171	517
Industry	2.4	10.3	9.1	2.7	10.8	35.4	307	477
Transport	0.0	0.7	23.7	0.1	0.0	24.4	468	469
Electric	18.4	2.8	0.7	11.1	[33.0]		517	
Energy	21.0	22.6	35.7	14.6		93.8		
Carbon	512	318	626	0			1463	1463

Source: EIA Annual Energy Review 1996, Tables 1.1, 2.1, 6.6, 7.3, 8.5, 8.12, and 10.2;
EIA Emissions of Greenhouse Gases in the United States, 1995, Table 5, 6, 7, 8, 9, 10, 11, and 12

transportation used more quads of fossil fuel. Assigning electricity's carbon emissions to the end use sectors again shows industry the highest followed by buildings. By fuel, petroleum was the source of 44 percent of carbon emissions and coal 36 percent.

Figure 2-1 shows carbon emissions for the major elements of each sector by fraction of the total (with emissions from the electric sector distributed to the buildings and industry sectors.) These elements, along with electric generation, are those that will require the greatest scrutiny in efforts to reduce emissions. Automobiles are the largest emitters, with about 17 percent. Industrial boilers come in second. If residential and commercial buildings were combined, as in Table 2-1, lighting and other appliances would be about as high as boilers.

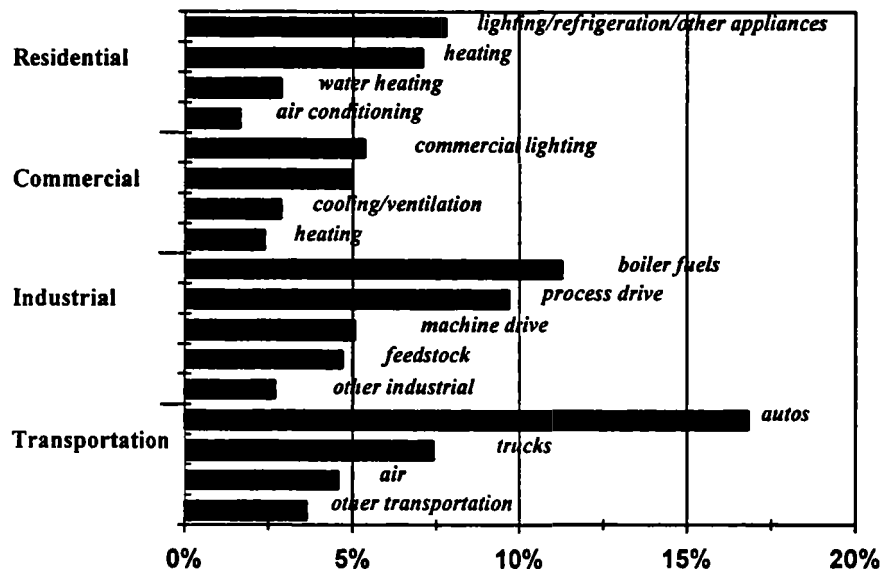
CO₂ emissions increased only slightly from 1980 to 1990, but much more rapidly over the past four years. If the economy continues to grow strongly, and energy prices remain low, CO₂ emissions are likely to continue to grow rapidly. Getting to the target of 1350 MtC as calculated in Box 2-1 will require reversing that trend. If prompt action (i.e., allowing early credits) is taken in anticipation of meeting the 2008-2012 commitment, emissions might peak around 2005. Otherwise the peak is likely to occur at a higher level in 2008, requiring much more drastic changes to meet the objective.

PROJECTIONS TO 2010

Determining the necessary changes depends on how high emissions would be in the 2008-2012 commitment period without any controls. Once the base case is estimated, usually with an energy-economics model, then various policy options to reduce fossil energy use to achieve the target of reduced CO₂ emissions can be analyzed.

Many energy projections to 2010 and beyond have been made with and without policies to reduce emissions of carbon. Table 2-2 shows three such projections. The first is derived from the High-efficiency, Low-carbon projection of the Interlaboratory Working

Figure 2-1
End use sources of carbon dioxide



Source: The Heinz Center, using data from the Energy Information Agency (1994, 1995b, 1997a, 1997b), the Office of Technology Assessment (1993), and Davis and Hu (1991).

TABLE 2-2 A
Energy Use and Carbon Emissions by Fuel and Sector, 2010

Interlab Controlled Case								
2010	Energy use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0.1	5.4	1.1	0.6	10.8	18.0	103	229
Commer	0.0	3.2	0.7	0.0	9.7	13.6	59	173
Industry	2.4	10.2	9.7	3.5	11.3	37.1	300	432
Transport	0.0	1.0	26.0	0.9	0.0	27.9	512	512
Electric	9.5	8.4	0.3	13.6	[31.8]		372	
Energy	12.0	28.2	37.8	18.6		96.6		
Carbon	309	408	629				1346	1346

Interlab Base Case								
2010	Energy use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Total	with elec
Resident	0.1	5.6	1.3	0.6	13.1	20.7	106	324
Commer	0.0	3.5	0.7	0.0	11.4	15.6	65	254
Industry	2.7	11.8	10.2	3.2	13.4	41.3	335	558
Transport	0.0	0.9	31.1	0.3	0.0	32.3	616	616
Electric	18.0	11.0	0.5	8.4	[37.9]		630	
Energy	20.8	32.8	43.8	12.5		109.9		
Carbon	534	474	745				1752	1752

Interlab Differences								
2010	Energy Use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0.0	-0.2	-0.2	0.0	-2.3	-2.7	-3	-95
Commer	0.0	-0.3	0.0	0.0	-1.7	-2.0	-6	-81
Industry	-0.3	-1.6	-0.5	0.3	-2.1	-4.2	-35	-126
Transport	0.0	0.1	-5.1	0.6	0.0	-4.4	-104	-104
Electric	-8.5	-2.6	-0.2	5.2	[-6.1]		-258	
Energy	-8.8	-4.6	-6.0	6.1		-13.3		
Carbon	-225	-66	-116				-406	-406

Note: See Appendix 2-1 for the methodology in preparing these values.

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions, Tables C-2.5.b; C-2.6.b; 4.1; 4.4; 4.5; 5.8; 5.10; and 6.4, and personal communication with Gale Boyd March 4, 1998.

TABLE 2-2 B
Energy Use and Carbon Emissions by Fuel and Sector, 2010

EPA/DRI 2010 Stabilization Case								
2010	Energy use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0	4.7	1	0	11.9	17.6	87	242
Commer	0	3.2	0.5	0	12.6	16.3	57	222
Industry	1.3	7.7	9.5		11.9	30.4	283	438
Transport	0	0.9	23.6	0.1	0	24.6	454	455
Electric	15.9	6.4	1	13.1	[36.4]		475	
Energy	17.2	22.9	35.6	13.2		88.9		
Carbon	426	322	609				1356	1357

EPA/DRI 2010 Base Case								
2010	Energy Use (Quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0.0	5.6	1.2	0.0	13.4	20.2	104	307
Commer	0.1	3.6	0.6	0.0	13.8	18.1	66	274
Industry	2.2	10.0	10.1	0.0	15.4	37.7	350	583
Transport	0.0	1.2	28.1	0.1	0.0	29.4	529	529
Electric	22.0	7.1	1.1	12.4	[42.6]		643	
Energy	24.3	27.5	41.1	12.5		105.4		
Carbon	602	393	698				1692	1693

EPA/DRI Differences								
2010	Energy Use (Quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0.0	-0.9	-0.2	0.0	-1.5	-2.6	-18	-65
Commer	-0.1	-0.4	-0.1	0.0	-1.2	-1.8	-9	-52
Industry	-0.9	-2.3	-0.6	0.0	-3.5	-7.3	-67	-145
Transport	0.0	-0.3	-4.5	0.0	0.0	-4.8	-75	-74
Electric	-6.1	-0.7	-0.1	0.7	[-6.2]		-168	
Energy	-7.1	-4.6	-5.5	0.7		-16.5		
Carbon	-176	-71	-89				-337	-336

Source: Personal Communication with J. Greenwald, White House Climate Change Task Force. From an unpublished memo "Summary Comparison DOE and EPA Carbon Stabilization Runs." Prepared by the Energy Information Administration for the White House Climate Change Task Force.

TABLE 2-2 C
Energy Use and Carbon Emissions by Fuel and Sector, 2010

DOE/NEMS 2010 Stabilization Case								
2010	Energy Use (Quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Fossil	with elec
Resident	0.0	5.0	1.1	0.5	11.8	18.4	95	225
Commer	0.1	3.3	0.6	0.0	9.6	13.6	61	167
Industry	1.8	10.4	9.5	0.0	11.5	33.2	289	417
Transport	0.0	1.2	27.2	0.2	0.0	28.6	542	543
Electric	7.8	11.1	0.2	13.7	[32.9]		364	
Energy	9.7	31.0	38.6	14.4		93.8		
Carbon	239	441	672				1352	1352

DOE/NEMS 2010 Base Case								
2010	Energy Use (Quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0.0	5.6	1.3	0.5	13.5	20.9	105	325
Commer	0.1	3.5	0.6	0.0	11.8	16.0	75	266
Industry	2.6	11.5	10.2	0.0	13.0	37.3	336	546
Transport	0.0	1.2	29.6	0.2	0.0	31.0	593	594
Electric	19.9	6.8	0.6	11.0	[38.3]		621	
Energy	22.6	28.6	42.3	11.7		105.2		
Carbon	561	407	763				1730	1731

DOE/NEMS Differences								
2010	Energy Use (Quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident	0.0	-0.6	-0.2	0.0	-1.7	-2.5	-11	-100
Commer	0.0	-0.2	0.0	0.0	-2.2	-2.4	-14	-99
Industry	-0.8	-1.1	-0.7	0.0	-1.5	-4.1	-47	-129
Transport	0.0	0.0	-2.4	0.0	0.0	-2.4	-51	-51
Electric	-12.1	4.3	-0.4	2.7	[-5.4]		-257	
Energy	-12.9	2.4	-3.7	2.7		-11.4		
Carbon	-331	31	-79				-379	-379

Source: Personal Communication with J. Greenwald, White House Climate Change Task Force. From an unpublished memo "Summary Comparison DOE and EPA Carbon Stabilization Runs." Prepared by the Energy Information Administration for the White House Climate Change Task Force.

Group⁵ which assumes a \$50 per metric ton of carbon permit price. The other two were from the Interagency Analytical Team (IAT)⁶. The Environmental Protection Agency used a model built by DRI (a private company). The Department of Energy used the NEMS model, built by the Energy Information Administration. All were done before the Kyoto conference and used 1990 emissions as a target for 2010. All IAT emissions-control scenarios assumed that reductions would be obtained through issuance of tradable permits at the earliest point of energy production (or import), with the policy phased in from 2000 to 2010. The scenarios discussed here do not include international trading or carbon sequestration. Some scenarios (EPA/DRI in particular) took some credit for reductions in other greenhouse gases, allowing a slightly higher carbon target. None of these analyses calculated average emissions for 2008-2012 as called for in the Kyoto Protocol, so projections for 2010 are used as a surrogate. Table 2-2 also shows the base cases for each analysis, where no controls on carbon emissions are applied, and the differences between the two projections.

Several changes were made to the Interlab projection. Most importantly, the 2 main approaches to reducing carbon emissions from the electric sector (customer demand reductions and generating fuel switching) had to be combined. These modifications are described in Appendix 2-1.

In addition, Table 2-3 summarizes all four of the IAT analyses for comparison. The Interlab-derived values for the controlled case are close to both the Second Generation Model (SGM) and Markal-Macro model runs. The EPA/DRI estimates for coal and carbon emissions are higher because some credit was given for reductions in other greenhouse gases, resulting in a higher target.

⁵ Scenarios of U.S. Carbon Reductions, Prepared by the Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies for the Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, September 1997.

⁶ Economic Effects of Global Climate Change Policies, unpublished draft report by the Interagency Analytical Team, June 1997. This work, in preparation for the Kyoto Conference, analyzed projections made by 4 different models.

TABLE 2-3
Comparison of IAT Results with the Interlab Report for 2010

Controlled Cases

	Energy Use (Quads)						Carbon
	Coal	Gas	Oil	Other	Electric	Total	<i>Total MtC</i>
Interlab	12.0	28.2	37.8	18.6	31.8	97.9	1346
EPA/DRI	17.2	22.9	35.6	13.2	36.4	88.2	1380
SGM	11.3	33.1	33.1	13.9	NA	91.4	1332
Markal-M	9.4	30.7	37.9	14.6	NA	92.6	1335
DOE/NE	9.7	31.0	38.6	14.4	32.9	93.8	1351

Base Cases

	Energy Use (Quads)						Carbon
	Coal	Gas	Oil	Other	Electric	Total	<i>Total MtC</i>
Interlab	20.8	32.8	43.8	12.5	37.9	108.7	1752
EPA/DRI	24.3	27.4	41.1	12.5	42.6	105.3	1693
SGM	23.9	33.2	36.5	13.4	NA	107.0	1729
Markal-M	22.5	29.0	43.4	12.9	NA	107.8	1741
DOE/NE	22.6	28.6	42.3	11.7	38.3	105.2	1730
EIA-AEO	24.0	29.6	44.3	14.2	40.2	112.2	1803

NA: Not Available

Source: Table 2-2 and Interagency Analytical Team, Economic Effects of Global Climate Change Policies, Draft Report, May 30, 1997, p15.

The Base Case results, also shown in Table 2-3, show some spread in individual fuels, but overall the projections are similar. The lower coal in the Interlab report may be due to its more detailed look at how competition is changing the electric industry. This table also includes the reference case from EIA's latest projection in the Annual Energy Outlook, 1998⁷. It is interesting to note the general increase in energy projections in the base cases from the IAT runs, completed in May 1997, through Interlab, completed in the summer of 1997, to EIA which was released at the end of 1997.

It is difficult to compare projections from different models, because they may use different approaches, techniques, and data bases. Even the starting points differ in some of these analyses. Nevertheless these results reflect key differences in assumptions as to how the energy system will react to changes. It is instructive to view the differences between the controlled and uncontrolled scenarios for each of the three models as shown in Tables 2-2 and 2-4. Comparing differences between base and controlled scenarios eliminates much of the idiosyncratic effect of different models and modelers.

Interlab shows all fossil fuels declining from the uncontrolled scenario. The largest share of the emission reductions (60 percent) comes from the electric sector because of demand reduction by customers and fuel switching by generating companies. Fuel switching includes a substantial increase in the amount of renewables, especially biomass. Preventing a nuclear decline contributes to the non-carbon part of this scenario. Interlab also predicts some fuel switching from coal to gas for electrical generation, but the use of gas in the sector actually declines from the uncontrolled case because demand reduction is greater. The building and industry sectors are expected to reduce their use of electricity considerably more than their use of fossil fuel. Substantial efficiency improvements are expected in the transportation sector, as is increasing use of non-fossil fuel.

⁷ U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook 1998, DOE/EIA-0383(98), December 1997, Appendix A.

TABLE 2-4
Percent Differences Between Uncontrolled and Controlled
Scenarios, Energy and Carbon Emissions in 2010

Interlab

	Energy Use (percent)						Carbon (percent)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident					-18	-13	-3	-29
Commer		-9			-15	-13	-9	-32
Industry	-11	-14	-5	9	-16	-4	-10	-23
Transport			-16	200		-14	-17	-17
Electric	-43	-24		62	[-16]		-41	
Energy	-42	-14	-14	49		-10		
Carbon	-42	-14	-15				-23	-23

EPA/DRI

	Energy Use (percent)						Carbon (percent)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident		-16			-11	-13	-17	-21
Commer		-11			-9	-10	-14	-19
Industry	-40	-23	-6		-23	-19	-19	-25
Transport			-16			-16	-14	-14
Electric	-28	-10		6	[-15]		-26	
Energy	-29	-17	-13	6		-16		
Carbon	-29	-18	-13				-20	-20

DOE/NEMS

	Energy use (percent)						Carbon (percent)	
	Coal	Gas	Oil	Other	Electric	Total	Primary	with elec
Resident		-11			-13	-12	-10	-31
Commer					-19	-15	-19	-37
Industry	-31	-10	-7		-12	-11	-14	-24
Transport			-8			-8	-9	-9
Electric	-61	63	-67	25	[-14]		-42	
Energy	-57	8	-9	23		-11		
Carbon	-59	8	-10				-22	-22

Note: Changes of 0.3 quads or less are not listed.

Changes are compared to the base case for each scenario.

Source: The Heinz Center, data from Table 2-2

EPA/DRI didn't have to find as many reductions (because of its assumption of credit for reductions in other GHGs), so coal use for electrical generation is down 28 percent instead of 43 percent as in the Interlab study. There is far less activity in renewables. Transportation improves almost as much as in the Interlab report. Efficiency improvements in the building sector is greater for fossil fuel, but less for electricity. Industry reduces its use of both fossil fuel and electricity substantially.

DOE/NEMS achieves most of its reductions from coal in the electricity sector. Gas actually increases significantly because of fuel switching. Transportation improves only half as much as in the other scenarios. Energy efficiency measures for both fossil fuel and electricity are less than in the other scenarios. The differences between Interlab and DOE/NEMS are particularly striking because the Interlab group used the NEMS model for part of its analysis, suggesting that specific inputs are as important as the model itself.

Table 2-4 focuses on the major changes predicted by these analyses. All predict major drops in coal use for electric generation, but they differ on the size of the drop. All predict about the same drop in electricity demand, but they vary considerably on their predictions for gas. All expect industry to decrease its use of all three fossil fuels, especially coal. Reductions of oil use in the transportation sector are down in all three, but DOE/NEMS shows significantly less drop.

These three scenarios predict some widely differing results--reductions in coal for electricity and petroleum for transportation vary by a factor of two, and industrial energy use and non-fossil energy changes by even more. Several factors could account for these differences. EPA/DRI apparently has higher price elasticities than used in the DOE/NEMS analysis; that is, consumers are faster to look for alternatives as prices of energy rise. Therefore, EPA/DRI predicts that prices need not rise as much to get the desired reduction. DOE/NEMS and, to a lesser extent Interlab, assume that large users are much more sensitive to energy prices than individuals. If this assumption is correct,

prices will have to rise higher than if responses to price signals were uniform. These factors are discussed in Box 2-2.

If the EPA/DRI perspective is correct, overall costs for the country as a whole will be lower because the reductions are balanced across the economy better than in the others. Relying on the electric industry to make most of the reductions, as in the DOE/NEMS forecast, could cause very wrenching changes in that sector. Not only will production have to decline from the level that will be reached by about 2005 because of efficiency enhancements in the buildings and industry sectors, but power companies must improve their own efficiency while converting or replacing many coal-fired plants with gas. Thus while declining and shutting down many otherwise useable (and only partially amortized) plants, the industry will have to invest heavily in new, lower-emitting plants. All this would be happening while the industry is already changing rapidly because of on-going restructuring from increased competition. Financial viability of the industry will be a major issue. The coal industry will be hit even harder. Coal mining regions, railroads and equipment manufacturers will suffer major losses.

Another difference among the scenarios is in technological optimism. Interlab expects significant advances in improved efficiency of vehicles and the use of biomass for electric generation that are not reflected in the other studies. If the levels postulated here are to be obtained, it is likely that aggressive R&D and commercialization will be required in addition to controls on carbon. This high level of optimism at least partly explains why the Interlab cost of carbon permits is considerably lower than the others. Interlab predicts that stabilization of emissions can be attained at \$50/MtC. EPA/DRI required about \$100 and DOE/NEMS about \$150/MtC⁸.

⁸ These figures are not completely comparable. Interlab assumed a set of energy policies while EPA/DRI and DOE/NEMS limited their policy changes to taxes forcing prices up.

Box 2-2
Price vs. Regulation

In the final analysis, reducing carbon emissions is a people issue. For all four sectors, it is people who have to make the decisions to purchase more efficient equipment, switch to natural gas or renewable energy, join a car pool, etc. There are three major policy approaches to getting people to take the necessary actions. One way is to attach a price to the carbon contained in fossil fuels. The second is to limit the amount of carbon certain users can emit. The third is to impose regulations. Other policies such as information programs and incentives can play a role but they are secondary to these.

The cost of burning fossil fuel can be raised by either: 1) taxing the carbon they contain or 2) by limiting the amount of carbon that can enter the energy system thereby causing prices to rise to where demand meets the lowered supply. Either way, price signals are a market approach to achieving the goal.

The second approach also uses the market to guide actions, but on a more restricted basis. Users such as utilities and large industrial companies need to acquire permits to emit carbon. Permits are either sold or allocated based on a fraction of past performance. Additional costs (especially for electricity) are passed on to customers, who then get price signals to reduce their consumption.

Economy-wide price signals influence every energy decision, not just selected ones. If the market works smoothly and efficiently, the goal will be met at the lowest possible cost. However, there is no consensus as to whether the market will function so well. Price increases will motivate some decision-makers more than others. If the difference is large, then those who are highly motivated would have to do more than their share to meet a given reduction goal. Prices would have to rise above the theoretical clearing point in order to provide that additional motivation, and all consumers would have to pay the higher price. In such a case, the market approach would be very expensive for the country.

Cost effective
Regulations, such as equipment efficiency standards, work to narrow or otherwise influence consumer choices. The corporate average fuel economy (CAFE) standard requires automobile manufacturers to produce a fleet each year with an average mileage that meets a certain standard. Manufacturers with a large share of large, poor-mileage cars may have to promote their smaller cars heavily and raise the price of the large cars to meet the average. Building standards require builders of new housing to improve insulation and reduce infiltration over what they might have found adequate to sell their houses. Similarly, equipment standards for appliances such as furnaces and air conditioners tend to eliminate the least efficient models that appeal to those more concerned with first cost than operating cost. The main objection to such regulations is that they may unduly affect consumer choice. Sometimes a low-cost, inefficient choice

be costly

Oh for
Pete's sake

is most economical, for example a water heater for a vacation home, where it is used only a few months of the year.

Each sector presents a different situation. Generators of electricity are very sensitive to the price of energy because it is a large fraction (about half) of the cost of their product. Manufacturers of energy-intensive products such as aluminum, chemicals, steel are also very aware of energy costs, which may be 10-30 percent of overall costs.

Elsewhere it is much less clear. Manufacturers whose energy costs are only a couple of percent of overall costs still have an interest in reducing them, but it will be much less important. Commercial enterprises are likely to be more interested in the appearance presented by their lights than the cost of operating them. Individual consumers tend to select the most car or house they can afford without much consideration of operating costs. Higher initial costs can be very unattractive even if they provide an excellent investment in the form of lower operating costs.

Nevertheless, energy price clearly does affect consumers. Following the energy crisis and period of high prices in the 1970's, many people insulated their homes, upgraded their furnaces, and bought more fuel efficiency cars. Such actions were a significant factor in reducing energy demand. The nation still enjoys the benefits of some of these actions in the form of lower energy costs. This spirit might be reawakened with a national commitment to lower carbon emissions and distinctly higher energy prices, but that is by no means certain.

It is clear that many energy-efficiency measures are not implemented to the degree that they could be cost-effectively. There are many reasons for that, for example lack of information, uncertainty over future conditions, aversion to complicated, unfamiliar technology. Some researchers have found that individual consumers, and even industrial decision-makers, require returns on investment to exceed 30 percent before they become interested in energy-efficiency. Many utility demand-side management (DSM) programs have worked well in helping their customers install efficient furnaces, air conditioners, and refrigerators. That is at least in part because utilities could take an integrated approach, supplying information, and often financing and subsidizing the costs. However, it is not clear that utilities will continue these programs under the current trend toward competition, as discussed elsewhere in this chapter.

This issue of energy "price elasticity"—how much consumers respond to increases in energy prices—has not been resolved despite at least 25 years of research. If policy makers believe that elasticity is low (i.e., that consumers will be very reluctant to reduce their use of energy,) then reductions may be cheaper to obtain with standards that will raise the efficiency of equipment that is available for people to buy. If elasticity is seen as high, price mechanisms may be the favored approach. Hybrid programs are also possible. The emission control programs discussed in the following chapter incorporate various types of standards as well as price mechanisms.

TABLE 2-5
Differences Between 1996 and 2010 Controlled, Interlab Results

	Energy Use (quads)						Carbon (MtC)	
	Coal	Gas	Oil	Other	Electric	Total	<i>Primary</i>	<i>with elec</i>
Buildings	0.0	-0.1	-0.4	0.0	-1.7	-2.3	-9	-115
Industry	0.0	-0.1	0.6	0.8	0.5	3.0	-7	-45
Transport	0.0	0.3	2.3	0.8	0.0	3.5	44	43
Electric	-8.9	5.6	-0.4	2.5	[-1.2]		-145	
Total	-9.0	5.6	2.1	4.1		4.1		
Carbon	-203	90	3				-117	-117

Source: The Heinz Center

It is also instructive to compare the controlled scenario with the 1996 data to see what sort of trajectory the nation must follow to achieve the target by 2010. This is done in Table 2-5 for the Interlab results. The buildings sector's use of fossil fuel will decline by about 5 percent below today's level in the 2010 control case, despite growth in the number of buildings and area per person. Consumption of electricity in buildings declines, by about 9 percent below today's levels. Industry's use of fossil fuel is below today's level, and electricity slightly above. Industry's biggest change is in the increased use of renewable fuels. Transportation is the only sector that grows in both energy consumption and carbon emissions. Most growth is in petroleum. Looking at the fuels, gas consumption is up in the controlled case by 23 percent. Oil use is up 4 percent from today, but coal is devastated, losing about 43 percent of its current business. Reduced coal use provides all the required reductions in CO₂ emissions (from 1996) plus enough more to balance increased use of oil and gas.

Steps to reduce emissions of CO₂ fall into three categories: improved efficiency, switching to non-carbon fuels (including biomass,) and switching to low-carbon fuels, in particular natural gas. Table 2-6 distributes the reductions for each of the three scenarios according to methodology described in Appendix 2-2. The results are extremely varied.

In all scenarios, **efficiency** is very important, ranging from 39 to 79 percent of the carbon reduction. Many efficiency improvements are available in all sectors. Some are economical now but haven't been implemented for a variety of reasons. Others could be made more attractive with policies to reduce emissions of GHGs. The Interlab study predicts that the entire economy can operate at essentially the same level in the controlled scenario as in the uncontrolled scenario, using 10.8 fewer quads (or 10 percent less energy) and reducing emissions by 218 MtC.

Non-carbon sources in the three scenarios range from a virtually negligible 5 percent to 36 percent. The Interlab study expects an additional 6.2 quads of non-carbon fuels

Table 2-6

**Types and Sources of Emissions Reductions--
Differences Between 2010 Uncontrolled and Controlled Carbon Emissions**

Interlab		Carbon (MtC)					Total	Percent
		Primary			electric	total		
		low-C	non-C	efficiency	efficiency	efficiency		
small sources	Resident			-3	-30	-33	-33	8%
	Commer			-6	-27	-33	-33	8%
	Transport		-12	-92		-92	-104	26%
large sources	Industry		-6	-29	-31	-60	-66	16%
	Electric	-40	-130				-170	42%
Total		-40	-148	-130	-88	-218	-406	
Percent		10%	36%			54%		100%

EPA/DRI		Carbon (MtC)					Total	Percent
		Primary			electric	total		
		low-C	non-C	efficiency	efficiency	efficiency		
small sources	Resident			-17	-25	-42	-42	13%
	Commer			-9	-21	-30	-30	9%
	Transport			-75	0	-75	-75	22%
large sources	Industry			-67	-53	-120	-120	36%
	Electric	-51	-18				-69	21%
Total		-51	-18	-168	-99	-267	-336	
Percent		15%	5%			79%		100%

DOE/NEMS		Carbon (MtC)					Total	Percent
		Primary			electric	Total		
		low-C	non-C	efficiency	efficiency	efficiency		
small sources	Resident			-11	-5	-16	-16	4%
	Commer			-14	-15	-29	-29	8%
	Transport			-51	0	-51	-51	13%
large sources	Industry			-47	-6	-53	-53	14%
	Electric	-162	-69				-231	61%
Total		-162	-69	-123	-26	-149	-379	
Percent		43%	18%			39%		100%

Source: The Heinz Center.

relative to the uncontrolled scenario, saving about 148 MtC. Other analysts expect very little by 2010. Renewable fuels (including biomass, which technically contains carbon, but can be employed on a sustainable basis) can be encouraged in all sectors, but electricity probably has the most potential, followed by transportation. Nuclear power is another non-carbon option, but the only contribution available by 2010 will come from extending the life of plants that would otherwise have been retired earlier.

Conversion or replacement of coal-fired power plants with natural gas will also be important. The power produced by a quad of coal, which emits 25.7 MtC, could be produced by about three quarters of a quad of gas, which emits only 10.8 MtC, saving 14.9 MtC. Such conversions will save about 40 MtC under the Interlab scenario, but 162 under DOE/NEMS. Conversion to natural gas presents fewer technical obstacles than renewable fuels.

Table 2-6 also arranges the data by type and source of reductions. Of Interlab's total 406 MtC, 236 (58%) will come from large sources—utilities and industry. About 16 percent of the total comes from industry, almost evenly split between improving the efficiency of electricity use and measures to improve the use of fossil fuel or switching to lower carbon fuels. However, it should be noted that many of the cost-effective opportunities for improving energy efficiency are in light manufacturing, because heavy industry already has greatly improved its efficiency. Light manufacturing facilities individual are, at most, medium, not large, sources of carbon.

The remaining 42 percent comes from small sources—cars, trucks, and residential and commercial buildings. Most of this is the result of end-use efficiency improvements, both in direct use of fossil fuels (e.g., more efficient cars) and use of electricity (e.g., improved lighting.) EPA/DRI is close to this split with 56 percent due to large sources. DOE/NEMS is even higher at 75 percent.

Table 2-7
Residential Energy End-uses and Carbon Emissions in 2010

Fuel	End-use	Primary Energy Use (quads)		Carbon Emissions (MtC)		
		Base	Controlled	Base	Controlled	Reduction
Electricity	Space heating	1.40	1.28	23	21	
	Space Cooling	1.43	1.31	23	21	
	Water heating	1.11	0.90	18	14	
	Refrigeration	0.90	0.82	15	13	
	Cooking	0.41	0.38	7	6	
	Clothes Dryer	0.61	0.52	10	8	
	Freezers	0.23	0.20	4	3	
	Lighting	1.02	0.67	17	9	
	Other uses	5.89	4.66	97	71	
	Total electric	13.00	10.76	213	167	46
Natural Gas	Space heating	3.88	3.81	56	55	
	Space cooling	0.02	0.02	0	0	
	Water heating	1.39	1.27	20	18	
	Cooking	0.14	0.16	2	2	
	Clothes dryer	0.05	0.09	1	1	
	Other uses	0.10	0.09	1	1	
	Total gas	5.58	5.44	81	79	2
Distillate Oil	Space heating	0.65	0.63	13	13	
	Water heating	0.10	0.09	2	2	
	Other uses	0.00	0.00	0	0	
	Total oil	0.75	0.72	15	14	1
LPG	Space heating	0.32	0.31	5	5	
	Water heating	0.09	0.08	2	1	
	Cooking	0.03	0.03	1	0	
	Other uses	0.01	0.01	0	0	
	Total LPG	0.45	0.43	8	7	1
Coal etc.	Total Coal	0.11	0.11	2	2	0
Grand Total		20.44	18.01	319	269	50

Source: Scenarios of U.S Carbon Reduction, Interlaboratory Working Group, Appendix C-2, Table C-2.5.b.

Note: Electricity energy values modified to include losses in generation and transmission.

Table 2-8
Commercial Energy End-uses and Carbon Emissions

Fuel	End-use	Primary Energy Use (quads)		Carbon Emissions (MtC)		
		Base	Controlled	Base	Controlle	Difference
Electricity	Space heating	0.35	0.29	6	4	
	Space cooling	1.52	1.26	25	19	
	Water heating	0.41	0.38	7	6	
	Ventilation	0.55	0.47	9	7	
	Cooking	0.09	0.09	1	1	
	Lighting	3.85	3.33	63	52	
	Refrigeration	0.47	0.38	8	6	
	Office PCs	0.29	0.29	5	5	
	Office other equipm	0.73	0.73	12	12	
	Other uses	3.15	2.49	52	38	
	Total electricity	11.40	9.71	187	151	36
Natural Gas	Space heating	1.36	1.16	20	17	
	Space cooling	0.03	0.02	0	0	
	Water heating	0.52	0.47	8	7	
	Cooking	0.23	0.23	3	3	
	Other uses	1.40	1.31	20	19	
	Total gas	3.54	3.20	51	46	5
Distillate Oil	Space heating	0.16	0.14	3	3	
	Water heating	0.05	0.05	1	1	
	Other uses	0.14	0.13	3	3	
	Total oil	0.35	0.32	7	6	1
Coal etc.	Total coal	0.34	0.34	7	7	0
Grand Total		15.63	13.57	252	211	41

Source: Scenarios of U.S Carbon Reduction, Interlaboratory Working Group,
Appendix C-2, Table C-2.6.b.

Note: Electricity energy values modified to include losses in generation and transmission.

The design of an emissions control program must reflect the fact that cost-effective opportunities for emissions reductions exist for both large and small sources, and in all sectors. Our prior experience with emissions trading programs in the United States has been only with large sources, primarily electric utilities. In Chapter 3, we present four alternative designs for a carbon emissions control system that recognize that the control approaches that work best for large sources owned by firms may not necessarily be those that work best for small sources chosen and used by individual consumers. Thus, some of the alternative designs in Chapter 3 are hybrids that include aspects of emissions trading and regulatory approaches.

SECTOR EMISSIONS REDUCTIONS

This section presents examples of the specific actions that result in the changes discussed above. It draws largely on the Interlab report for its discussion of technologies. “Cost effective” refers to energy with the \$50 per metric ton carbon permit price, not to today’s energy price. The Interlab results also imply aggressive implementation of non-price policies (e.g., efficiency standards) for some sectors such as buildings.

Buildings

The major use of fossil fuel in buildings is for heating, hot water, and cooking. Electricity is also used for these purposes and for cooling, lighting, refrigeration, and other electric equipment.

Heating and cooling services depend on the efficiency of the building envelope. New buildings can be designed fairly easily to be highly efficient. In fact, if passive solar features are included, heating and cooling requirements can be almost negligible. However, two factors will limit the gains that can be expected from new construction. First, some people will be unwilling to accept unusual designs or additional capital costs for efficiency improvements no matter how much they save on a life-cycle basis, and some builders will not be willing to incorporate them. Second, new construction in any year is only a couple of percent of existing stock, and turnover is very low. Therefore

the building stock in 2010 will not be greatly different from now. Overall, building retrofits for efficiency will be more important than new buildings in reducing energy requirements.

Retrofits such as caulking, additional insulation, and storm windows have been available for many decades. Many people undertook these measures in the 70's and 80's in response to higher energy prices. Many more buildings could still be usefully retrofitted now.

Improving the efficiency of equipment is even more important than improving the building shell, in part because equipment turns over much faster. Most of the refrigerators, air conditioners, washing machines, etc. that exist now will be replaced by 2010. If efficiency improvements can be incorporated by 2002, a large fraction of the equipment in service in 2010 will reflect the changes.

Table 2-7 lists the significant energy consuming items in the residential sector and the carbon emissions that are attributed to that usage for the base case and controlled case. Table 2-8 does the same for the commercial sector. For example, residential gas water heaters currently consume 1.4 quads of energy. In 2010, 30 percent of all existing water heaters will still be in use. These consume about 33.6 million BTU (MMBTU) annually on the average. The typical new unit available now consumes 29.7 MMBTU, so the average of all operating models will decline as they replace existing units. In addition, advanced units with improved insulation, electric ignition, and flue dampers with per unit energy consumption of 23 MMBtu/year could come on the market.

A new gas heater with these energy efficient features would cost \$126 more than a typical new unit. The purchaser would spend \$2.15 for every MMBtu saved amortized over the lifetime of the equipment⁹. For most consumers that would be a profitable

⁹ Interlab Study on U.S. Energy Efficiency and Greenhouse Gas Emissions, Appendix C-3. "Assumptions for Energy Efficiency Calculations," page B-3.7.

investment (a typical marginal cost for gas might be \$3.00/MMBtu), but not necessarily sufficiently attractive to overcome uncertainties over the value of the investment and possibly increased maintenance costs due to the greater complexity. Furthermore, the customer has to know about the option and be in a position to order it, which may preclude much new house construction where the developer sells already completed houses, and rental units. In such cases the decision maker may be more interested in lower capital costs than operating costs.

The Interlab high efficiency scenario for 2010 assumes that the achievable adoption level is 65 percent of maximum cost-effective levels, (using a 7 percent discount rate, a highly questionable assumption.) Because individual consumers are likely to require a more generous energy savings before they are motivated to buy more efficient equipment, financial incentives and other policy initiatives such as public information or equipment standards probably would be required. The control policies discussed in the next chapter should be judged on the basis of whether they are likely to prove adequate.

Industry

Energy use in the industrial sector is complex, but the five most energy intensive industries (Petroleum and Coal Products; Paper; Chemicals; Primary Metals; and Stone, Clay and Glass Products) account for about 70 percent of the total. These are described in Box 2-3. The industrial sector made remarkable progress in energy efficiency in the 1970's and 1980's in response to higher prices and concerns over reliability of supply. Fossil fuel use was lower in 1996 than in 1973, and electricity use up only about 10 percent. In that period, industrial output rose substantially.

The controlled scenario expects some additional efficiency improvements (2.4 quads of fossil fuel and 2.1 quads of electricity as shown in Table 2-2) relative to the uncontrolled scenario, but no massive savings. Heavy manufacturing has less potential for increased efficiency than light industry because the higher cost of energy has led to a

Box 2-3
Energy-Intensive Industries

Industries are characterized using data collected by the Bureau of the Census from establishments (plants) that are classified in a particular industry based on the value of the production of the plant and the industry that is identified as the origin of that product. This classification system, known as the Standard Industrial Classification (SIC), is being superseded this year by the North American Industry Classification System (NAICS). In addition Administration in the Manufacturing Energy Consumption Survey (MECS).

According to the 1994 MECS, the most energy-intensive industries were, in descending order, Petroleum and Coal Products (NAICS 324); Paper and Allied Products (321); Chemicals and Allied Products (325); Primary Metals (331); and Stone, Clay and Glass Products (327). The range of intensity of these industries is from 44.3 to 13.3 thousand Btu per dollar of output (Tbtu/\$). A brief description of these five most energy-intensive industries follows.

Petroleum and Coal Products. The major activity in this industry is converting crude petroleum into the petroleum products widely used in our economy - gasoline, diesel, fuel oil and lubricants. The process is a complex one of first separating the crude into different products, then recombining these components into the desired products. The separation is done through distillation and cracking that requires high temperatures and pressures, and is affected by the density of the original crude. Environmental considerations have greatly increased the complexity of this process, as reformulated and oxygenated fuels are increasingly needed to assure clean air quality. Another factor that has made for increased energy use in this industry is the declining availability of light crude and the greater processing requirements for heavy crude. Petroleum refining is the most energy-intensive industry with an intensity of 44.3 Tbtu/\$.

Paper and Allied Products. This industry converts fiber, usually from wood, into paper, pulp or paperboard, and then into a variety of products. The process begins with wood, which is first debarked and chipped, then either mechanically or chemically reduced to a slurry that is bleached, then formed into pulp, paper, or board. Though paper making is a very energy-intensive process, much of the energy used is derived from the biomass that is the basic feed stock for the process. The Forest Products Vision process combines this industry with wood products manufacturing, which includes saw mills, plywood mills and engineered wood products. In 1994, energy intensity was 18.5 Tbtu/\$.

Chemical and Allied Products. The major segments of this industry are basic chemicals; resins, synthetic rubber and manmade fibers; pesticides, fertilizer and other agricultural chemicals; pharmaceuticals and medicines; paints, coatings, sealants and adhesives; soap, cleaning compounds and toilet preparations; and other chemical products. Basic chemical production includes petrochemicals, industrial gases, and other inorganic chemicals, and other organic chemical manufacture. Basic chemical production uses the bulk of the energy required by this industry and creates the largest volume of products. In all of chemical manufacturing, heat and pressure are used to separate and combine chemical building blocks into saleable products, either for final consumers or to other manufacturing. In 1994, energy intensity was 16.0 Tbtu/\$. When only basic chemicals are considered, the intensity is about twice as high.

Primary Metals. This industry includes the production of iron and steel (a Vision industry), aluminum (another Vision industry), and a variety of non-ferrous metals - lead, copper and zinc are the most important. The production of iron and steel falls into three sub-industries. *Integrated producers* transform iron ore into pig iron, then convert this to steel. The refined steel is cast or rolled into primary products such as sheet, bars, and billets. *Specialty steel producers* convert pig iron or steel products such as stainless and other alloy steels. *Minimills* produce primary steel products from scrap steel, usually in an electric arc furnace. Aluminum producers convert alumina (aluminum oxide) into aluminum metal using an electrolytic process. The major producers also convert ore, usually bauxite, into alumina, but the operation falls within the chemical industry classification. The intensity of this industry in 1994 was 15.3 Tbtu/\$.

Stone, Clay and Glass Products. "Nonmetallic Mineral Products, under NAICS, includes cement, glass (a Vision Industry), bricks, lime and other stone and ceramic products. Pyroprocessing, or the application of heat to assure a chemical reaction, is required in most of these subindustries, which is what makes them so energy-intensive. Cement and lime are formed at high temperatures in a kiln; glass is produced by melting silica sand; bricks, china and pottery are just clay until fired. The intensity of this industry is 13.3 Tbtu/\$.

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions, p.43

continuous search for improvements. An estimate for the overall savings available is shown in Table 2-9. Improvements include simple housekeeping measures (cleaning steam traps), installing insulation on pipes and walls, better burners for boilers and furnaces, more efficient electric motors, and improved processes.

Additional carbon equivalent emission savings may come from low carbon technologies. Some companies have installed co-generation units for combined heat and power production, a process that greatly reduces the waste heat rejection of separate generating units. Co-generation could be greatly expanded, especially with the advent of competition in the electric power industry. Fuel switching to gas or biomass would also reduce emissions of CO₂. Process changes can also result in lower CO₂ emissions from sources other than fossil fuel combustion. For example, aluminum reduction cells consume a carbon anode in the process of reducing aluminum oxide to aluminum metal, releasing CO₂. The development of a cost-effective inert anode would eliminate this source.

Each industry is unique in many ways, and changes must be tailored to specific conditions. Some technologies are common to all, such as electric motors, boilers, and combined heat and power.

Transportation

All major forms of transportation have greatly increased their energy efficiency over the past 25 years, but this trend has largely leveled off. Both automobiles and trucks are now sold more on the basis of horsepower and other features than gas mileage, reflecting changes in customer priorities. Major reductions in energy consumption

Table 2-9
Industry-Specific Reductions in Carbon Emissions (MtC)

	Electric	Fossil	Total
Heavy Manufacturing	5.9	14.8	20.6
Pulp & paper	1	2.3	3.3
Bulk Chemicals	1.9	3.2	5.1
Petroleum	0.6	5.2	5.8
Glass	0.2	0.3	0.5
Cement	0.1	0.5	0.6
Iron & steel	1.1	2.3	3.4
Aluminum	0.4	0	0.4
Other	0.6	0.9	1.5
Light Manufacturing	17.8	9.7	27.4
Non-manufacturing	3.4	10.4	13.8
Total	27	34.9	61.9

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Emissions, Table 4.6.

could be gained in the transportation sector if manufacturers incorporated technologies now available, and if customers favored highly efficient cars. Further reductions in carbon emissions could be obtained by the use of alcohol and other non-fossil fuels (possibly including hydrogen.) Five quads of fossil fuel are expected to be saved in the Interlab scenario relative to the uncontrolled scenario, mostly via improved economy but with some alternative fuel.

A variety of steps could be taken in the near-term to increase vehicle economy, including weight reduction, aerodynamic drag reduction, reduced engine losses, and improved automatic transmissions and tires. Some advanced technologies could be introduced in time to contribute to meeting the 2010 goal, including direct-injection stratified charge gasoline engines and gasoline/electric and diesel/electric hybrid vehicles. Table 2-10 shows some of the more important technologies and their potential contribution to improved economy. It also includes some safety enhancements that would have negative implications for economy.

Alternative fuels have even more potential for reducing CO₂ emissions. At present, alternative fuels represent only a tiny fraction of all the fuel sold, mostly as additives to gasoline. In particular, ethanol from cellulosic biomass (plant material such as wood, agricultural residues, and municipal wastes instead of the commonly used grain) could approach (but not reach) the price of gasoline on an energy basis by 2010. At the expected price, ethanol would still be used as a blending agent (to increase the octane of gasoline and reduce emissions of regulated air pollutants). With additional price and other incentives, ethanol could be an independent fuel, but that is not likely to happen before 2010.

Table 2-11 compares the carbon emissions expected in 2010 with those of 1997 by transport mode. Over half the emissions and 70 percent of the reductions are expected from light-duty vehicles. New car economy is expected to rise from 27.5 now to 43.1 miles per gallon. Making the necessary changes would add about \$900 to the cost of the

car. Even at an implicit discount rate of 20 percent¹⁰, this investment would be cost-effective (at the assumed \$1.20 price of gasoline.)

Table 2-10
Potential Transportation Fuel Economy Gains from New Technology in 2010

Technology	Fuel Economy Improvement (%)
Material substitution	9.9
Drag reduction	9.2
Engine friction	5.0
Tires	5.0
ACC	1.0
Electric transmission	1.5
Electric power steering	1.5
Diesel hybrid	54.0
Safety/Environmental	
Air bags	-1.0
ABS	-0.5
Side-impact protection	-0.5
Roof crush protection	-0.3
Air Emissions Standards	-1.0
Total % improvement	100.0

Note: The percent improvement refers to the current 27.5 mpg. These technologies, if fully implemented, could result in a 55 mpg average automobile (100% more efficient than now).

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions, Table 5.3.

Electricity

More reductions in CO₂ emissions are expected from this sector than all others combined in all three analyses. Of the total 406 MtC expected by Interlab, 258 are attributed to electricity. As shown in Table 2-6, 88 MtC result from customer demand reductions in the buildings and industry sectors. The electric sector is directly responsible for the other 170 MtC. Most would come from replacement of coal by

¹⁰ New cars are owned by the initial purchaser for about 4 years, during which time much of its value has depreciated, including any additional investment for improved economy. Therefore most of that investment has to be paid off with the first 4 years to be of interest to the initial purchaser, even though it will continue to provide benefits for the remainder of the car's lifetime. This factor raises the discount rate for those future benefits beyond the level the purchaser might apply to other, longer-term investments.

Table 2-11
Carbon Emissions (MtC) by Transportation Mode

	1997	Base	Control	Reduct'n
Light-duty vehicles	279	346	273	73
Freight trucks	73	95	81	14
Freight Rail	9	10	7	3
Shipping	31	43	42	1
Air Transport	60	84	70	14
Military, transit, other	35	39	39	0
Total	487	616	512	104

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions
Table 5.11.

renewable technologies such as biomass, wind, and from capture of landfill methane. Extended nuclear plant life would serve the same non-carbon role, at least for a few years, but the effect is small and temporary. Together, renewables and nuclear in the Interlab scenario lead to a reduction of 130 MtC. Another 40 MtC would come from switching from coal to gas. In the IAT scenarios, fuel switching from coal to gas is more important than switching to renewables, presumably because of greater skepticism over the economics of renewable technology.

Over the past twenty years, improved end-use efficiency has been in the interests of both the utilities and their customers. Customers saved money through lower electric bills, and utilities avoided having to build expensive new plants. Many utilities instituted demand side management (DSM) programs to assist customers in finding and installing energy-efficiency equipment. However, it is not at all clear that this situation will continue. As discussed in Box 2-4, increasing competition in the electric power industry already is diminishing utility interest in these programs. Alternative means may have to be found to motivate consumers to make the investments necessary to achieve the 88 MtC reductions due to lower electric demand (see also Box 2-2).

Box 2-4

Potential Impact on Carbon Emissions of Competition in the Electric Power Industry

The U.S. Government and many state governments are promoting increased competition in the electric power industry. The Energy Policy Act of 1992 was one of the key factors in removing barriers to competition, but many states had already been moving in that direction. The main purpose is to bring the discipline of the market place to an economic activity that historically has been heavily regulated.

The traditional structure has been vertically integrated utilities that generate most of their own power, often at large plants in remote sites, deliver it to load centers on high voltage transmission lines, and then distribute it to customers on lower voltage local lines. Each utility is responsible for delivering all the electric power needed by customers in its area. In return for this grant of monopoly, the utility's rates to customers are controlled by a state regulatory agency. While many utilities have been diligent in controlling costs and keeping prices low for their customers, others have been less so, and there is a wide range in the cost per kilowatt, even among neighboring utilities. Competition is expected to allow the efficient electric companies to expand their operations, which, at least in theory, will lower average costs.

Competition could take many forms. A logical outcome would be restructuring of vertically integrated utilities into their three main components: generation, transmission, and distribution. Under such a scheme, which is somewhat similar to the way the natural gas industry is evolving, generating companies could sell their output to the highest bidder. That could be a transmission company, a distribution company, or a large consumer such as a big manufacturing facility. Transmission companies, which would still be regulated, would control and deliver most power, dispatching generating units to meet demand at the lowest possible cost. Distribution companies also would continue to play their traditional, regulated role, delivering power to most customers.

Increased competition raises several issues relevant to efforts to reduce carbon emissions:

- If competition works, prices will drop. That would undercut efforts to conserve, since high price is a motivating factor. All the scenarios discussed in this chapter count on significant electricity demand reductions (about 22 percent of all reductions in the Interlab scenario.) These estimates would be affected by lower prices.
- Many utilities have actively sought to help customers improve their efficiency of use of electricity through demand side management (DSM) programs. One of their main interests was avoiding building new generating plants. Competitive generating companies will have the opposite interests—building more plants and selling more power. Many utilities already have been reducing or eliminating their DSM programs in part to cut operating costs to get ready for competition. This trend further threatens estimates of substantial demand reduction to reduce emissions.
- On the positive side, competition is likely to spur the use of efficient gas-fired combustion turbines and co-generation facilities. To the extent that these replace coal-fired units, carbon emissions will drop. However, some may also replace higher cost nuclear units, which emit no carbon.
- Activities such as R&D could be reduced if a more fragmented and competitive industry loses interest in collective action. The Electric Power Research Institute has supported R&D for renewable energy. Utilities have felt some obligation to pursue these technologies to help meet long term goals even when not immediately competitive.

None of these issues are necessarily fatal to efforts to reduce carbon emissions and improve the efficiency of electricity use. Distribution companies may still be agents for efficiency improvements although they are not likely to be as active as utilities had been. Energy service companies also may play a large role. However, neither is likely to combine the interest integrated utilities had in reducing demand with their credibility with customers and financial resources. For example, service companies might be paid on the basis of the energy savings their investments produce. However, energy savings cannot be measured. They have to be calculated based on estimates of how much energy would have been consumed without investment. Individual consumers are likely to be wary of such abstract concepts.

Non-carbon fuels are particularly effective because every quad of coal they replace reduces emissions by about 25 million metric tons of carbon. No single renewable technology will be very important, but collectively they could exceed 10 percent of generation by 2010 and grow rapidly thereafter. Table 2-12 shows estimates of potential

Table 2-12
Renewable Energy Technology Potential for Reducing Carbon Emissions by 2010

Renewable Technology	Capacity Additions (total GWe)	Electricity/year (TWh)	Carbon Emission Reduction (MtC/yr)
Biomass Co-firing	8 to 12	58 to 88	16 to 24
Wind	8 to 23	28 to 81	6 to 20
Hydropower	10 to 16	23 to 35	3 to 5
Land-fill methane	3 to 7	20 to 50	25 to 53
Photovoltaics	3 to 5	6 to 10	1 to 2
Geothermal	6 to 14	47 to 110	6 to 16
Solar thermal	0 to 2	0 to 6	0 to 1
Total	38 to 79	182 to 380	57 to 121

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions, Table 7.5.

contributions to reductions. Hydroelectric power is by far the biggest renewable currently. It can be expanded, but many of the potential sites present environmental concerns. Furthermore, accommodating other uses of the facility (e.g., flood control, recreation) may limit the amount of power that can be generated. It also should be noted that hydroelectric generation is highly dependent on rainfall, and the major hydro areas, such as the Northwest, could see reduced rainfall as a result of climate change.

Biomass, mostly in the form of wood burned for co-generation in the forest products industry, is the second largest renewable energy source. Biomass as a fuel for electric generation could grow about 50 percent by 2010, to about 65 TWh¹¹, about 2 percent of total generation. The Interlab report suggests that co-firing with coal may be a particularly attractive option to reduce carbon emissions from existing units at costs lower than full replacement.

Currently, municipal solid waste (MSW) is the third most important renewable. Exploiting MSW has the added advantage that methane emissions are reduced. Methane is a potent GHG produced while waste decomposes in a landfill. It can be captured with appropriate equipment and burned for its energy value (methane is the principal constituent of natural gas). Regulations on the release of methane from landfills are also a powerful inducement to capturing it deliberately. MSW also can be burned directly and the heat used to generate power. With either approach, energy is produced and methane release reduced.

Wind could start to become important by 2010. Many wind farms have been constructed in California and other places where conditions are favorable. The economics of wind are very promising, though growth recently has been slowed by declining electricity prices.

¹¹ Energy Information Administration, Annual Energy Outlook, 1998, DOE/EIA-0383(98), December 1997, p199.

Switching from coal to gas for generating electricity has considerable potential. The electric power industry now dispatches generating units to meet changing loads largely on the basis of the cost of generation. Large coal plants often are among the plants with the lowest cost per kilowatt-hour. If a substantial cost for the carbon emitted were included, that calculus would change, and large reductions in CO₂ reductions could be obtained. There is not at present a wide range of plants to choose from, at least at peak load, but that could change rapidly. As coal plants are retired, they can be replaced by gas-fired plants. Alternatively, they could be converted to burn gas in the existing boiler. Not only do gas-fired plants produce less carbon per BTU, but modern gas turbines can be far higher in efficiency than existing coal plants.

The potential for such switching is very high. The amount of switching that would be economical depends on the instituted carbon charge, the gas-coal price differential that can be expected by 2010, and the economic value of lower emissions of other controlled pollutants such as SO₂ and NO₂ that would follow from conversion to gas. Other factors that might become important include a potential rise in the cost of gas turbines if orders outpace manufacturing capability, and the ability to break long-term coal supply contracts. Table 2-13 shows estimates of how much CO₂ emissions might be reduced by repowering for certain conditions. The value of the reductions of SO₂ and NO_x are very important in the economics of coal-to-gas conversions. The Interlab scenario suggests that the amount of switching will be less than the maximum because the target can be met at lower cost with renewables.

SECTOR DECISION MAKING

The scenarios discussed above suggest what must happen to the nation's energy system to meet the Kyoto Protocol. How that could be made to happen is, of course, a different question. As noted in Chapter 1, the types of policies that can be implemented can be classified under the categories of fuel supply restrictions, emissions limitations, and regulations such as efficiency standards. Four policy packages that establish a control and trading system based on these three approaches are the subject of the next chapter.

Table 2-13
Coal to Gas Repowering Potential

Externality Cases	Incremental Removal of (million tons):			Affected GW
	Carbon	SO2	NOx	
None	0	0	0	0
Low	23.6	0.3	0.6	20.2
High	83.4	2.5	1.9	83.3

Notes: Low externalities are \$700/ton for Nox
High externalities are \$100/ton for SO2 and \$1400/ton for Nox.
Gas/coal price differential in 2010 is \$1.18/MMBtu.
Includes a carbon permit price of \$50/metric ton.

Source: Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions, Table 7.2.

Energy taxes are not part of these policies, but price signals follow restrictions on the entry of fossil fuels into the energy system, thereby affecting all energy users.

Emissions limitations would be applied to large users of fossil fuels, electric generators in particular, but perhaps also heavy industry. Regulation refers to efficiency standards for equipment that uses energy. This section focuses on the decision makers in the energy system to review how they might react to policies to reduce carbon emissions.

The most important decision makers are listed in Table 2-14. These are the people who have to implement (or make it possible for energy users to implement) measures to perform various functions with reduced emissions of carbon. There are three ways to do this as shown in Table 2-6: improve efficiency; convert to a low-carbon fuel, or; convert to a non-carbon technology. For the most part, the policy initiatives to instigate one approach will work for all three. For example, fossil fuel price increases from fuel limitations will lead to efficiency improvements and fuel switching to either natural gas or non-carbon fuels.

Of the three approaches, efficiency will be the most important. Estimates of efficiency's share of the total reductions in the three scenarios were 54, 79, and 39 percent (average 57.) Next might come converting to low-carbon fuels, estimated at 10, 15, and 43 percent (average 23,) or non-carbon fuel with 36, 5, and 18 percent (average 20.)

Building sector reductions will come almost entirely from efficiency improvements. Building owners will be the key decision makers on investments to improve efficiency, but many others listed in Table 2-14 will be involved. All these actors have their own interests at heart, and that does not necessarily lead to installation of the most cost-effective option. The homeowner may be confused by the comparison of lower operating costs with higher purchase costs, or may be considering a move in a couple of years; an expensive, high-efficiency furnace or air conditioner may not add much to the resale value. The contractor may not want to carry a high-priced option that doesn't sell very well. Developers typically install low-end equipment that the buyer does not often

Table 2-14
Energy Decision Makers

Buildings

- home buyers
- homeowners replacing existing equipment
- contractors installing and selling the equipment
- stores that stock and promote equipment
- developers building new homes
- renters
- landlords
- banks and other mortgage lenders
- commercial tenants
- commercial building owners

Transportation

- automobile and truck purchasers and users
- dealers
- manufacturers
- banks and other lenders
- insurance companies
- public transportation officials
- taxpayers

Industry

- heavy manufacturing company executives
- light manufacturing executives
- non-manufacturing industrial executives
- facility managers
- financial investors
- stock holders
- manufacturers of energy using equipment

Energy Companies

- Electric utilities (or their successor divisions)
- independent power producers
- oil companies
- gas companies (including pipelines and distributors)
- coal companies
- shipping companies
- equipment manufacturers
- renewable energy entrepreneurs

Source: The Heinz Center

notice (e.g., furnaces): hidden quality doesn't sell well. Landlords have little interest in installing high efficiency equipment if the tenant pays the utility bills. Alternatively, tenants may be careless with heat and hot water if the landlord pays the bills. Relatively few banks apply sophisticated analysis in their lending review to credit the borrower with the lower operating costs of a higher priced house.

If price is to be the motivating factor, it may require a large increase. The EPA/DRI scenario predicts that energy savings will average about 4 million BTUs of fossil fuel and 600 KWh for every person in their homes. Meeting this target for a family of three might require improving the insulation and tightness of the house, replacing the refrigerator and water heater with highly efficient models, and possibly several other measures. These investments might cost \$1000 to \$2000 beyond what ordinary equipment would cost, and would save about \$150 to \$200 per year in energy costs¹². It is questionable whether the average family will be willing to spend that much based just on calculated cost-effectiveness. Supplementary information and incentive programs could be helpful in overcoming market barriers, thereby lowering the necessary price increase.

Regulations such as efficiency standards are likely to be effective where they can be applied in this sector. If the only refrigerators available are highly efficient models, people will buy them despite the additional cost. Demand for energy is then moderated, and prices need not rise to the painful level. However, standards are not appropriate for all equipment. Table 2-7 lists "Other uses" totaling 6 quads in the base case. These are the uses that, being too small to list, are probably too small to regulate. In addition, standards are ineffective for improving existing building shells, so only the part of the potential improvement in heating and cooling energy represented by equipment would be

¹² Approximate estimate based on methodology and data in the Interlab Appendix C-1, and assuming an average 15 year lifetime of the investment. Investments are assumed to save 12 million BTUs and 1800 KWh.

affected. Of the 20.44 quads for the base case in Table 2-7, perhaps 8 quads are reasonably subject to regulatory improvements¹³.

In the commercial part of the building sector (Table 2-8,) the scope for regulation also would be about 8 quads (out of 15.63). However, commercial establishments are operated more cost-effectively than residences, so the potential for improvements may be less. For example, many hotels have replaced hallway lights with compact fluorescent lamps because their efficiency is well worth the additional cost when they are operated continuously. Thus commercial buildings may be closer to light industry than residences in the response to price signals.

The **transportation sector** bears similarities and dissimilarities to buildings. Carbon reductions will come almost entirely from efficiency improvements, but there is some potential for non-carbon fuel (alcohol additives, as discussed in the Interlab report.) Achieving the 104 MtC of reductions in emissions estimated by the Interlab study will call for active participation by many actors listed in Table 2-14. Some of the control and trading programs discussed in the next chapter include direct requirements on manufacturers to improve fuel efficiency. Others would work indirectly through fuel prices.

Individuals buy most of the vehicles, and many are not very interested in fuel economy. If the price of gasoline goes up modestly, they are likely to continue buying the same types of vehicle and maintaining the same driving habits. The typical car might use about 600 gallons per year. For many people, a price increase of even \$0.50/gallon, which would average \$25/month, would not make a major dent in their budget (though they may complain vociferously about it.) Others, of course, would be very aware of increasing costs and would look for better efficiency on their next purchase, as many did

¹³ These rough estimates were made by summing the named equipment uses and adding 25% of the heating and cooling. The latter is assumed to be the fraction of the energy used in heating and cooling that could be eliminated if all equipment were replaced by perfectly efficient versions.

after the energy crises of the 1970s and '80s. Overall, price signals are likely to have only modest impact unless they are quite high.

Regulation could cover most of the energy used in the transportation sector, given enough time. There are only a relatively few manufacturers, and all products are known and traceable. The corporate average fleet economy (CAFE) standards imposed in the '70s are still in place and increasing them would be straightforward (procedurally if not politically.) Other forms of regulation might also be feasible, such as basing standards on corporate past performance. What fuel economy standards do not do, however, is cover driving habits or encourage public transportation. In fact, the lower cost of driving due to higher fuel economy encourages more driving. Designing the actual standard must take this factor into account.

Technological and economic feasibility is not enough to raise automobile economy by over 50 percent (as called for by the Interlab study.) Manufacturers have to produce these very efficient automobiles, and consumers have to select them from among all their other options. Manufacturers have to foresee demand for these cars several years before they can introduce them to the marketplace. Furthermore, fuel consumption in 2010 will be significantly affected only if new vehicle economy is improved several years earlier in order to replace a substantial fraction of the operating fleet. That means that significant steps have to be taken by industry within the next few years.

At present there is strong consumer resistance to gasoline taxes and strong industry resistance to toughened CAFE standards to increase economy. Without substantially increased interest in fuel economy on the part of consumers (which is possible with further evidence of global climate change), the transportation sector may be one of the most difficult in which to attain the target for reductions of emissions.

The 0.6 quads of non-carbon fuel expected by the Interlab study would be even more complex to instigate than efficiency improvements. The oil companies and their dealer

networks would have to be involved along with alcohol manufacturers and biomass producers. Car manufacturers might have to be the main force behind this initiative. If they saw increased alcohol use as a less expensive alternative to increased efficiency, they could coordinate the necessary activities. Thus their motivation would be the same (anticipated price increase or fuel economy standards based on carbon emissions) as for efficiency improvements.

The **industrial** sector gets almost all its carbon reduction from efficiency improvements, although Interlab sees an additional 0.3 quads of non-carbon fuel. Most companies are quite capable of deciding for themselves how to invest to lower costs and increase production. In general, industry responds effectively to price signals. Energy is a large cost item for many manufacturing companies, and a price signal gives proportional incentive to implement efficiency measures.

However the Interlab report expects most improvements to come from light manufacturing because these companies have not been so diligent in searching for opportunities (see Table 2-9). Since energy is only a few percent of total costs for such companies, the price signal is small and energy prices may have to rise considerably before investments to conserve would be very interesting to production and financial managers. Regulation in the form of efficiency standards for the common technologies, such as electric motors, may be effective for such companies. Direct regulation of emissions would be difficult to apply to small companies and non-manufacturing companies because there are a great number of them.

A cap on emissions--especially if the permits were tradable--could be effective with heavy manufacturing companies. Many large facilities are already regulated for air pollutant emissions, and this principle could be extended relatively easily to emissions of carbon. Enforcement would call for monitoring fuel purchases which should be easier than measuring stack emissions of SO₂.

The electricity sector may well be the most sensitive to policy changes because energy is such a high fraction of overall costs. Furthermore, the advent of new technologies, especially the gas turbine, and the introduction of competition in the industry (discussed in the previous section) may, up to a point, accelerate the transition to a lower carbon future. Unlike the other sectors discussed above, electricity is projected by all three scenarios to utilize efficiency, low-carbon fuels, and non-carbon fuels. Almost all the reductions produced by actions of the electric industry itself will be from conversion to low- or non-carbon fuels, and the policy initiatives will not necessarily differ whichever is the main goal.

Either economy-wide restrictions on fuel carbon or restrictions on carbon emissions from this sector would produce rapid responses. However, the changes would be difficult and expensive, and could not be completed in just a few years. Planning the transition will have to start soon for minimum disruption.

All the alternative non-carbon and low-carbon technologies discussed in the previous section would be favorably affected by an increasing the cost of high-carbon fuels. Biomass and wind have institutional infrastructures that could expand production fairly rapidly if the economics were right. Wind also has drawn enthusiastic entrepreneurs who would like to increase their activity. While price signals could be effective in promoting renewable development, capping carbon emissions from utilities could have the same effect. Utilities themselves could develop renewables or purchase the power from independent power producers as a way of avoiding high-priced carbon fuels.

These two types of policies should work no matter how far competition in the electric industry progresses. Under the current, integrated system, utilities are required to meet demand. If they can not do that at reasonable cost by burning the fossil fuel available under the control system, they will have to convert to lower carbon generation or buy power from someone who can produce within limits. Under competition, generating companies may not have the same obligation to meet demand, but some companies will

find ways to lower costs and undercut the competition. Reducing carbon emissions will be a major way to do that.

CONCLUSION

The United States can reduce its emissions to 1990 levels, but precisely how that might occur is still unclear. Modeling analyses contain many simplifying assumptions of how the economy functions, and many unpredictable events will occur before 2010. Such analyses are better as a guide to the changes effected by policy than as predictions of the actual future. In addition, policies are likely to be more complicated than the relatively simple carbon charges modeled in these analyses.

Nevertheless, the three scenarios presented here contain much useful information on how to attain that common goal. Each has different sectoral emphasis for attaining the total reduction. While these differences stem from different modeling approaches, they may also reflect a more fundamental reality; when policy is implemented, it is likely to be messy, affecting some sectors more than others.

Thus, to a degree, each sector can be looked at independently. Each will make some contribution to the goal, but more or less than even the best model might predict. This fuzziness is depicted in Table 2-15. The first part is the average of the maximum and minimum reductions for each sector calculated by the three scenarios as shown in Table 2-6. The next two parts show the maximum and minimum values in Table 2-6. Thus Table 2-15 presents a range for each sector instead of specific values. The total carbon emissions for the maximum and minimum entries bracket the target.

This table is useful to see how one sector can be played off against another. If one chooses to meet the target, but desires to go easy on the transportation sector, for example, then it will be necessary to force other sectors, such as electricity, to bear more of the burden. It would be difficult to meet the target if any sector reduces much

Table 2-15
Sectoral Bounds of Carbon Emission Reductions

Average		Carbon Reduction (MtC)			
		low-C	non-C	efficiency	total
small sources	Resident			30	30
	Commer			31	31
	Transport		4	73	77
large sources	Industry		2	78	80
	Electric	84	72		157

Maximum		Carbon Reduction (MtC)			
		low-C	non-C	efficiency	total
small sources	Resident			42	42
	Commer			33	33
	Transport		12	92	104
large sources	Industry		6	120	120
	Electric	162	130		231

Minimum		Carbon Reduction (MtC)			
		low-C	non-C	efficiency	Total
small sources	Resident			16	16
	Commer			29	29
	Transport			51	51
large sources	Industry			53	53
	Electric	40	18		69

Note: Values in the Total column are not necessarily equal to the sum of the other column which may be from different scenarios

Source: The Heinz Center.

less than the minimum listed here. Conversely, it is likely to be very expensive to force any sector to reduce more than the maximum.

The policies in the next chapter can be viewed with these ranges as background.

Economy-wide price increases (from restrictions on fuel sales) affect each sector, but some are more sensitive than others. Restrictions on carbon emissions are targeted on certain activities, but the resultant price increases affect all sectors. Efficiency standards may effectively lead to reductions where they are targeted, but they can only cover part of the economy.

Selecting the elements of the policy package to be implemented will call for skillful balancing of interests and views. It is not possible at this stage to produce a policy road map with a precise calculation of the least-cost combination. The economic and technological uncertainties are too great. In general, however, if one believes that most people and institutions will react rationally to price signals, one should give fuel restrictions first consideration. Alternatively, if it seems easiest to target those sectors that will react fastest, then emissions limitations may be favored. Efficiency standards probably can not do the job by themselves, but they can be an important supplement to make up for deficiencies in the two market approaches.

Appendix 2-1

Notes on Modifications to the Interlab Scenarios:

1. For the buildings sector, total energy use and carbon emissions are the same as in Chapter 3 of the Interlab study for both scenarios, but renewables are specifically identified here. The Interlab Group had lumped renewables (0.6 quads, mostly firewood, in 1990) with fossil fuel, though the carbon emissions had been calculated correctly. Specific fossil fuel use was determined from Appendix C-2.
2. For the industry sector analysis, the quantities of fossil fuels as listed were provided by Gale Boyd, of Argonne National Laboratory. These differ slightly from those in the report because there had been a small error in the computer calculations. The carbon emissions of the Interlab report (Chapter 4) are used, but the stated assumption on energy sequestering had to be modified to attain a better balance. For both scenarios, 6 quads of oil were reserved for non-energy use and said not to contribute to carbon emissions. However, when the carbon emissions for the three fossil fuels were added up, in both scenarios they were too low by about 15 MtC. It is assumed here that the sequestered fuel is about 5.3 instead of 7 quads. Not all non-energy carbon stays sequestered, and that factor may have been reflected in the model but not reported. The use of renewables was increased from the Interlab report to be consistent with EIA historical data, but that does not affect carbon emissions.
3. Energy and carbon emissions for the transportation sector were taken from table 5.8 of the Interlab report. Motor gasoline, distillate, jet fuel and residual are oil products. The 2.1 quad "other" in the low carbon scenario consists of 1.0 quads of gas (used in pipeline compressors, which will have to increase to handle the increased gas transmission,) 0.9 miscellaneous oil products and 0.2 of other renewables. Total renewables of 0.9 quads when this is added to the cellulosic ethanol. Most renewables are used as fuel additives. In the uncontrolled case, oil use is up substantially and renewables down, mostly because the initiative to pursue cellulosic ethanol would be insufficiently vigorous.
4. The Interlab calculations for electricity (chapters 6 and 7) were complex and not entirely consistent. Chapter 6 considers carbon-based dispatch of generation and conservation measures to reduce demand. Chapter 7 addresses fuel switching by generators. However, the 2 chapters are not closely linked even in the summary. Nowhere is a table included showing how the electric industry will meet demand while meeting its carbon budget, and apparently that calculation was not made.

The numbers used in the low carbon scenario in table 2-2 of this report were derived starting from the allowable carbon emissions. The other 3 sectors are responsible for a total of 973 MtC, which is 372 less than the goal of 1346 MtC. Therefore 372 MtC is the target for the electric sector. Since the total load is known (3420 TWh from 31.8 quads in table 6.4), division of the 372 MtC among the 3 fossil fuels must follow

determination of the load generated with fossil fuel, which must generate all the power that the non-carbon fuels do not. According to chapter 7, improved nuclear operations should compensate for the few closures expected by 2010, so assume the same 7.1 quads as 1996. Renewables could add about 280 TWh (Table 7.5) which is equivalent to about 2.6 quads. Adding that to the 3.9 of 1996 yields 6.5 for renewables. Total “other” is then 13.6 quads. At an average heat rate of 10,370 BTU/kwh, this could produce 1310 TWh, leaving 2110 TWh for fossil. Oil is likely to continue its rapid decline, so assume only 0.3 quads yielding 30 TWh and 6 MtC. Thus coal and gas must produce 2080 TWh and emit 366 MtC. This analysis assumes that the average generator in 2010 produces 101 TWh per quad of coal and 133 TWh per quad of gas (values derived from the data in the appendices for the equipment used in 2010). Since all other values have been assigned, the two unknowns quantities of coal and gas can be calculated:

$$101C + 133G = 2080$$

$$25.7C + 14.47G = 366$$

These simultaneous equations are solved for $C = 9.5$ quads and $G = 8.4$ quads.

For the Uncontrolled Case, nuclear is assumed to be down about 10% to 6.3 quads. Only about 1 quad of renewables is added to the current 3.9 for a total 4.9. Total “other” is 11.2 quads, leaving 26.3 for fossil. Oil might be a bit higher than in the controlled scenario, at 0.5 quads. Coal is assumed to drop a bit to 16 quads (relative to 1996) with increasing competition, and gas supplies 9.8.

5. Several minor inconsistencies between the summary and the sector chapters were resolved by using the detailed sector information wherever possible.

Appendix 2-2 Sources of Emissions Reductions

There are 3 ways to reduce carbon emissions from fossil fuel combustion without curtailing activities:

- * improved efficiency
- * conversion to non-carbon fuels
- * conversion to natural gas.

Following is an explanation of the accounting for the Interlab numbers in Table 2-6. The methodology for the EPA/DRI and DOE/NEMS results are similar.

Most of the 9 MtC from **buildings** is due to efficiency improvements (4.6 fewer quads). Some fuel switching is expected from oil to gas, but that will be ignored here because the impact is small.

Of the 35 MtC from **industry**, 6 is from increasing use of non-fossil fuels (0.3 quads replacing oil and coal). There is very little conversion to natural gas since gas consumption is down significantly. Efficiency accounts for 29 MtC.

Transportation's 104 MtC is 12 from non-carbon fuels (0.6 quads of alcohol) and 92 from efficiency.

The **electric** sector's total reduction of 258 MtC is a result of both user efficiency improvements (4020 TWh in the base case down to 3420 TWh) and generation decarbonization. It is apportioned between the two trends (using a cross-averaging technique) as 88 MtC from efficiency and 170 from decarbonization. The latter is again divided between non-carbon replacements (5.2 quads worth 152 MtC at the average remaining carbon intensity) and low-carbon fuels (the remaining 18 MtC; even though the use of natural gas for electric generation is lower in the controlled case than in the base case, it is higher than in 1996 and there is room for conversion from coal.)

Thus the totals are:

- * efficiency -- 218
- * non-carbon -- 148
- * natural gas -- 40

CHAPTER 3

ALTERNATIVE DESIGNS FOR A DOMESTIC SYSTEM TO CONTROL GREENHOUSE GAS EMISSIONS

Emissions trading will be central to any control system enacted to implement the terms of the Kyoto Protocol. The Kyoto Protocol recognizes international emissions trading as a method for Annex 1 (developed) nations to meet their emissions reduction commitments. President Clinton has announced that domestic and international emissions trading will be central to his climate change policy. However, little attention has been paid to the actual design of such a domestic program. A trading system could apply to fossil fuel producers, combustors, or a mixture. It could be designed to stand alone or be combined with regulatory standards, such as emissions standards. The design of a domestic control program will be critical as the debate moves from the targets and timetables agreed to in Kyoto to consideration of a control system to meet those commitments.

Presented here are alternative designs for a domestic program to control greenhouse gas emissions. In this chapter we will use the emissions reduction opportunities from Chapter 2 to help specify possible designs. We describe four alternatives. Our discussion of these four alternatives focuses on the emissions cap, control points, and coverage. For some designs we also consider allocation schemes, emissions standards, and trade implications. The chapter also includes a short discussion of how alternatives could incorporate early reduction credits, multiple greenhouse gases, electricity restructuring, and international reductions. In an appendix to this chapter, we conclude with an extensive discussion of different allocation methods. Allocating emissions permits is central to three out of four designs. Our discussion provides a more general description and comparison of different methods for allocating permits.

INTRODUCTION TO EMISSIONS TRADING

Emissions trading attempts to introduce flexibility into environmental controls. It allows the polluters themselves to develop the most cost-effective mix of controls, creating emissions reductions at lower costs than traditional command-and-control regulations.

Tietenberg (1985) gives a discussion of some economic aspects of emissions trading. A comparison of this approach to other environmental policy approaches is contained in Office of Technology Assessment (1995). Fisher et al. (1996) provides a similar comparison of policy instruments specific to climate change. A landmark study advocating the use of emissions trading and other market-based strategies to address national environmental problems was Project 88 (Stavins, 1988). This study, sponsored by Senators Wirth and Heinz, created a bipartisan constituency for using market-based instruments to attack environmental problems.

Overview of types of trading systems

According to Dudek et al. (1995), essential components of all trading system include: a method for assigning a limited property right to emit, the mechanisms for exchanging these rights, and opportunities for regulatory review and enforcement. These authors describe three basic trading models - the emissions reduction credit (ERC) model, the "cap and trade" or allowance trading model, and the discrete emissions reduction (DER) or open market model.

Dudek et al. (1995) describes the ERC model in the following manner. A permitted source makes a permanent emission reduction, obtains certification of the reduction from the local air quality regulator in the form of a permit modification, trades the credit, and obtains approval for the trade from the regulator. Under the ERC model, reductions are voluntary, permanent, and certified prior to exchange. The EPA's Emissions Trading Policy Statement (Environmental Protection Agency, 1986) codified the different types of trades acceptable under the ERC trading model. The rather cryptic terms used to describe these types of trades include "bubbles", "netting", and "offsets."

A cap and trade or allowance trading model requires that a source obtain an allotment of emissions permits to cover the emissions they generate over a given period of time. The source can obtain these permits through a government run auction or allocation system, or by trading with other market participants. At the end of the control period, the source submits accounting information to the regulator, retiring sufficient permits to cover their

emissions. Permits are fungible, and individual reduction strategies do not need regulatory review.

An example of a cap and trade system is the acid rain allowance system. Title IV of the Clean Air Act Amendments of 1990 uses tradable emissions permits or “allowances” to cut electric utility emissions by 50 percent or about 9 million tons. This represents the first large-scale application of permit trading to environmental controls. The Act sets a permanent cap on total annual allowances allocated to utilities. Under this system, utilities are allocated allowances based on their historical fuel consumption and a specified emissions rate. Each allowance allows a unit to emit one ton of sulfur dioxide. Allowances held by utilities may be bought or sold or banked for use in future years. The Environmental Protection Agency’s Acid Rain Program is in charge of the program. They operate the annual auction, opt-in program, emissions monitoring and reporting, and allowance tracking system as well as reconciling the annual emissions of a unit with its allowance holdings.

In contrast to the ERC program, the open market approach involves trading tons of already accomplished emission reductions, known as Discrete Emissions Reductions (DER). (The name “open market” was coined to reflect the absence of an emissions budget or cap, the so-called “closed market” systems.) A source measures and documents actual emission reductions and trades them. Unlike ERCs, DERs are not certified by the government at the time of creation. Rather, buyers of DERs evaluate the relative cost and quality of the reductions, make a purchase, and then seek government approval for their use. The government examines the DER after the trade is completed. The open market approach is not designed to replace existing regulatory systems, but is designed to exist simultaneously with them or serve as a precursor to more comprehensive trading systems. The EPA has proposed a general DER trading rule, their 1995 Open Market Policy Statement for States, to aid states in developing these program (Environmental Protection Agency, 1995).

INTRODUCTION TO ALTERNATIVE CONTROL DESIGNS

Other studies of domestic trading systems design (e.g., Smith et al., 1992; Environmental Law Institute, 1996), have organized systems around the point in the energy system that emissions are controlled. “Upstream” or “fuels” systems control carbon at or near the point of extraction. “Downstream” or “combustion” systems control carbon at or near the point of combustion.

The approach of the Heinz Center and its research collaborators has been somewhat different. We have attempted to construct a series of approaches focused around differing sets of core beliefs and values. The alternatives describe here have their own particular advantages including:

- compatibility with the current regulatory structure (Option I)
- reliance on a pure market approach (Option II)
- recognition of political compromises needed to enact controls (Options III and IV).

Our first alternative (Option I) has been constructed with an eye towards designing a control system that most closely resembles the methods and policy approaches incorporated under the Clean Air Act. This familiarity minimizes surprises—but does include some well understood weaknesses as well as strengths. The second alternative (Option II) is a “pure” market based approach, of greatest interest to those who believe that relying on price signals alone will lead to a preferred outcome.

The remaining two alternatives anticipate the outcome of political compromises that might be needed to enact a program. Option III is similar to Option II. Here, the focus is on sending the “right” fuel price signals through the economy. However, this alternative pays close attention to who may have to be “compensated” by assigning valuable pollution permits to large coal users as well as producers to meet fairness concerns about changing government policy. Option III also incorporates standards on combustion equipment to address the concerns of those that believe that relying solely on price signals will not necessarily produce the most efficient solution. Likewise, Option IV is

fairly close to the first, that is, it too focuses on the direct emitters of carbon dioxide. But again, as under Option III, some losers, such as coal producers as well as those who burn coal, are compensated.

OPTION I: TRADING/REGULATING CARBON DIOXIDE EMISSIONS AT THE POINT OF COMBUSTION WITH A HYBRID SYSTEM.

Basic control system description

Option I is a hybrid, end-use trading system allocating permits based on historical emissions to the largest individual consumers of fossil fuels (electric utilities, large industrial manufacturers, and process emitters) and capturing through regulatory or other types of tradable systems the more diffuse and smaller users of energy (residential and commercial fossil fuel users, smaller industrial firms, and transportation). Figure 3.1 displays a simplified representation of this design and Table 3.1 contains its description. Table 3.2 contains more detail on how this option affects each of ten major emissions categories.

The motivation is to control both combustors and end users in a manner most similar to the current regulatory structure to ease implementation. The design includes emissions trading among utilities and other large sources (similar to the current acid rain control program) and performance standards for appliances, vehicles, and other energy consuming devices (similar to those adopted in National Appliance Energy Conservation Act and the Energy Policy Act). A secondary goal is to avoid a gasoline price hike (a political constraint, rather than environmental objective). Option I relies on tradable vehicle fuel efficiency standards to limit emissions from cars and trucks.

Under this system, utilities and large industrial combustors of a certain size (e.g. boilers with fossil fuel use greater than 100 million Btu/hr or facilities consuming more than 1,000 tons of coal per year) would be required to hold permits. Each permit would allow a facility to emit a metric ton of carbon. Currently electric utilities and combustion of fossil fuels by large industrial manufacturers account for approximately 47 percent of all carbon dioxide emissions.

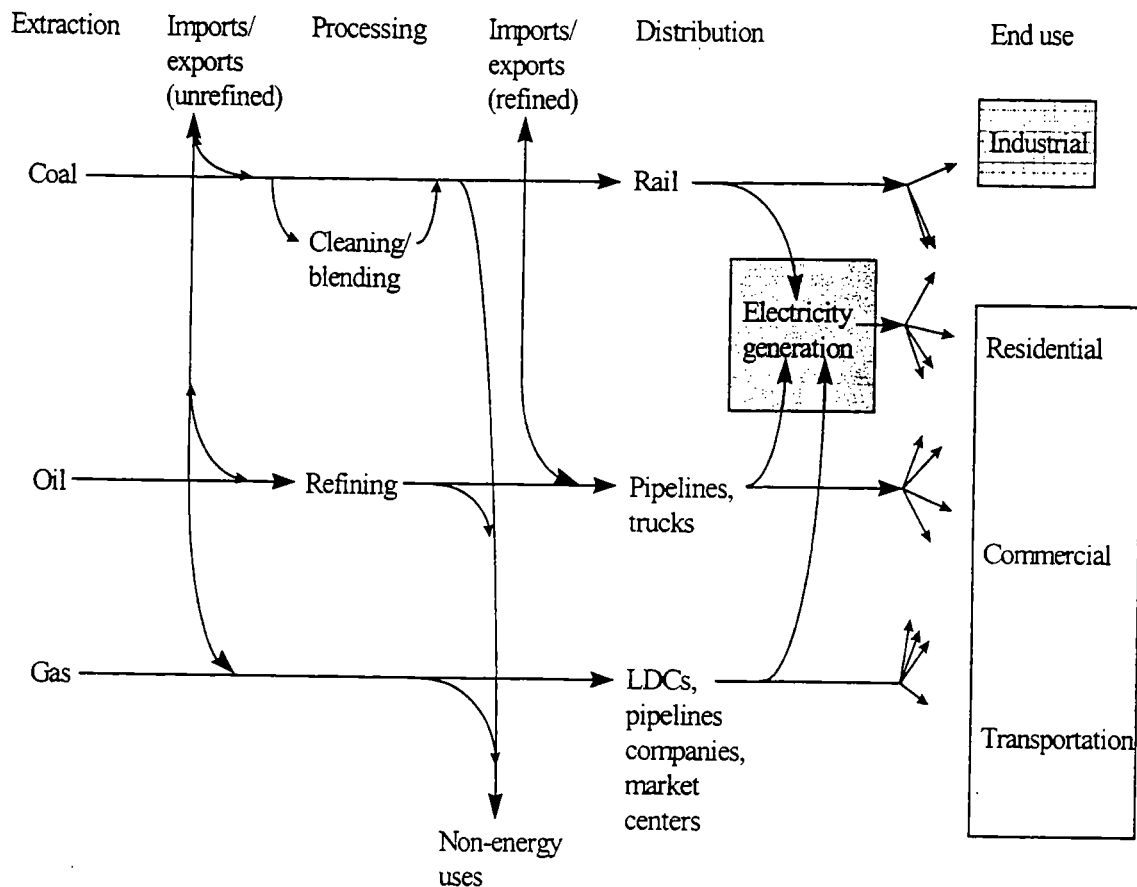


Figure 3.1 - Energy flows captured under *Option I: Trading/regulating carbon dioxide emissions at the point of combustion with a hybrid system*. Here the shaded region (electric utilities) and a portion of meshed region (large industrial combustors of fossil fuels) would be covered under a trading scheme. Other end uses (the region outlined in a rectangular box) would be regulated with efficiency standards. For light duty vehicles and trucks, this would be a tradable CACE.

Much of transportation-related emissions would be covered by efficiency standards regulating emissions rates. For cars and trucks, these could be a corporate average carbon emission standards (CACE). Transportation currently represents about 32 percent of all carbon dioxide emissions, with about 50 percent of transportation's emissions (about 16 percent of total emissions) coming from light duty vehicles. The CACE would be a tradable standard, as explained later.

Residential, commercial, and small industrial emitters of carbon would be partially regulated through efficiency standards for major appliances, HVAC equipment, water heaters, windows, lighting, and building shells. This would cover the approximately 11

Table 3.1 - Description of Option I: Trading/regulating carbon dioxide emissions at the point of combustion with a hybrid system.

- Allocate permits to large combustors and regulate more diffuse combustors through standards. Standards on automobile manufacturers will be tradable.

- *Points of control for trading system*

- *Fossil-fuel fired electric generators required to hold permits

- *Large industrial combustors and emitters required to hold permits

Large industrial combustors of fossil fuels

All refineries internal use of petroleum

Cement manufacturers process emissions

- *Point of control for regulated system*

- *Manufactures of fossil fuel transportation equipment

Tradable CACE for light duty vehicles and trucks

(tradable with large combustors and other auto manufacturers)

- *Manufacturers of commercial/residential equipment

Efficiency standards for HVAC equipment

Efficiency standards for water heaters and refrigerators

Efficiency standards for lighting

Efficiency standards for other household appliances

Efficiency standards for building shells

- *Core permit trading system*

- *Permits allocated to large fossil fuel combustors based on historical (e.g. 1990) emissions

- *Permits can be generated by auto manufacturers by beating some pre-specified CACE standard

- *Additions to permit trading system*

- *Set aside programs using permits skimmed off from allocation to finance early reduction credits and create incentives for renewable energy generation and energy conservation

- *Multigas trading

- *Carbon sequestration

- *Annex 1 and non-Annex I (Clean Development Mechanism) trading

Table 3.2 - Carbon control policies on emissions sources for Option I.

	<i>Emissions and % of 1994 inventory (MtC)</i>	<i>Affected by cap (price)</i>	<i>Affected by standards on manufactures of energy using equipment</i>	<i>Not affected</i>
<i>utility</i>	509 (36.5%)	emissions capped at fraction of 1990 levels	indirectly by standards on electricity using equipment	
<i>large manufacturing combustion</i>	164 (11.7%)	emissions capped at fraction of 1990 levels	efficiency standards for facility HVAC, other energy using equipment	
<i>small manufacturing fuel combustion</i>	18 (1.2%)		efficiency standards for facility HVAC, other energy using equipment	emissions from primary fuels unaffected by cap
<i>manufacturing electricity use</i>	188 (16.1%)	price signal from electricity sector cap	efficiency standards for facility lighting, other energy using equipment	
<i>non-manufacturing industrial</i>	93 (6.6%)	price signal from electricity sector cap on electricity-using equipment	transportation-related emissions regulated under efficiency standards	no controls directed at whole sector
<i>space heating and cooling (primary fuel and electricity)</i>	182 (13.1%)	price signal from electricity sector cap on electric space heating and cooling	efficiency standards for furnaces, air conditioning units, and building shells	
<i>lighting</i>	90 (6.5%)	price signal from electricity sector cap	fluorescent light efficiency standards	
<i>appliances</i>	209 (15.0%)	price signal from electricity sector cap	efficiency standards on refrigerators, water heaters	no efficiency standards for other appliances (e.g., televisions, clothes washers and dryers)
<i>cars and trucks</i>	347 (24.9%)		tradable efficiency standards with other auto manufacturers or large combustors	
<i>other transport</i>	103 (7.4%)		efficiency standards	

percent of all emissions from direct combustion in the residential and commercial sectors. It would also provide double coverage, along with a cap on electricity emissions, on the approximately 13 percent of all emissions that result from air conditioning, lighting, and electric hot water. These would increase the efficiency standards on refrigerators and freezers, central and room air conditioners, water heaters, furnaces, direct heating equipment and other energy-consuming devices adopted as part of the 1987 National Appliance Energy Conservation Act (NAECA) as well as the standard on lighting, office equipment, and electric motors adopted in the 1992 Energy Policy Act (EPACT). Although building shells are the purview of local and state governments, EPACT was partially successful in getting states to adopt more energy efficient building codes for new commercial and residential construction.

Basis for permit allocation

Allowances would be allocated to the large manufacturing industrial and electricity sectors based on historical carbon emissions, for example, emissions in 1990. Developing the allocation takes several steps.

The first step calculates the emissions cap for these two sectors. We estimate the emissions cap for electricity generators and all of industry using the system-wide cap and the potential reductions discussed in Chapter 2. The emissions cap for all sectors, after adjusting the Kyoto target for potential carbon sequestration and international trading, is 1350 MtC. The Interlab, DRI, and NEMS studies, described in Chapter 2, estimates the most cost-effective level of control for the residential, commercial, transportation, industrial, and electricity-generation sectors. Using the average of these three studies, we estimate the emissions from the industrial and electricity sectors at 700 MtC (400 for electricity generators and 300 for industrial). For the electricity sector this is about 83 percent of carbon emissions in 1990; for the industrial sector this is over 100 percent of their direct emissions.

However, not all industrial emissions would be covered under Option 1. For starters, approximately 20 percent of emission fall in the non-manufacturing industrial category.

This is emissions from agricultural, fishing, mining, construction, and forestry. Additionally, there are innumerable small manufacturing facilities that would be administratively difficult to include in a trading system. We assume that only 90 percent of manufacturing's two largest categories of energy consumption, boilers and process heaters, are covered (see Table 3.14 for a breakdown of industrial emissions by category). This puts the emissions target for the portion of the industrial sector that we feel is amenable to a cap at approximately 160 MtC, which is about 55 percent of all direct industrial emissions.

Because we have assumed 50 MtC would be purchased overseas, we further lower the target for these two sectors by 50 MtC. We divide this further to presume that 375 MtC would be allocated to electricity generators and 135 MtC would be allocated to industrial sources.

Although we've stated that under Option I, 47 percent of emissions are under the cap, the percentage of emissions allocated to this sector is somewhat lower (40 percent). This is because, as shown in Chapter 2, the reduction potentials for each sector is not the same. Each of the studies of emissions reduction potential attempts to equalize the marginal cost of reduction across all sectors. Electricity shows a much greater potential for emissions reductions than the other sectors. Although it would be much more straightforward to develop the emissions cap for large manufacturers and electricity sectors based on 1990 emissions, such a cap would imply that the emissions outside the cap would have to be ratcheted down by an amount greater than most studies deem cost effective or even possible.

Thus, the amount of emissions permits that would be allocated to these sectors is 375 MtC for electricity generators and 135 MtC for large industrial manufacturers. Under Option 1 these permits would be allocated to sources based on their emissions in a base year such as 1990.

Tradable CACE standard

The tradable corporate average carbon emissions (CACE) standard would be designed to allow the automotive industry a great deal of flexibility in meeting the standard. The CACE would be a two sided target, where any automaker beating the target could generate allowances for sale and any automaker not able to meet the target would be able to purchase allowances. These allowances would be estimated by translating emission rates from autos into lifetime emissions. Carbon emissions are a result of energy consumption and thus can be estimate from year-by-year vehicle miles and fuel efficiency. To be most effective, the allowances bought or sold—and the current market price of allowances—might be required to be posted on the vehicle sticker so that each purchaser can see how much he or she paid or saved for exceeding or beating the standard.

The allowances generated by automakers for beating a CACE would be a 10-year stream of dated allowances representing the time path of emissions reductions resulting from their action. Thus, for example, a fleet of vehicles produced in 2010 that was more efficient than the applicable standard would be given allowances for each year between and 2010 and 2020. These could be traded with other auto manufacturers, utilities or large industrial emitters, or banked. (Note, however, electric vehicles could not count as part of the corporate average or else reductions would be double counted.)

Most of the permits given to an automaker in a given year would be useable in some future year. This would help in the development of a futures market for allowances. However, automakers requiring permits (not meeting the CACE) may be required to hold all the permits up front, making it difficult for automakers to exceed their CACE standard in the early years.

The lag time involved in vehicle stock turnover becomes a critical issue with the use of a CACE standard to control automotive emissions. The CACE standard would obviously only apply to new cars -- older vehicles in the fleet would not be covered. After a 5 year time period, approximately 47 percent of automobiles and trucks would be built to meet

the new emissions standards (Davis and Hu, 1991). Because new vehicles are driven more than their older counterparts, the average percent of emissions covered would be about 55 percent. Thus, imposing standards on the transportation sector requires around a 5 year lag time before half of emissions are covered. However, the Kyoto Protocol does not allow banking of early reductions. Any early phase-in of the CACE, which would be quite helpful for meeting the Kyoto Protocol's cap, will need to be financed with credits from the first budget period or through some other mechanism (tax credits or other incentives not directly tied to permits). Credits could be awarded for only that portion of lifetime emissions reductions achieved after the beginning of the first budget period in 2008.

Partial coverage and double coverage

One problem with this hybrid system is that it leaves large sectors of emissions outside the emissions cap. Option I is a partial cap on carbon emissions, much as Title IV of the Clean Air Act Amendments of 1990 is a partial cap on sulfur dioxide emissions because it only requires allowances for electric utilities. Emissions from large industrial facilities and electricity generation—and thus indirectly emissions from all electric devices—would be capped under Option I. Emissions from other end uses would not be capped, but would be subject to standards. Generally, systems that rely on standards provide less certainty that the desired level of reductions will be achieved than under a full cap and trade system. Efficiency standards (carbon CAFE as well as other standards) typically regulate emissions rates, not quantity of carbon emitted. Emissions from these sources would not fall under a strict cap but be subject to usage factors beyond the reach of the permit system. For example, high efficiency cars might be driven more than anticipated or more cars may be sold, increasing emissions above the desired target.

Also outside of the emissions cap and regulatory system would be emissions from non-manufacturing industrial (construction, mining, agricultural, fishing, forestry) and small industrial facilities. The non-manufacturing industrial sector currently consumes about 18 percent of industrial energy use. However, much of the carbon emissions from this energy use would be covered indirectly through emissions controls on transportation and

electricity. Similarly, small manufacturing facilities would only be controlled through their electricity use.

Most of the emissions from energy use within buildings will be covered by either the cap on the electricity sector, efficiency standards, or both. Refrigerators, air conditioners, and other equipment that use electricity will be “double covered” by both the limits imposed by the cap and by efficiency standards. Note that just like automobile standards, standards that affect gas or oil burning equipment in buildings (e.g., furnaces) can only affect new sources. Thus the “coverage” of this part of the control program will be low at first and then increase through time as old equipment is retired and replaced by new and more efficient technology.

Value of permits passed out under permit allocation

Another issue associated with any allocation system is the value of permits passed out under Option I’s allocation. Allocating permits as opposed to auctioning them can partially compensate controlled entities. A critical aspect of this issue is assessing what is fair compensation for the increased costs or loss in revenues occurring from carbon controls. This is, of course, a political, rather than an analytical decision. We will provide some background information on the value of these permits versus some financial data from controlled entities to help inform the decision.

Using the cap for the electricity sector developed earlier and energy data (EIA, 1997a), one can estimate the value of permits passed out to the electricity sector under Option I. Assuming permits would be valued at \$75/metric ton of carbon (tC), the value of the permits annually allocated to the electricity sector would be about \$28 billion (with a range of \$9 billion at \$25/tC to \$56 billion at \$150/tC). As a point of comparison, the net electric utility operating income for investor-owned utilities in 1990 was \$34.6 billion on revenues of \$157.3 billion and expenses of \$127.9 billion. Net generation assets for investor-owned utilities in this same year was \$344.9 billion. Assuming that these permits were allocated to utilities for 30 years with a discount rate of 18 percent and that permit prices were constant over that time period, then the net present value of this string

of permits would be \$155 billion (with a range of \$66 billion at \$50/tC to \$310 billion at \$150/tC).

Note that under Option I's cap for the electricity sector we are proposing to allocate only 80 percent of their 1990 emissions. Thus, we calculate the value of permits assuming that only 80 percent of historical carbon is passed out in allocated permits.

Most of these permits would go to only a portion of the electricity sector, the coal-fired generators. These are also the entities under the greatest pressure to reduce emissions in most carbon control schemes. Table 3.3 shows the amount of carbon consumed, the value of that carbon, and some financial indicators for the second, third, and fourth largest consumers of coal among investor-owned utilities (the largest consumer of coal among electricity utilities is the Tennessee Valley Authority, a public utility). This table shows that for two of the utilities, PacificCorp and Georgia Power, the value of the carbon allocated (assuming \$75/tC) under Option I would exceed their net operating income.

Table 3.3 - Carbon consumption and financial statistics for 3 largest consumers of coal (in terms of short tons) among the investor owned utilities (all data for 1994). Note the value of the carbon is reduced by a factor of .73 because the electricity sector cap is 73% of the 1996 emissions.

	Carbon from fossil fuels consumed (10 ⁶ metric tons carbon)	Value of 73% of the carbon at \$75/t C (10 ⁶ dollars)	Electricity operating revenues (10 ⁶ dollars)	Electricity operating expenses (10 ⁶ dollars)	Net operating income (10 ⁶ dollars)	Net plant assets (10 ⁶ dollars)	NPV of permits for a 30 year stream at 18% discount rate
Georgia Power	17.2	942	4,160	3,267	893	10,489	5,202
Texas Utilities Electric Co.	16.2	887	5,604	4,312	1,292	17,999	4,899
PacificCorp	14.8	810	2,648	2,042	606	7,472	4473

Of course, comparing the value of permits to net operating income is but one way to assess the fairness of permit allocation and not necessarily the best one. Additionally, the value of permits in the future is highly uncertain. The issue of wealth transfer derived from the permit allocation will be a continuing focus of our study.

Overall and distributional effects

All programs designed to significantly control energy sector carbon dioxide emissions will have major overall and distributional consequences. During the upcoming collaborative process we hope to help shed some light on these impacts further. We also hope to incorporate modeling analysis from the AMIGA model to look at sector-specific domestic impacts and the SGM model to look at the potential for international reductions to lower the overall impacts.

GATT issues

The General Agreement on Tariffs and Trade (GATT) poses particular issues for allocation systems. In essence, GATT does not allow domestic products to be given any special advantages that would make them more competitive than foreign rivals. Some trade experts argue that allocating permits to domestic manufacturers gives these products an unfair advantage over their foreign competitors. Under Option I for example, domestic steel manufacturers would be given something of value that is not available to foreign manufacturers, some of whom may be under carbon regulations in their home country. Continuing discussions are underway with experts within and outside of the government on the GATT implications for all control designs that include permit allocations.

Standards lag and early reduction credits

A critical transition issue associated with Option I is the lag time necessary to have standards cover a significant portion of the energy consuming equipment. As discussed under the CACE description, it takes about 5 years for new CACE standards to impact over 50 percent of automotive emissions. This lag can vary widely as some equipment such as lighting, refrigerators, and hot water heaters turns over within a decade or two whereas building stock can take a much longer time. A partial solution to this problem is to give early reduction credits for any of the regulatory standards tightened earlier than 2008. However, any early reduction credits must come from the United States' first budget period because under the Kyoto Protocol early reductions by Annex I nations cannot be banked. Again, credit could be limited to that portion of the reductions that

would occur after 2008. Incentives to adopt more efficient equipment earlier could also use tax rebates, information programs, research and development funding, and government procurement.

Early reduction credits may also be extended to early utility and industrial reductions (i.e., those under the cap). But here again, a key issue is whether the United States is willing to accept a lower cap in the first budget period to encourage early reductions. If this is acceptable, credit might nevertheless be quite limited. For example, credits to these sectors might be limited to facilities built after a set date (e.g., no credit for facilities constructed prior to 1980 as these might be replaced prior to 2012 anyway. Reductions due to fuel switching or improved efficiency of output could also be given credit. Reductions due to decreased production might have to be disallowed due to the difficulty of determining whether compensating increases were just shifted to other facilities

OPTION II: LIMITING FOSSIL FUEL CARBON AT THE NARROWEST POINT ALONG THE SUPPLY CHAIN. PERMITS AUCTIONED.

Basic control system description

Option II caps the amount of carbon in fossil fuel that can enter the economy by imposing limits on sales from energy producers and distributors. Permits are auctioned (rather than given away) at the point of extraction for coal, refining for petroleum, and distribution for natural gas. Permits would also be required for imports of refined petroleum products. Figure 3.2 shows a schematic of this design and Table 3.4 describes this option. Table 3.5 contains more detail on how this option affects each of ten major emissions categories. This option comes closest to a “pure” market based alternative and gives incentives for efficiency improvements to all energy users. The overall cap on permits available through auction would be set based on the Kyoto target. Using Chapter 2, this cap would be at 1300 MtC lowered by the amount deemed necessary for any set aside programs.

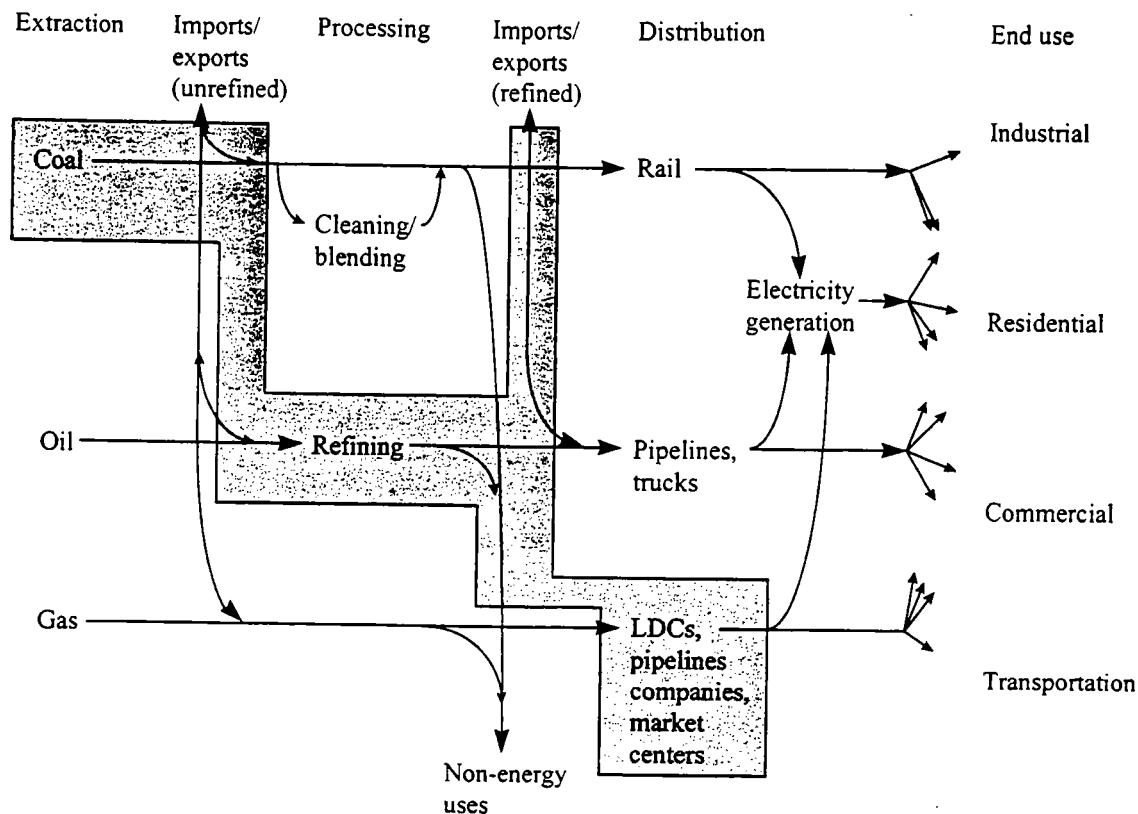


Figure 3.2 - Energy flows captured under *Option II - Limiting fossil fuel carbon at narrowest point in the supply chain. Permits auctioned*. This is a pure auction system that captures carbon at a point in the system where there are a minimum but still large number of permit holders.

Table 3.4 - Description of Option II: Limiting fossil fuel carbon at the narrowest point along the supply chain. Permits auctioned.
• Extractors, refiners, and distributors required to obtain permits through an auction or by purchasing them from other permit holders.
• <i>Points of control for trading system</i> * Coal extractors required to hold permits * Oil entering into refineries required to hold permits * Importers of refined petroleum products required to hold permits * Natural gas pipeline companies required to hold permits
• <i>Core permit trading system</i> * Permits auctioned to controlled entities
• <i>Additions to permit trading system</i> * Set aside programs using permits skimmed off from cap to create incentives for renewable energy generation and energy conservation * Multigas trading * Carbon sequestration * Annex 1 and non-Annex I (Clean Development Mechanism) trading

Table 3.5 - Carbon control policies on emissions sources for Option II.

	<i>emissions or % of 1994 inventory (MtC)</i>	<i>Affected by cap (price)</i>	<i>Affected by standards on manufactures of energy using equipment</i>	<i>Not affected</i>
utility	509 (36.5%)	price signal from cap on primary fuels		
large manufacturing combustion	164 (11.7%)	price signal from cap on primary fuels		
small manufacturing fuel combustion	18 (1.2%)	price signal from cap on primary fuels		
manufacturing electricity use	188 (16.1%)	price signal from higher electricity prices due to cap on primary fuels		
non- manufacturing industrial	93 (6.6%)	price signal from cap on primary fuels (including higher electricity prices)		
space heating and cooling (primary fuel and electricity)	182 (13.1%)	price signal from cap on primary fuels (including higher electricity prices)		
lighting	90 (6.5%)	price signal from higher electricity prices due to cap on primary fuels		
appliances	209 (15.0%)	price signal from cap on primary fuels (including higher electricity prices)		
cars and trucks	347 (24.9%)	price signal from cap on primary fuels		
other transport	103 (7.4%)	price signal from cap on primary fuels		

Parry et al. (1996) and Parry (1997) conclude that an auction system has a smaller economic impact than a system in which permits are allocated provided auction revenues go for reducing taxes on labor. The Interagency Analytical Team (1997) analysis emphasizes that the choice of revenue recycling options will determine the economic efficiency of the auction system. Their conclusions indicate that using revenues to reduce personal income tax rates, though politically popular, lowers Gross Domestic Product more than a system in which permits are allocated to combustion sources.

The motivation for the particular configuration of this system is to choose control points that minimize the number of permit holders, lowering administrative burden and transaction costs. The supply chain narrows at the point of oil refinement, with output from thousands of oil producers being sent to a lesser number of refineries. Pipelines represent a similar narrowing point for natural gas. Coal lacks a similar essential narrowing point, so we propose that it be regulated at the point of extraction. This system lowers the number of permit holders compared to a system controlling exclusively at the point of extraction. There are approximately 180 petroleum refineries, 130 natural gas pipeline companies, and 2800 coal companies that would be required to hold permits under this proposal.

This system would capture almost all energy-related carbon that could potentially end up in the atmosphere. Because allowances are auctioned rather than allocated, one does not have to worry about violating GATT rules prohibiting advantages to domestic producers (discussed under Option III). As a majority of oil and a small but growing fraction of natural gas is imported, this is an important consideration. Additionally, permitting oil as it enters into refineries captures energy used in the refinement process. It would not, however, account for fossil fuels used for non-energy purposes or exports of coal.

Permitting points for coal and natural gas

There is some question as to whether these are the best control points for coal and natural gas. Using other points in the coal system, such as at the preparation plant or shipping,

would minimize the number of required permit holders. But not all coal passes through preparation plants and coal shipping, usually by railroad, can be more variable than gas pipelines. Currently we feel that the point of extraction is the least ambiguous control point. An alternative control point was recently suggested by one collaborator. Their contention was that, since a high percentage of coal is combusted by a fewer number of entities than companies that mine coal, it is at the point of combustion that the coal system narrows. We will explore this idea further in the future.

Our current proposal for this design is for pipeline companies to be the point of control for natural gas use. Under deregulation of the natural gas industry, the Federal Energy Regulatory Commission has separated transmission and storage services from the sale of natural gas. Thus, pipeline companies would not own the product for which they would be required to hold allowances. An alternative control point would be to require that permits be held by the operators of local distribution systems or, if gas is removed from a pipeline before it reaches a local distribution system, by the person receiving the natural gas at the time of its removal. This was the language used in the 1993 Btu tax, proposed in 1993. The primary disadvantage in requiring local distribution companies to hold permits is that this is not a constriction point in the natural gas system.

OPTION III: FULL CAP AND TRADE ON EXTRACTORS AND IMPORTERS WITH REGULATORY ASSIST. PERMITS ALLOCATED TO SUPPLIERS AND COMBUSTORS

Basic control system description

An option for a more complex, but possibly more politically attractive system is shown in Figure 3.3. Option III is a system controlling energy suppliers augmented by regulatory standards. Table 3.6 describes its basic components. Table 3.7 contains more detail on how this option affects each of ten major emissions categories. Under this system, all producers or importers of fossil fuels must hold permits to cover their carbon production. The overall cap on permits allocated would be set at 1300 MtC, as described in Chapter 2, lowered by the amount deemed necessary for any set aside programs.

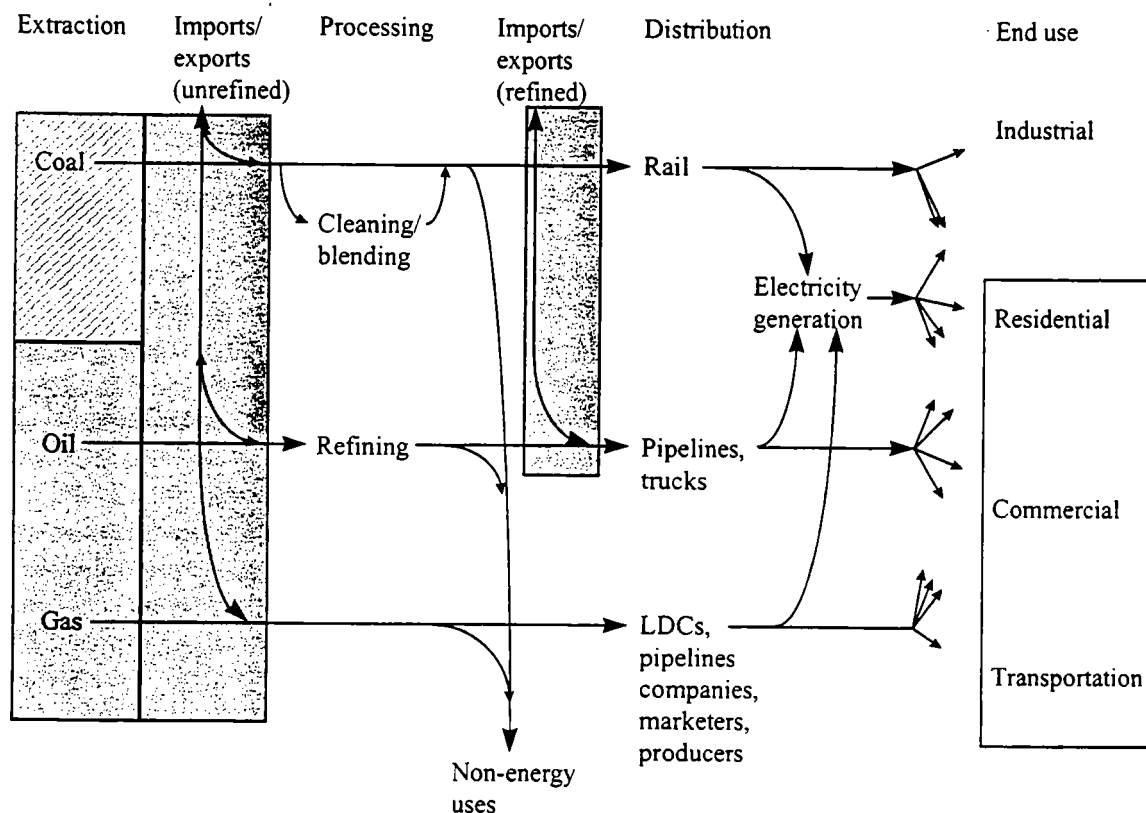


Figure 3.3 - Energy flows captured under *Option III - Full cap and trade on extractors and importers with regulatory assist*. Permits allocated to suppliers and combustors. Under this system, domestically produced and imported fossil fuels would be allocated permits (solid and diagonal shading). The allocation of permits for coal (diagonal shading) would be split between producers and combustors. End uses (the region outlined in a rectangular box) would be regulated with efficiency standards.

Option III allocates allowances to fossil fuel producers as well as coal combustors. The allowance allocation to oil and natural gas uses the carbon content of their production or importation in a base year such as 1990. Using 1990 as the base year, the allocation would have to be lowered slightly by the ratio of the 1300 MtC cap (minus whatever is diverted for set aside programs) divided by the 1990 production. The total allocation to coal is calculated in the same manner as for oil and natural gas, but it is split evenly between producers and combustors. Coal producers are allocated somewhat less than half of their carbon production. Remaining allowances go to large coal combustors based on their consumption in the base year. Regulatory standards augment the design to improve the overall performance of the system.

Table 3.6 - Description of Option III: Full cap and trade on extractors and importers with regulatory assist. Permits allocated to suppliers and combustors.

- Extractors and importers required to hold permits with permits allocated to both suppliers and coal combustors, standards on manufacturers of residential/commercial energy consuming equipment used to augment trading system.

- *Points of control for trading system*

- * Coal, oil, and natural gas extractors required to hold permits
- * Importers of natural gas, coal, and unrefined and refined petroleum products required to hold permits

- *Point of control for regulated system*

- *Manufactures of fossil fuel transportation equipment
CACE for light duty vehicles and trucks
- *Manufacturers of commercial/residential equipment
Efficiency standards for HVAC equipment
Efficiency standards for water heaters and refrigerators
Efficiency standards for lighting
Efficiency standards for other household appliances
Efficiency standards for building shells

- *Core permit trading system*

- *Permits allocated to large fossil fuel extractors and importers as well as large coal combustors based on historical (e.g. 1990) production and emissions. Permits

- *Additions to permit trading system*

- *Set aside programs using permits skimmed off from allocation to finance early reduction credits and create incentives for renewable energy generation and energy conservation
- *Multigas trading
- *Carbon sequestration
- *Annex 1 and non-Annex I (Clean Development Mechanism) trading

The motivation of such a system is to use the permit allocations to compensate fossil fuel producers and coal combustors and use standards to improve system performance. A small fraction of the allocation could be held back to use to support projects increasing energy efficient and the use of renewable energy sources.

Regulatory standards under Option III would not be tradable as allowances. If standards were tradable, as they are in Options I and IV, there would be the problem of double counting reductions. For example, if an automaker would beat their CACE to generate

Table 3.7 - Carbon control policies on emissions sources for Option III.

	<i>emissions or % of 1994 inventory (MtC)</i>	<i>Affected by cap (price)</i>	<i>Affected by standards on manufactures of energy using equipment</i>	<i>Not affected</i>
utility	509 (36.5%)	price signal from cap on primary fuels, mitigated by permit allocation to coal utilities	indirectly by standards on electricity using equipment	
large manufacturing combustion	164 (11.7%)	price signal from cap on primary fuels, mitigated by permit allocation to large coal using industries		
small manufacturing fuel combustion	18 (1.2%)	price signal from cap on primary fuels		
manufacturing electricity use	188 (16.1%)	price signal from higher electricity prices due to cap on primary fuels		
non-manufacturing industrial	93 (6.6%)	price signal from cap on primary fuels (including higher electricity prices)	transportation-related emissions regulated under efficiency standards	
space heating and cooling (primary fuel and electricity)	182 (13.1%)	price signal from cap on primary fuels (including higher electricity prices)	efficiency standards for furnaces, air conditioning units, and building shells	
lighting	90 (6.5%)	price signal from higher electricity prices due to cap on primary fuels	fluorescent light efficiency standards	
appliances	209 (15.0%)	price signal from cap on primary fuels (including higher electricity prices)	efficiency standards on refrigerators, water heaters	
cars and trucks	347 (24.9%)	price signal from cap on primary fuels	efficiency standards	
other transport	103 (7.4%)	price signal from cap on primary fuels	efficiency standards	

permits, it would also reduce petroleum demand, generating extra permits for oil extractors and importers.

An alternative approach is to allow Emissions Reduction Credits (ERC) trading only among all manufacturers that fall under the standards. Credits would be calculated based on lifetime emissions of each energy consuming device (car, refrigerator, etc.) This would provide a “safety” valve to allow more stringent standards to be set than might otherwise would be acceptable if every product and manufacturer had to meet its target.

Issues in the treatment of coal extractors and combustors

Allocating permits to both coal producers and large coal combustors recognizes that these are the two most vulnerable sectors under carbon controls. Granting permits free of charge is a tool to compensate controlled entities for the losses they would incur and improve the political viability of a control design. The design of Option III also recognizes that, because coal has a greater carbon content per unit energy, so too is the value of coal’s allowances per unit energy. The value of permits allocated under this option seems to be sufficient to compensate coal producers with substantial amounts remaining to compensate large coal combustors for the loss of useful life of their facilities. If we again assume that the value of permits is \$75 per metric ton of carbon, the value of the carbon produced in 1990 by the coal sector for domestic consumption was \$38 billion - about twice the value of production (with a range of \$13 billion at \$25/tC to \$101 billion at \$200/tC). In 1990 the value of the coal produced in the United States was approximately \$22 billion.

Option III does not address all of the distributional issues associated with allocating permits. The possible losers under carbon controls include not only companies that extract and combust coal, but also the employees and communities that depend upon these companies for their livelihoods. Thus additional policy measures may be needed to compensate all of the parties most affected by carbon controls.

GATT issues

According to preliminary discussions held with trade experts, allocating permits to fossil fuel extractors requires that, somewhere in the import chain, permits also be allocated. Clearly it would be quite difficult politically to adopt a system that gives a permit allocation to, for example, Iraq or Iran. One suggestion was to allocate permits to the importer of foreign oil. Others have said that this would be insufficient to cover the problem, thus calling into question whether any trading system allocating permits to domestically produced and foreign energy sources would be both acceptable domestically and legal under GATT. Clearly this issue must be resolved if the type of approach presented is to be seriously considered.

Use of standards with a fuels cap

Regulatory standards are included in this option as “backstop measures” to improve the performance of the system. Many economists argue that a price signal alone is the preferred approach to induce the “correct” amount of energy efficiency improvements. In this view, capping carbon at the point of production is sufficient to optimize consumers’ choices in the purchase of energy consuming equipment. However, other studies have shown that individual consumers seem to be far more interested in lowering up-front costs than lifetime fuel savings when it comes to purchasing energy saving equipment.

An example of this argument can be seen in Novice and Crandall (1996) and Green (1997), who present contrasting views of the importance of price versus regulatory signals for improving automobile efficiency. Novice and Crandall argue that it was the oil price hikes of the late 1970’s that induced increases in automotive efficiency. Green (1997) argues that it was the CAFE standards that increased efficiency in autos and that energy prices would have to be very high to achieve the same efficiency increases. Consumers often choose the certainty of lower up-front costs over the uncertainty of the performance of energy efficient equipment and are often concerned about the possible reduction in amenity associated with using more efficient technologies. Introducing standards for end use equipment helps to address this tendency and, at least in the opinion

of some, reduce the cost of carbon reductions. Box 2-2 contains a further discussion of price versus regulation.

OPTION IV: TRADING/REGULATING CARBON DIOXIDE EMISSIONS AT THE POINT OF COMBUSTION WITH A HYBRID SYSTEM. PERMITS ALLOCATED TO COMBUSTORS AND COAL EXTRACTORS

Basic control system description

Another option for a more complex but possibly more politically attractive system is shown in Figure 3.4. Option IV is a combination of Option I, which imposes a “cap and trade” system on large combustors, and Option III, which splits the coal allocation.

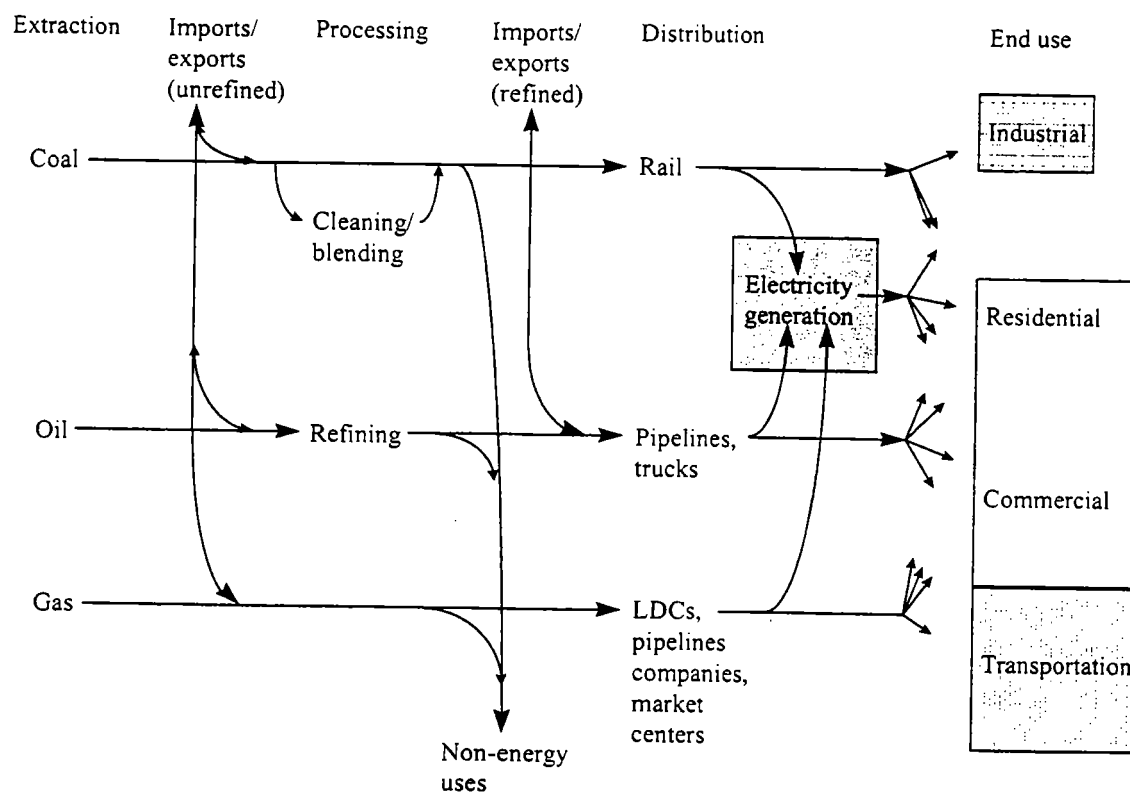


Figure 3.4 - Energy flows captured under Option IV: Trading/regulating carbon dioxide emissions at the point of combustion with a hybrid system. Permits allocated to combustors and coal extractors. Here the electric utilities (shaded region) and large industrial combustors of fossil fuels (square meshed region) would be covered under a trading scheme. Some of the permits not allocated to combustors would be allocated back to coal extractors. The transportation sector (vertical meshed region) will be regulated with a tradable emissions cap on future emissions potential. Other end uses (the region outlined in a rectangular box) would be regulated with efficiency standards.

between coal extractors and coal combustors. Table 3.8 describes its basic components. Table 3.9 contains more detail on how this option would affect each of ten major emissions categories. As with Option I, Option IV allocates permits to the largest individual consumers of fossil fuels (electric utilities, large industrial manufacturers, and process emitters) and focuses on manufacturers of energy consuming equipment to improve the efficiency of the more diffuse and smaller uses of energy (e.g., residential and commercial fossil fuel use and transportation). In contrast to Option I, Option IV would: 1) allocate permits to coal extractors in addition to large combustion sources; 2) emissions based on a type of performance standard rather than on historic emissions; and 3) come closer to a true cap on automotive emissions.

As under Option III, the motivation for using permit allocations to compensate fossil fuel combustors and coal producers is to help compensate those most hurt by the new policy. The somewhat more constraining approach to controlling motor vehicle emissions adds a bit more certainty about the reductions likely to be achieved from this sector. As with the other allocation options (Options I and III), this system could hold back a small fraction of the allowances to support projects that increase energy efficiency or renewable energy.

Basis for permit allocation

This option allocates permit to the industrial and electricity sectors using a two step procedure. First, the emissions cap for each sector is calculated using historical energy usage and the carbon content of natural gas. Thus, the total emissions allocated to each sector is based on the emissions that would have occurred if natural gas – the lowest carbon emitting fuel – had been substituted for coal and oil in a base year such as 1990. For the electricity sector this would produce a total cap of 295 MtC; for the large industrial manufacturers this would produce a total cap of 135 MtC. Assuming again that these two sectors would purchase 50 MtC of permits overseas, the amount of permits allocated under Option IV would be 380 MtC.

The second step develops the allocation to individual electricity and industrial facilities. For electricity generators, permits are allocated to individual sources based on their share

Table 3.8 - Description of Option IV: Trading/regulating carbon dioxide emissions at the point of combustion with a hybrid system. Permits allocated to combustors and coal extractors

- Allocate permits to large combustors and regulate more diffuse combustors through standards. Standards on automobile manufacturers will be tradable cap on emissions potential.

- *Points of control for trading system*

- *Fossil-fuel fired electric generators required to hold permits

- *Large industrial combustors and emitters required to hold permits

- Large industrial combustors of fossil fuels

- All refineries internal use of petroleum

- Cement manufacturers process emissions

- *Manufactures of fossil fuel transportation equipment required to hold permits

- Tradable CCE cap for automobiles

- *Point of control for regulated system*

- *Manufacturers of commercial/residential equipment

- Efficiency standards for HVAC equipment

- Efficiency standards for water heaters and refrigerators

- Efficiency standards for lighting

- Efficiency standards for other household appliances

- Efficiency standards for building shells

- *Core permit trading system*

- * Cap on permits allocated to large fossil fuel combustors based on historical (e.g.1990) energy usage and natural gas emissions coefficient. Permits allocated to individual fossil fuel electricity generators based on output performance standard. Permits allocated to large industrial combustors based on input performance standard. Extra permits allocated to coal extractors based on historical production

- *Permits allocated to automakers based on fleet's future emissions commitment

- *Additions to permit trading system*

- *Set aside programs using permits skimmed off from allocation to finance early reduction credits and create incentives for renewable energy generation and energy conservation

- *Multigas trading

- *Carbon sequestration

- *Annex 1 and non-Annex I (Clean Development Mechanism) trading

Table 3.9 - Carbon control policies on emissions sources for Option IV.

	<i>Emissions or % of 1994 inventory (MtC)</i>	<i>Affected by cap (price)</i>	<i>Affected by standards on manufactures of energy using equipment</i>	<i>Not affected</i>
utility	509 (36.5%)	emissions capped at fraction of 1990 levels	indirectly by standards on electricity using equipment	
large manufacturing combustion	164 (11.7%)	emissions capped at fraction of 1990 levels	efficiency standards for facility HVAC, other energy using equipment	
small manufacturing fuel combustion	18 (1.2%)		efficiency standards for facility HVAC, other energy using equipment	emissions unaffected by cap
manufacturing electricity use	188 (16.1%)	price signal from electricity sector cap	efficiency standards for facility lighting, other energy using equipment	
non- manufacturing industrial	93 (6.6%)	price signal from electricity sector cap on electricity- using equipment	transportation- related emissions regulated under efficiency standards	no controls directed at whole sector
space heating and cooling (primary fuel and electricity)	182 (13.1%)	price signal from electricity sector cap on electric space heating and cooling	efficiency standards for furnaces, air conditioning units, and building shells	
lighting	90 (6.5%)	price signal from electricity sector cap	fluorescent light efficiency standards	
appliances	209 (15.0%)	price signal from electricity sector cap	efficiency standards on refrigerators, water heaters	no efficiency standards for other appliances (e.g., televisions, clothes washers and dryers)
cars and trucks	347 (24.9%)		cap on emissions tradable with other auto manufacturers or large combustors	
other transport	103 (7.4%)		efficiency standards	

of total electricity output. Individual industrial sources receive their share of the industrial total based on the amount of fossil fuel energy they purchased in the base year. Appendix 3-1 describes these allocation methods in greater detail.

Under this option, we propose that the allocation to individual sources change through time. The original allocation would apply to the first budget period of 2008 to 2012. For the second budget period, the *total* emissions allocated to each sector would remain the same as for the first. However, the allocation to *individual* sources would be recalculated using the same approaches described above, but based on the electricity generated or energy purchased in 2010 (or a recent multi-year average.) By updating the allocation to individual sources, new electricity generators or industrial sources eventually are treated equally with existing sources and sources that shut down eventually stop receiving permits. This also creates an incentive for reducing emissions through both fuel switching and use of more efficient generating technologies, while still providing some compensation to controlled entities.

The cap on industrial and electricity sector emissions is quite a bit less than 1990 emissions and even less than the modeling studies presented in Chapter 2 estimate to be the most cost-effective level of control for each sector. Under Option 1 we assume that the allocation to the industrial and electricity sectors would be capped at about 510 MtC. Compared to the Option 1 cap, Option 4's allocation cap is 380 MtC. This allows a significant allocation (perhaps 100 MtC) to be dispensed to the industry most adversely affected by carbon controls, the coal industry. At 100 MtC and a permit price of \$75/tC, the value of the allocation (\$9 billion) is almost half of the value of the coal production sold domestically in 1990 (\$19 billion). Option IV's cap also provides a large number of permits (perhaps 30 MtC) for financing early reduction credits, creating incentives for renewable energy generation and energy conservation, and auctioning to new entrants.

The allocation of permits back to coal producers could take several forms. It could be a permanent allocation, giving permits based on historical coal production. Depending on the value of these permits, there may be little incentive left to stay in the coal business –

an advantage to some but a disadvantage to other. The allocation could be limited to a given time period, such as for two budget periods (2008-2012 and 2013-2017), after which the permits could be placed in the auction pool. This would provide some limited compensation to coal, while allowing an eventual source of revenue to the government from the permit auction.

The allocation back to coal producers could also take the form of a rolling average or other mechanism that would only allocate permits to producers active in the market. This would give coal producers some incentive to continue producing coal if they wished to continue to receive permits. Basing the original allocation of permits on natural gas hits coal-fired electricity generators and industrial coal users hard. However, allotting permits to coal producers using a rolling average may lessen this impact. Since coal-fired utilities and large industries are the only significant consumers of coal, producers may be forced to bundle their coal with carbon permits.

The differential treatment of industrial facilities and electricity generators is important in terms of its incentives for cogeneration. To provide a real incentive for cogeneration, an output-based allocation scheme incorporating the efficiency of producing both electricity and steam is needed. This alternative's allocation does not provide such an incentive. In future work, we hope to explore this issue in greater detail.

Tradable Corporate Carbon Emissions Cap

Another difference between this system and Option I is that the Corporate Carbon Emissions (CCE) standard would be a firmer cap on carbon emissions from light duty vehicles and trucks. The design of this cap is modified from DeCicco (1993). Under this system, each automaker would be given an allocation of current and future year permits representing the future emissions commitment from autos manufactured in that given year. Each automaker's emissions commitment would then be determined by summing up their sales in each class. Automakers would have the option of purchasing permits from other automakers or from utilities or industrial sources should the cars they

manufacture represent a higher emissions commitment than their allocation or sell permits should their fleet represent a lower emissions commitment than their allocation.

A key difference between the tradable CACE described under Option I and the CCE proposed for Option IV is how each is affected by variations in production. Purchases of automobiles is much more variable than, for example, the purchase of electricity. The CACE proposed under Option I is less impacted by interannual variability, since the CACE is not tied to the number of cars produced, just the efficiency of these cars. For the capped CCE, interannual variability could cause automakers to either be short or have excess permits not due to the efficiency standard but due to the variability in production. Additionally, the capped CCE offers automakers the option of producing fewer lower efficiency cars or a greater number of high efficiency cars, a choice not available under a corporate average.

As discussed in relation to the CACE system in Option I, the cap on this sector's emissions would not fully take effect for many years. And as discussed under Option 1, one must carefully craft the early years of the program to compensate. Using Davis and Hu (1991), about 80 percent of emissions would be covered 10 years after the introduction of the CCE. Additionally, since the emissions cap would be based on an estimate of lifetime miles made at the time of production, there would be no real controls on the actual miles driven.

COMPARISON OF CONTROL DESIGNS ALTERNATIVES

There are many ways to compare and contrast the alternative control designs. In this section we first make some observations on their basic differences. We then compare the alternatives in terms of their emissions coverage and effects on various energy use categories. A more comprehensive set of policy evaluation criteria to compare the alternatives is under development. This comprehensive set of criteria will be presented and discussed at upcoming meetings with study collaborators.

Basic differences among alternatives

Table 3.10 displays a simple way to conceptualize the differences among the basic design elements of the options. The alternatives can be thought of as varying in two ways. The first is whether they cap carbon at fuel producers (Options II and III) or they cap CO₂ emissions from large combustors and control more diffuse emissions sources with standards (Options I and IV). The second is whether they are relatively simple designs (Options I and II) or whether they reflect designs that could emerge from the political process (Options III and IV). As shown in this table, our designs encompass the range of possible alternatives set out by these two factors. These basic differences can help us begin to assess what qualities in a given option make them attractive to policymakers.

Table 3.10 - Comparison of control options in terms of their primary control mechanism and level of complexity.		
	Economy-wide fuel carbon cap and trade <i>Reliance on price signals (fuel and electricity)</i>	Partial emissions cap; Product standards for small sources (some tradable) <i>Electricity price signals, standards</i>
Relatively simple designs	<i>Option II</i>	<i>Option I</i>
Political compromise designs	<i>Option III</i>	<i>Option IV</i>

Options II and III are likely to be most attractive to those who believe that fuel pricing mechanisms are likely to lead to the most desirable outcomes. (Although option III does contain standards, its cap on fossil fuel carbon production implies that a large degree of its control will result from fuel pricing). Options I and IV are likely to be most attractive to those who believe that pricing mechanisms are most effective with large firms, especially those with large energy costs, but less so with individual consumers and even firms where energy is only a minor cost of doing business. Under these options, manufacturers of energy consuming technologies—cars, furnaces, refrigerators, and so on—are either regulated through efficiency standards or given economic incentives to improve the efficiency of their products. The notion here is that it may be more efficient

to provide incentives directly to, for example, auto manufacturers, to undertake efficiency improvements than to rely on consumers who are far more sensitive to today's costs rather than tomorrow's return on investment.

The designs of several of the alternatives have also been constrained by other aspects of the policy environment or perceived institutional and market "realities." Thus, possibly the single most attractive political aspect of options I and IV in comparison to the other two is that gasoline prices are much less affected. Options II and III, because they cap carbon supplies, will cause a direct increase in gasoline prices. The costs of new cars must rise, of course, to pay for the changes needed to improve efficiency, but it may be politically more acceptable to accept these latter costs than the former. Another aspect of Options I and IV is that they rely heavily on electric utilities. Utilities are used to trading pollution credits under the current Clean Air Act and have both familiarity with energy management programs and the trust and access to residential and commercial customers who are responsible for a large share of emissions.

Economic modeling of these four alternatives is scheduled for the latter half of this project, and will be covered in the final report. However, it is interesting to compare them with the three projections discussed in Chapter 2. Option 1, with its focus on utilities and large industry is most like the DOE/NEMS scenario. Seventy-five percent of all reductions came from those two sectors in that scenario. Options 2 and 3 are closer to the EPA/DRI scenario. The economy-wide price signal produces a more balanced result. Option 4 is closer to Interlab: most reductions from the electric sector, but substantial improvements from transportation.

Comparison of emissions coverage

Table 2.1 shows carbon dioxide emissions from both combustion of primary fuels and electricity use by end use sector. This table can help assess emissions coverage for the various control designs in a broad sense. It shows that buildings (residential plus commercial), industry, and transportation are each responsible for about one-third of total carbon emissions. However, these numbers are somewhat misleading since large

industrial combustors are only a portion of total industrial emissions and highway emissions are not the only transportation emissions. Tables 3.11-3.14 display carbon dioxide emissions by end use within each major sector. These tables show a finer level of detail from which to assess the emissions coverage of the schemes. Figure 3.5 shows this same information graphically.

Coverage under Option I

Option I covers utilities and large industrial combustors under an emissions cap. Assuming that the criteria for defining a large facility is written to capture 90 percent of emissions from primary fuel used for boilers and process heating, such a system would include a little less than half (47 percent) of total carbon emissions under the cap.

Most of the rest of emissions would be covered under controls on manufacturers of energy consuming equipment, for example, manufacturers of cars and trucks. This covers about 41 percent of emissions, for a total coverage of 88 percent of emissions under both the emissions cap and standards. But close to 10 percent of emissions would not be covered, for example, some primary fuel combustion within the non-manufacturing industrial firms.

Option I also has some double coverage (emissions affected by both the cap and standards). Specifically, efficiency standards on cooling, lighting, and large appliances coupled with caps on electricity sector emissions combine to create double coverage on these energy uses. Residential and commercial electricity use for equipment that would have standards associated with them (refrigerators, water heaters, air conditioners, lighting) emit about 13 percent of total emissions.

Coverage under Option II

Option II covers almost all potential emissions. There may be small sources of leakage (missed emissions during production or transportation), the largest difficulty may be the desire to account for the use of fossil fuels for feedstocks. About 14 percent of petroleum and 3 percent of natural gas production ends up being used for non-fuel purposes.

Table 3.11 - Residential carbon emissions broken down by end use and energy source. Electricity sector emissions account for conversion losses. Shown below the carbon emissions is the percentage of total energy carbon emissions from each end use.

	Carbon emissions (million metric tons)	% electricity	% primary	other breakdowns
Lighting/refrigeration /other appliances	108 (7.8%)	100%	0%	refrigerators (22%), miscellaneous (22%), lighting (15%), television (12%)
Space heating	98 (7.0%)	21%	79%	natural gas is largest source of primary energy emissions (69% of primary energy)
Water heating	39 (2.8%)	43%	57%	natural gas is largest source of primary energy emissions (85% of primary energy)
Air conditioning	23 (1.6%)	100%	0%	

Table 3.12 - Commercial sector carbon emissions broken down by end use and energy source. Electricity sector emissions account for conversion losses. Shown below the carbon emissions is the percentage of total energy carbon emissions from each end use.

	Carbon emissions (million metric tons)	% electricity	% primary	other breakdowns
Lighting	74 (5.3%)	100%	0%	
Other	68 (4.9%)	52%	48%	hot water heaters (37%), miscellaneous (22%), office equipment (19%)
Cooling/ventilation	39 (2.8%)	100%	0%	cooling makes up 73% of emissions, ventilation the other 27%
Space heating	33 (2.4%)	27%	73%	natural gas is largest source of primary energy emissions (69% of primary energy)

Table 3.13 - Industrial sector carbon emissions broken down by end use and energy source. Electricity sector emissions account for conversion losses. Shown below the carbon emissions is the percentage of total energy carbon emissions from each end use.

	Carbon emissions (million metric tons)	% electricity	% primary	other breakdowns
Machine drive	115 (8.2%)	97%	3%	
Boiler fuels	93 (6.7%)	0%	100%	natural gas (50%) and coal (37%) are largest sources of emissions
Non-manufacturing industrial (construction, mining, agricultural, fishing, and forestry)	93 (6.6%)	40%	60%	includes some transportation emissions
Process heat	83 (5.9%)	0%	100%	natural gas is largest source of primary energy emission
Other manufacturing	80 (5.7%)	27%	73%	electro-chemical, miscellaneous, non- process energy use

Table 3.14 - Transportation sector carbon emissions broken down by end use and energy source. Electricity sector emissions account for conversion losses. Shown below the carbon emissions is the percentage of total energy carbon emissions from each end use.

	Carbon emissions (million metric tons)	% electricity	% primary	other breakdowns
Light duty vehicles	274 (19.6%)	0%	100%	autos (68%), light duty trucks (32%)
Freight trucks and buses	73 (5.2%)	0%	100%	freight trucks (95%), buses (5%)
Other transportation	63 (4.6%)	23%	77%	ships (48%), pipelines (33%), rail (18%)
Airplanes	40 (2.8%)	0%	100%	

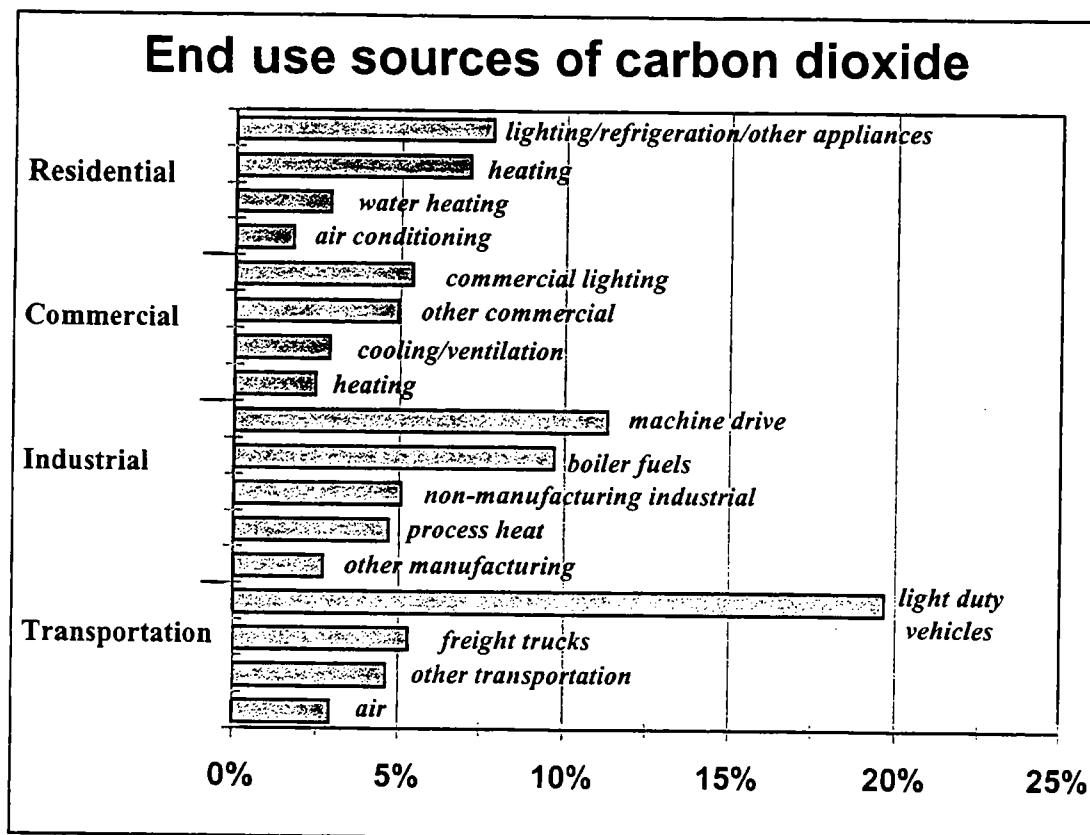


Figure 3.5 - Percentage of carbon dioxide emissions resulting from major end use categories. The breakdown is keyed to 1994 energy use data. This figure uses information from the Energy Information Agency (1994; 1995b; 1997a; 1997b), the Office of Technology Assessment (1993), and Davis and Hu (1991).

However, a certain fraction of that production eventually end up as emissions, with that fraction different for each application. Current usage patterns results in about 5-7 percent of carbon production being sequestered. Policy makers may choose to exempt carbon that will not end up as emissions from the permitting system.

Coverage under Option III

Option III, like Option II, is a supply side design covering almost all potential emissions. This option also augments the cap with standards on combustion equipment. The amount of double coverage is higher than in Option I. Efficiency standards on autos, trucks, space heating, cooling, lighting, and large appliances manufacturers coupled with caps on

primary fuel carbon combine to create double coverage on about 50 percent of emissions sources.

Coverage under Option IV

Option IV, like Option I, is a partial cap on combustion. However, this cap is extended to include a loose cap on auto and truck emissions. As discussed earlier, the cap on vehicle emissions requires a long phase-in period and is more uncertain than the utility and industrial portion. Including all vehicle emissions raises the emissions covered by the cap to 72 percent. Again, as with Option I, total coverage adds up to 88 percent and about 13 percent of total emissions are double covered by both standards and the cap.

ADDITIONS TO A DOMESTIC PERMIT TRADING SYSTEM

The above descriptions have dealt solely with domestic carbon dioxide emissions from energy consumption. However, both the Administration's proposal and the Kyoto Protocol allow multiple greenhouse gases, carbon sequestration, and international reductions to be part of an eventual control program. These additions are listed in the tables describing control alternatives. Future work will concentrate on adding these features to the control options. We begin this analysis with a short synopsis on multiple greenhouse gas emissions and the linkage to the international system.

Multiple Greenhouse Gases

The Kyoto Protocol sets out carbon emissions caps for developed countries based on the aggregate emissions of six categories of greenhouse gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The Protocol establishes that the total emissions will be calculated in terms of carbon dioxide equivalents, using the 100-year global warming potentials for each of the gases. These other greenhouse gas emissions are important to include in the system because there are possibly emissions reduction that may be cost effective compared to carbon reductions.

The Protocol also authorizes parties to engage in emissions trading between each other based on the total caps composed of these gases. The United States argued in the Kyoto

negotiations for multi-gas targets and emissions trading because they confer economic and environmental advantages. International multi-gas trading offers greater flexibility in meeting the targets at lower cost and ensures that growing sources of gases are controlled using market-based incentives (rather than regulatory limitations).

Within this international framework, the United States may choose to implement multi-gas trading among domestic entities on a source-by-source basis. Some sources of emissions may be more amenable to inclusion in a cap and trade program while others are better managed through voluntary means or regulatory programs. Although further work remains to be done to examine which sources could be included in a domestic trading program, there are three broad types of sources, which vary in the certainty of monitoring emissions and emissions reductions and in the number of entities.

First, some sources are clearly amenable to inclusion in a domestic trading program because emissions are already monitored and reductions in emissions can be derived on a site-by-site basis. For example, electric generators also emit non-CO₂ greenhouse gases (such as methane and nitrous oxide) as a by-product of fossil fuel consumption. Other greenhouse gas emitters, such as industrial producers of certain gases or products, may also be few in number and have emissions that are easily monitored.

The second group is made up of sources for which emissions are less readily known but emissions reductions are amenable to tracking and monitoring. For example, methane from landfills is readily collected and either used for energy purposes or flared. These types of sources could potentially engage in emissions trading (e.g., on an opt-in basis), based on the easily measured emissions reductions.

The third group is composed of sources that are large in number (e.g., tens of thousands or more) and/or have emissions and emissions reductions that are not readily verifiable. These sources are likely to be less amenable to inclusion in a carbon trading program and perhaps more suitable for voluntary or regulatory measures. For example, agricultural

use of fertilizer generates nitrous oxide but emissions and emissions reductions from specific end uses are not readily measurable.

As further work is conducted on a source-by-source basis for emitters of these non-CO₂ gases, the trading designs illustrated in this paper can readily accommodate additional participants. Inclusion of appropriate sources of non-CO₂ gases in a domestic trading system can, in many cases, provide greater flexibility to firms who emit multiple gases and provide more opportunities for cost-effective reductions in emissions.

International Reductions

The linkage with an international system will obviously depend upon the rules for who can participate in trading and how much trading is allowed under the international system. The Kyoto Protocol deals with trading among Annex I countries in Articles 6 and 16bis. It also allows for parties to jointly fulfill their reduction commitments under Article 4 (a EU-like umbrella that the US could form with countries such as the OPEC Pacific nations, Canada, and Russia to assign differential reduction responsibilities while still meeting a joint reduction goal). Although Article 16bis makes no mention of private companies participating in trading, Article 6 does. Article 6 is a form of joint implementation for Annex I countries. It states that “A party included in Annex I may authorize legal entities to participate, under its responsibility, in actions leading to the generation, transfer, or acquisitions” of emissions reductions. The United States may also push for similar language associated with Article 16bis, allowing private entities to obtain emissions reductions overseas. Article 13, the Clean Development Mechanism, provides a way for private entities to obtain reductions from non-Annex I countries.

Such language makes it likely that private companies not able to meet their reduction responsibilities internally or domestically could go overseas to obtain emissions credits. However, it is clear that some parties want limits to the amount of credits that can be obtained internationally. Articles 6 and 16bis both state that “any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emissions

limitation and reduction commitments” Future negotiations will determine the exact meaning of “supplemental”.

Under Options I and IV, the partial caps, it may be the federal government that will purchase permits internationally. Under these options and an international trading system, the United States could verify if the capped portion of emissions (large combustors and, for Option IV, automobiles) meet their requirements. However if, at the end of the budget period, the standards do not achieve their hoped for reductions, the federal government would have to go out and purchase permits internationally. Such a system could help create a soft landing for the United States under a hybrid control system, allowing overseas reductions to be used to meet the cap while waiting for equipment turnover to occur.

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APPENDIX 3-1

ALLOCATION SYSTEMS

Allocating emissions permits is central to three out of the four designs we presented earlier. This is for two reasons. First, we anticipate that some form of compensation for the burdens imposed by a control system will be needed. Giving away permits is one way to accomplish this. The second is simply that there are more possible permutations for allocation systems. For an auction system, we see the critical design criteria as being where is the most efficient point to require permits. If the desire is to allocate permits -- that is, give out permits worth a considerable amount of money -- there are many ways to slice the pie. Within our control system alternatives we present three that encompass a range of the possible designs. In this section we will discuss the design of a permit allocation in greater detail, and, where applicable, describe proposed and implemented examples of the different types of allocation methods.

Three critical design issues associated with allocation systems are

- the “quantity” the permit allocation is based on (e.g., carbon production or emissions, energy production or consumption, or some measure of emissions per unit of output)
- the total amount of permits given away, and
- whether the allocation changes over time.

We attempt to describe these issues in more detail and describe how each can affect the design of an allocation scheme. We will separate methods for allocating permits on the supply side and on the combustor side.

SUPPLY SIDE ALLOCATIONS

Permits on the supply side could be allocated to those involved in extracting, importing, refining, or transporting fossil fuels. The allocation could be based on the carbon content of the fuel, the energy content, or on a “performance” metric, for example linking the allocation to a low carbon-content fuel standard.

Carbon-based allocation

A simple approach to allocating carbon permits is to give them out based on some fraction of historical carbon supplies. Controlled entities would be given carbon permits based on the carbon they produced, transported, or refined in a historic base period. Using this allocation method gives the greatest number of permits to the largest carbon producers.

Table 1 shows what the allocation to fossil fuel suppliers would look something like if one uses the Kyoto target as the cap and 1990 as the base year. Chapter 2 calculates that this cap would be at approximately 1300 million metric tons of carbon (MtC). Under this allocation method, coal would receive 36% of the permits (468 MtC), petroleum would receive 44% (572 MtC), and natural gas would receive the remaining 20% (260 MtC) of

Table 1 - Carbon allocations going to fossil fuel suppliers based on three different allocation formulas. The cap is set at 1300 million metric tons of carbon as described in Chapter 2. The carbon-based allocation assumes that all fuel categories reduce their carbon production in proportion to their 1990 values. The energy-based allocation gives out permits proportional to energy, not carbon, production. The performance-based allocation uses natural gas as the performance standard and gives out permits based on energy production and the carbon content of natural gas. The difference between these last two methods and the carbon based allocation is shown in parenthesis. For reference, the table also shows the 1996 and forecasted 2010 emissions. The forecasted numbers represent the average of the three modeling scenarios presented in Chapter 2. (Numbers may not add up due to rounding.)

	Coal (MtC)	Petroleum (MtC)	Natural gas (MtC)	Total (MtC)
Carbon-based allocation	465	571	264	1300
Energy-based allocation	369 (-96)	569 (-2)	362 (+98)	1300
Performance-based allocation (using natural gas as standard)	276 (-189)	426 (-145)	271 (+7)	974 (-326)
1996 carbon emissions	524	621	318	1463
Forecasted 2010 emissions	569	735	419	1723

permits. From the EIA preliminary estimate of 1996 emissions (EIA, 1997), the cap is 56 MtC below current emissions from coal, 49 MtC below current emissions from petroleum, and 58 MtC below current emissions from natural gas.

Energy-based allocation

An energy-based allocation gives out permits in proportion to energy, not carbon, production. This method takes the total emissions cap and allocates it in proportion to the amount of energy produced, transported, or refined. Compared with a carbon-based allocation, this method favors suppliers of fuels with lower than the average carbon content at the expense of high carbon fuels. Controlled entities would be granted permits based on the amount of energy they supplied and the carbon per unit energy factor needed to keep emissions at the cap. Although this method could be stationary, allocating permits to existing entities and not updating the allocation through time, several proposals of this form have included a means to periodically revise the allocation. Such an approach adjusts the allocation to a changing market, for example, eventually allocating permits to new market entrants.

Table 1 compares this method to a historic, carbon-based allocation. As shown in this table, natural gas suppliers receive greater permits and coal fewer than the carbon-based approach.

Performance-based allocation

A performance-based supply-side allocation can be based on a standard, such as the carbon content of natural gas, and a historic level of energy production. Such a system favors fuels with carbon content at or below the standard. This method can supply permits to other entities. These “extra” permits could be used as incentives to develop energy efficiency and renewable energy sources or compensate additional industries heavily affected by carbon controls, for example, utilities that burn coal.

Table 1 shows the impact of this allocation if the standard is set at the carbon content of natural gas. For natural gas, this is a slight improvement over the carbon-based

allocation. This allocation hits coal the hardest, reducing its allocation by 189 million metric tons. It also reduces petroleum allocation by 145 million metric tons. Its net result is to lower the amount of allowances given out to 974 million metric tons, 326 million metric tons below the Kyoto target. These extra permits could then be used to reward developers of renewable energy sources and energy conservation methods, compensate heavily hit industries, or auction with revenues going to the treasury.

COMBUSTION SIDE ALLOCATIONS

Permits can also be allocated on the emissions side, that is to those who directly burn fossil fuels or to manufacturers of combustion equipment. As with supply side allocations, permits can be allocated on carbon emissions, energy combustion, or on a “performance” standard, again for example linking the allocation to low carbon emissions fuel. On the combustion side, one can also distinguish between allocation methods on the input side or output side of a control point.

An input method for allocating permits uses the inputs (carbon or energy) to a control point as the basis for allocating permits; an output system uses products that emerge from the control point. For example, if the control point is at electricity generation, an input system could be based on fossil fuel or carbon used in generation whereas an output system could be based on carbon per kilowatt-hours of electricity generated. This distinction is critical for who among electricity generators will receive a permit allocation. A system based on carbon inputs to electricity generation would only allocate permits to generators who use fossil fuels whereas a system based on carbon per kilowatt-hours could include non-fossil fuel generators (nuclear, hydro, solar, wind) in the allocation.

Allocation based on historical carbon emissions

A simple approach to allocating carbon permits is to give them out based on some fraction of historical carbon emissions. As with the carbon-based supply method for allocating permits, this system allocates the greatest number of permits to those with the highest emissions.

Table 2 shows the allocation to the electricity sector using a cap on electricity sector carbon emissions of 375 MtC. We developed this cap using the three modeling scenarios presented in Chapter 2 that estimate the most cost-effective level of control for each sector and assume that generators purchased an additional 50 MtC of emissions credits overseas (thus, although the allocation is 375 MtC, the emissions would be 425 MtC). This table shows permits allocated to generators based on their 1990 emissions. Compared with 1996 emissions (shown on the next to last line of Table 2), both coal and natural gas-fired electricity generators would need to obtain more credits or reduce emissions under this carbon-based allocation method (as they would under most allocation methods).

For petroleum-fired electricity generators, the permit allotment under a historical emissions-based allocation (as under most allocation methods) is higher than their current emissions. Just as the Russia gains emissions credits greater than their current emissions due to their economic collapse when the international allocation uses 1990 as the baseline, petroleum-fired electricity generators generate credits in excess of their current emissions due to their decline in generation between 1990 and the present.

Both the Illinois Environmental Protection Agency and the Pennsylvania Department of the Environment have proposed trading programs to improve urban air quality (Illinois' controls volatile organic material emissions and Pennsylvania's controls nitrogen oxides) allocating trading allowances based on historical emissions. Most existing trading programs, even if they have initially attempted to use historical emissions as a basis for allocating permits, have ended up incorporating some measure of performance so as to not penalize emitters that have previously taken steps to reduce emissions.

Input allocation based on energy combustion

An energy-based allocation gives out permits in proportion to fossil fuel energy consumed, not carbon emitted. As with the supply side energy-based allocation scheme, this method takes the total emissions cap and allocates it in proportion to the amount of

Table 2 - Carbon allocations going to all electricity generators based on alternative input and output allocation formulas. The cap is 375 MtC. The carbon emissions method allocates permits based on 1990 emissions and all generators reduce their carbon emissions proportionally. The input-based energy method allocates the cap in proportion to energy combustion. The input-based performance method uses natural gas as the performance standard and gives out permits based on energy production and the carbon content of natural gas. The output-based generation methods allocates the cap based on carbon per kilowatt-hours. They can allocate to fossil fuel generators only or both fossil fuel and non-fossil fuel generators. The output-based performance method uses a natural gas turbine generator with a heat rate of 9,000 Btu per kilowatt-hour as the performance standard. They can allocate to fossil fuel generators only or both fossil fuel and non-fossil fuel generators. The difference between all other methods and basing the allocating on carbon emissions is shown in parenthesis. For reference, the table also shows the 1996 and forecasted 2010 emissions. The forecasted numbers represent the average of the three modeling scenarios presented in Chapter 2. (Numbers may not add up due to rounding.)

	Coal (MtC)	Petroleum (MtC)	Natural gas (MtC)	Nuclear (MtC)	Hydro (MtC)	Total (MtC)
Carbon emissions allocation	322	21	32	0	0	375
Input-based energy allocation	299 (-23)	23 (+2)	53 (+21)	0	0	375 (0)
Input-based performance allocation	234 (-87)	18 (-3)	42 (+9)	0	0	294 (-81)
Output-based generation allocation (fossil fuels)	301 (-20)	23 (+2)	51 (+19)	0	0	375 (0)
Output-based generation allocation (fossil fuels and non-fossil fuels)	209 (-113)	16 (-5)	35 (+3)	77 (+77)	38 (+38)	375 (0)
Output-based performance allocation (fossil fuels)	206 (-180)	15 (-8)	35 (-4)	0	0	257 (-118)
Output-based performance allocation (fossil and non-fossil fuels)	206 (-180)	15 (-8)	35 (-4)	76 (+76)	37 (+37)	371 (-4)
1996 carbon emissions	461	16	40	0	0	517
Forecasted 2010 emissions	486	12	129	0	0	627

energy combusted. Such a system grants more permits to users of fuels with lower than the average carbon content and less permits to users of high carbon fuels compared with the historical carbon emissions allocation method.

Table 2 shows how this method affects the allocations and how the allocation differs from an emissions-based allocation. Compared to the carbon-based approach this results in a transfer of 23 MtC of permits from coal-fired generators to electricity generators using natural gas and petroleum.

Input allocation based on the carbon emissions rate of a low carbon fuel

This performance-based method uses a standard, such as the carbon content of natural gas, as the target and allocates permits based on this standard multiplied by the energy combustion. As described in the supply-side discussion, this method can be used to rake off permits that can then be used to reward or compensation other entities. Allocating carbon permits using such a performance standard will penalize coal and petroleum users and is neutral to natural gas.

Table 2 shows the impact of this allocation if the standard is set at the carbon content of natural gas. For natural gas, this is an improvement over the carbon-based allocation. This allocation hits coal-fired electricity generators hard, reducing their allocation by 87 MtC from the emissions-based method. It also reduces petroleum-fired electricity allocation by 3 MtC. Using this performance-based method results in 81 MtC being left over from the electricity sector cap. These left over permits could be used as incentives to develop energy efficiency and renewable energy sources or compensate industries heavily affected by carbon controls, such as the coal industry.

The Federal Acid Rain Program uses a hybrid of this approach for allocating sulfur dioxide permits. In that program permits are allocated to electricity generators based on average emissions from 1985 to 1987, with the allocation being capped by a input performance standard (2.5 pounds of sulfur dioxide per million Btu in Phase 1 and 1.2 pounds of sulfur dioxide per million Btu in Phase 2). The Phase 2 limit of 1.2 pounds of

sulfur dioxide per million Btu is the upper end of low sulfur coal.

Output allocation for fossil-fuel electricity generators

Permits can be allocated based on electricity generated, as opposed to the energy input-based allocation described earlier. The method described here allocates permits to fossil fuel generators only. As with an energy input-based allocation, this system rewards combustors generating electricity with a lower than average rate of carbon emissions and penalizes those that generate electricity at a higher than average rate of carbon emissions. This approach also rewards generators who more efficiently convert fossil fuel to electricity.

Table 2 shows the impact of using this output-based allocation method. Such a system results in fewer permits allocated to coal and more to petroleum and natural gas generators compared to using historical emissions as the basis for allocation. This table also shows that the energy input-based and this output-based allocation methods vary little. This may point to an advantage of the input scheme since it is applicable to both electricity generators and industrial combustors alike, while on average yielding very similar results.

Senate Bill 687 introduced into the 105th Congress proposes using an output-based performance standard to allocate nitrogen oxides, sulfur dioxide, and carbon dioxide permits to electric generation facilities of 15 megawatts or greater. This bill only covers fossil fuel emitters. It establishes the generation performance standard by dividing a national emissions cap by a forecast of the electricity produced by covered facilities. Lashof et al. (1997) describes the use of an output-based method for allocating carbon dioxide permits for the electricity and industrial sectors.

Output allocation for all electricity generators

A second output-based approach allocates permits based on electricity produced, but in this variant, permits are allocated to both fossil and non-fossil fuel generators. This

would provide a windfall to non-fossil fuel generators and reduce the allocation to most fossil fuel generators.

Table 2 shows the impact of using an output-based allocation method that gives permits to both fossil fuel and non-fossil fuel generators. Compared to the historical emissions-based method, such an approach basically results in a transfer of permits from coal-fired generators to nuclear and hydropower. The allocation to coal-fired generators falls by 113 MtC while the allocation going to the non-fossil fuel sources increases by 115 MtC compared to the emissions-based method.

Senate Bill 1097 introduced into the 105th Congress proposes using an output-based performance standard to allocate a fixed number of nitrogen oxides permits to States in proportion to the State's share of total electric power generation. States can either determine their own method of allocating permits or allocate permits to individual facilities based on the facilities share of total net electric power generated.

Output allocation based on "performance" of electricity generators

This performance-based method uses as its standard the emissions rate of a low carbon fossil fuel electricity generator with a heat rate of 9,000 Btu per kilowatt-hour (somewhere between a new coal-fired steam plant and a natural gas combined cycle plant). Allocating carbon permits using such a performance standard gives relatively fewer allowances to generators with an emissions rate above this standard and relatively greater allowances to those below it. This standard could be used to allocate permits to fossil fuel generators only or both fossil fuel and non-fossil fuel generators. As with the other performance-based allocation systems discussed earlier, this method can be used to set aside permits that can be allocated as compensation or rewards to other entities.

Table 2 displays the impact of this allocation where permits are given to fossil fuel generators or all electricity generators. This system results in the least amount of permits for fossil fuel generators of all the allocation methods. For the method that gives permits only to fossil fuel plants, the allocation to electricity generators is 257 MtC, which is 118

MtC below the cap. When permits are allocated to all generators, the allocation to electricity generators is 371 MtC tons, which is 4 MtC below the cap.

IMPACTS OF ALLOCATION METHODS ON PERMIT ALLOTMENTS TO LARGE ELECTRICITY GENERATORS

We now consider how varying allocation methods impact the number of permits allotted to the largest electricity generators. We focus on the 15 largest electricity generators in 1996, according to the EIA (Smith, 1998). These generators represent approximately 36 percent of all electricity generated, 30 percent of electricity generated from fossil fuels, and 30 percent of total carbon emissions from the electricity sector. They also account for 93 percent of all electricity generated from nuclear energy.

Table 3 shows the impact on the number of permits allocated to these utilities under five different allocation methods. These allocation methods give out permits in proportion to historical emissions, input energy, input “performance”, and electricity output. As with our earlier analysis, we assume that the cap on electricity emissions is 375 MtC.

A first set of observations concerns the total number of permits allocated under the alternative methods. The historical emissions, input energy, and output-based fossil electricity generation allocation methods all result in a similar total number of permits allotted to these generators. This is because these generators have a similar percentage of the sector’s total carbon emissions, fossil fuel energy input, and fossil fuel electricity output (approximately 30 percent of the total sector). The third method, the input-based performance allocation, uses the generators’ energy consumption in 1996 and the carbon emissions rate of natural gas as the basis for developing the allocation. This method results in the fewest number of permits given out, both to these utilities and the electricity sector in general. Under the last method shown in Table 3, the output-based method allocating based on total (fossil and nonfossil) electricity output, the number of permits given out to this set of generators is the greatest (although the number of permits given

Table 3 - Carbon allocations going to the 15 largest electricity generators based on alternative input and output allocation formulas. The descriptions of the methods are the same as those used in developing Table 2. The electricity sector cap is 375 MtC.

	Carbon emissions allocation	Input-based energy allocation	Input-based performance allocation	Output-based generation allocation (fossil fuels)	Output-based generation allocation (fossil fuels and non-fossil fuels)
TVA	17.63	16.53	13.68	17.18	18.35
Georgia Power	12.46	11.69	9.67	11.34	11.53
Commonwealth Edison	5.66	5.51	4.56	5.18	11.33
Duke Power	7.23	6.79	5.62	7.41	10.83
Texas Utilities	11.74	13.67	11.31	13.25	10.74
Alabama Power	9.93	9.34	7.73	9.87	8.79
Houston Light	7.73	8.95	7.41	8.85	8.46
USCE-N Pacif Div	0.00	0.00	0.00	0.00	8.15
Florida Power & Light	4.68	6.52	5.39	7.22	7.66
Virginia Ele & Power	6.01	5.73	4.74	6.02	7.27
Pacificorp	10.73	10.08	8.34	9.63	7.13
Carolina Power & Light	4.88	4.58	3.79	4.67	6.09
Detroit Edison	8.54	8.22	6.80	7.89	5.88
Arizona Public Service	3.67	3.53	2.92	3.52	5.88
Pacific Gas & Electric	1.30	2.13	1.76	2.11	5.19
Total	112.19	113.28	93.71	114.14	133.28

out to the whole sector remains the same as for all methods except for the third one). This is due to the concentration of nuclear power among these generators.

A second set of observations concerns the distribution of permits among the generators. Moving from the emissions-based allocation to methods that allocate based on carbon efficiency (all other methods) results in relatively more permits being allocated to utilities that have the least amount of coal. Under the input-based performance allocation, for example, the largest consumers of coal, TVA and Georgia Power, both receive only 78 percent of the permits they would receive under the emissions-based allocation. This is in contrast to the largest consumers of natural gas, Texas Utilities Electric Company and Florida Power and Light who receive 96 and 115 percent, respectively, of the permits they would receive under the emissions-based allocation. The obvious extreme is for the United States Army Corps of Engineers North Pacific Division, who only obtain permits under the output-based generation allocation for both fossil fuels and non-fossil fuels generation.

MODIFYING PERMIT ALLOCATIONS THROUGH TIME

An important design issue is whether the allocation of permits will change through time. Permits can be allocated permanently using a single baseline period or the allocation can change as entities enter and exit the market. Permanent allocations give predictability to the market, promoting trading of future allocations. However, permanent allocations can create economic disadvantages to new entrants and reward entities that are no longer viable in the marketplace. We will discuss two ways that the permit allocation can change over time. The first is to base the permit allocation on a rolling baseline, so that every few years the allocation is recalculated. The second way is to slowly phase out the allocation of permits over a few decades. This phase out could end with all permits being auctioned or only a fraction of permits auctioned.

Rolling baseline allocation

Recalculating the allocation after a certain length of time after the initial allocation has several advantages. It corrects for new entrants and shut downs by reallocating to those

actively engaged in the market. It also may remove some of the political pressures associated with the initial allocation. However, such a system takes away some of a firm's incentive to make reductions and generate a long time stream of credits. Additionally, high permit values could allow some high emitting entities to remain operating longer than they might have without the permit allocation.

Senate Bill 1097 proposes such an approach for allocating nitrogen oxide permits. It allocates permits based on a rolling average of the affected facilities' share of total net electric power generation. The Environmental Law Institute (1997) addresses the use of such a system for a domestic carbon dioxide control strategies. They propose using a moving average allocation to fuel producers based on sales of fossil fuels. They argue that reallocating to suppliers using a short averaging period would not cause firms to modify their behavior to increase their permit allocation.

Transition from allocation to auction

A system could transition from an initial allocation to an auction system. This could be a complete shift to an auctioned system or a partial shift where some fraction of permits would be auctioned. This could reduce the pressure to get the initial allocation "right". A transition to an auction system would help level the field for new entrants while reducing the incentives for obsolete facilities to keep operating. Such a system would also raise revenues that could be used to offset other taxes. It provides an easier phase-in for firms that otherwise could be faced with sudden permit needs under an auction system. When viewed on a net present value basis, transitioning to an auction system out in the future may not be that different from a stationary allocation.

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